A strategy for using sensory analysis for category appraisal to develop new and improved products

by

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B.S., University of Rajasthan, 2009
M.S., Kansas State University, 2017

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Food, Nutrition, Dietetics, and Health
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Abstract

Food companies face the challenge of high product failure rates with 75%-90% of new food and beverage products failing within one year of launch. A majority of these products are either copy-cat, line extensions, or reformulation of existing market products. New product development (NPD) is mainly guided by marketing teams with short-term business horizons (e.g., create a new flavor for an existing product, change the color or shape, “create news”, short-term sales increase, etc.) at the expense of the true product innovations wanted and needed by consumers. The scientific insights of consumer needs and behavioral and psychological science are generally complicated, less understood, and marketing teams often overlook consumer-relevant aspects. Thus, considerable work is directed at finding new technologies or processes that can create a new product without knowing whether that new product will actually fulfill consumer needs.

A comprehensive sensory science-based system for new food product development is required. This research is one part of a strategy to develop example strategies for sustainable, successful food product development to meet the needs of both consumers and industry. The overall research objectives were set in partnership with the industry to produce new snack ideas to create “global” product concepts. In this project, products were targeted at international markets to address larger consumer needs. The strategy for ideation and product roadmaps was driven by a detailed assessment of international market products. The initial rounds of research included products from diverse markets (e.g., the United States, China, India, Ghana, Mexico, Colombia, Italy, Thailand). After careful consideration of the market potential, the innovative orientation of Japan (JP) and South Korea (Republic of Korea) (SK) markets, in addition to those of the U.S. were chosen for further product exploration, assessment, and ideation.

Food companies are continuously exploring international markets for new flavors, textures, packaging concepts, and products for inspiration. An effective way of gathering information is to conduct on-site research but international research presents many new challenges. Therefore, the first study was designed to determine and address the methodological challenges of conducting a product category assessment in an unfamiliar country (JP). The results (published) highlight the onsite challenges and potential solutions required to conduct international research in an unfamiliar country. For example, the country's culture, law, language, customs, identity, people, product category of interest, data collection, product procurement, sampling, evaluation, and product shipment. Overall, the basic process template developed in this study is a valuable tool to perform a product category analysis in an unfamiliar country.

The primary focus of this research was on texture which serves as a focus for the development of snack foods because flavor generally is easy to manipulate across various countries for similar snack products. A sensory texture lexicon for descriptive panels applicable to various processed and unprocessed snack foods (e.g., crackers, chips, vegetables, yogurt, etc.) was needed to profile snacks on sensory parameters. Thus, the second study (published) developed a multi-parameter and multi-sense sensory texture lexicon with trained descriptive panels. Eighty-five different snack and snack-like foods from eight countries were evaluated in detail. The results included the translation of the developed lexicon terms, definitions, techniques, and references terminologies into four major international languages (English, Hindi, Mandarin, and Spanish). Researchers and manufacturers can use the developed lexicon to assess snack food categories in various countries and can profile any new snack food developed to see if it matches or deviates from the target texture.

In studies across countries and cultures, it is important to understand consumer terminologies and factors that can affect terminology when consumers describe their experience, concerns, and needs in snack foods. This research examined conceptual perception and linguistic barriers as key limiting factors in the cross-cultural food product development process which reduces the validity and general applicability of research results. The texture terms developed by sensory scientists are easy to translate at a scientific level to produce consistent information across cultures but are far too technical to be used to describe products to consumers. Thus, the third study (published) combined linguistic and contextual perception to explore consumer texture vocabularies. The results demonstrated that the vocabulary used by consumers to describe sensory characteristics of snack foods depends on context, culture, previous exposure, was specific to products, etc. We found divergent understanding and use of terms in each culture meaning that translation of English sensory terms without context can be problematic for non-English speaking cultures. The research results are important to understand as global companies want to market their new innovative products to local consumers as well as consumers in other cultures.

The fourth study explored the robust JP and SK snack food markets to generate new snack concepts for global marketplaces. Ninety-six JP and 124 SK snack foods were categorized using sensory science tools such as product categorization, projective mapping (PM), and descriptive profiling. This research work demonstrated how developers can find white space in the marketplace by sorting in-market products using a 2-dimensional PM. Descriptive analysis was used to identify the main sensory attributes of the JP and SK snacks. The principal component analysis of descriptive data allows accessing product positioning and comparison of products in the marketplace to discover white spaces. Sensory profiles obtained from a wide

range of snack foods can inspire researchers to create new product concepts with different and multi-sensory profiles. This work created a framework to discover white spaces in the marketplace and nurture new snack texture concepts to fill the identified white spaces by exploiting the main sensory attributes as product characteristics.

In NPD, researchers frequently use statistical methods such as cluster analysis to segment consumers into groups based on some measure of product acceptance or to group products by sensory characteristics. However, researchers overlook the stability of clusters produced by clustering methods. Some statistical clustering methods can provide different results simply by re-running the analysis. The objects in the clusters (consumers or products) can change clusters, which influence the final solution and interpretation of data. The fifth study applied hierarchical agglomerative clustering (HAC), *k*-means (KM), and fuzzy clustering (FC) to a large descriptive sensory data set and compared cluster results obtained from these methods. The clustering frequency matrix was produced for KM solutions, and attributes (objects) were reorganized into groups via manual clustering (MC). Results showed that using various clustering methods and producing a clustering frequency matrix could be valuable in identifying reliable clusters in large data sets. The study concludes that results from one clustering trial and one method may not be reliable. Therefore, researchers must validate results using other cluster methods. The outcomes of this study can help to enhance confidence in results produced by clustering applications.

Overall, the results of this research can help build sustainable product development systems based on examples using various food products and objectives for new food product development. By applying the research results industry and research institutions can make important progress in product development, and solve many complex issues related to the product development process.

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Dedication

This work is dedicated to both my parents who were not able to study beyond high school but put all efforts to ensure that their son not only gets a college education but gains the highest level of education. They encouraged me throughout my life and made enormous sacrifices in their personal lives to make their son’s life better.

Chapter 1 - Literature Review

Development of new food products

"The world of food continues to change" (Beckley, Herzog, & Foley, 2017). Food is greatly influenced by product's intrinsic sensory properties (e.g., appearance, aroma, taste, texture, etc.), extrinsic properties (e.g., brands, labels, price, packaging, nutrition, health, sustainability, etc.), and consumer choices (Fernqvist & Ekelund, 2014; Symmank, 2019). Consumer choices and trends are changing more rapidly than ever and food companies must adopt a multidimensional approach for new product development (NPD). Continuous development and innovation is the only way to succeed and survive (Guiné, Ramalhosa, & Valente, 2016).

The NPD in the food and beverage sector happens for several reasons. Several examples are listed (Fuller, 2016; Grunert, 2017; Guiné et al., 2016).

1. Growth and profitability: Companies want to grow business both geographically and financially to make more profits to pay workers and shareholders.
2. Product life cycle: Almost products have a limited life cycle. Food companies must replace or rejuvenate products according to consumer and market trends to survive.
3. Changes in consumer preferences: Consumer demands change and individual aspects of liking, health, convenience, "natural", organic, on-the-go, functional foods, sustainability and other aspects can become more or less important. Increased concern about sustainability, the invention of processes for creating foods such as plant-based meat analogs, insect protein supplemented foods, changes in packaging materials, the the advent of food traceability, and many other issues associated with environmental

issues are creating new opportunities for market disruption by new products.

4. Changes in the marketplace: The evolution in shopping behavior, such as the advent of e-commerce, has forced developers to design products that can respond to those changes in the marketplace.

5. Creation of new niche markets: The development of new technologies and new insights into possibilities allow food companies to work aggressively creating new products for markets that were unheard of, untapped, or unavailable previously. Rapid transportation makes “meal kits” available in many places; insights into toddlers, working mothers, elders, etc. The expand in designs for foods targeted to those segments; the more information on diet expands markets for foods made for special dietary needs such as high protein, sensitivities and allergies, illness, etc.; changes in lifestyle, the rise in participatory activities and others create category segments that were untapped before.

6. Change in food legislation by governments or agricultural policies: Modifications to trade laws, increased regulation of some industries and deregulation in others, changes in allowable ingredients and processes, all have the potential to dramatically change internal and external markets.

7. Food availability: Our increased ability to transport food over long distances, especially fresh foods from one part of the world to another changes those foods available to consumers. Similarly, the reduction in availability that local issues such as strife, wars, migration, corruption, etc., and global issues such as the coronavirus pandemic and changes in weather patterns can have on food distribution and availability can rapidly modify food availability and, therefore, consumption patterns. For example, a) coronavirus pandemic lockdown has increased the consumption of home-prepared foods

especially of legume, fruit, and vegetable intake among adolescents in Spain, Italy, Brazil, Colombia, and Chile (Ruiz-Roso et al., 2020), b) increased the consumption of snack foods, desserts, sweets, and fresh foods in the home, and a 47% increase in consumption of nonperishable processed foods (Adams, Caccavale, Smith, & Bean, 2020), and c) the demand for online grocery shopping surged dramatically in coronavirus pandemic (Martin-Neuninger & Ruby, 2020).

The literature provides numerous definitions of a new product such as 1) "A product not previously manufactured by a company and introduced by that company into its marketplace or a new marketplace", or 2) "the presentation or rebranding by a company of an established product in a new form, a new package or under a new label into a market not previously explored by that company" (Fuller, 2016). A general classification of new products is presented in Table 1.1 (Fuller, 2016), reproduced here with some modifications. In NPD, the market and sales are not greatly impacted by line extension, reformulation, or repackaging of food products, except in a few cases. The innovative or creative products resulted from a high level of research not only create a great impact on the market but also bring new consumers. However, even after producing large amounts of literature on new food product development (NFPD), the success rate remains low (Costa & Monteiro, 2018).

It is a well-known fact that 75%-90% of new food and beverage products fail within one year of launch, and 45% last less than six months (Dijksterhuis, 2016; Kemp & Hort, 2015; Koester & Mojet, 2012). Food companies and new product developers invest considerable amounts of money and time to develop each of these products, but developers fail to identify product flaws in the early stages of development. The framework for new product development

usually follows a series of steps such as idea generation, screening and evaluation, business analysis, development, consumer testing, and market launch. The success of a new product depends on numerous factors such as 1) unique product concept, 2) a detailed understanding of the market, 3) comprehensive predevelopment work, 4) cross-functional teamwork, and 5) participation of sensory and consumer (Fuller, 2016; Guiné et al., 2016).

Ideation or idea generation is considered the most important part of NPD, especially in the early stages of development (Fuller, 2016; MacFie, 2007). The ideas must fulfill the desires and needs of the targeted consumer. It should also meet the company's financial objectives. Food companies and product developers continuously look for ideas through market research. Generally, food companies use three primary sources: 1) marketplace (customer profiling, retail data, through distributors), 2) inside the company (sales team collaboration with retail buyers, and customers in own stores, and 3) outside marketplace (trade exhibitions, international or foreign marketplaces, competitor's product assessment). A successful idea requires a comprehensive understanding of markets and trends to predict changing consumer needs and preferences (Cooper, 2018).

The marketplace offers great diversity not only in terms of products but also in consumers. Researchers must decide before-hand on what market they will develop a product for, who will be the target consumer, which market to explore for idea generation, and wherein market the product will be positioned (Murley et al., 2020). Developers can leverage market research to discover gaps or "white spaces" in the market (Johnson, 2018). White spaces are perceived as consumer needs, differ greatly from one marketplace to another. Global marketplaces are the hub of new ideas due to its diversity, innovation, and traditional food products (Grunert, 2017; Grunert & van Trijp, 2014).

Table 1.1.

Classification of new food products development, characteristics, and examples.

Types of new product development	Characteristics	Examples
Line extensions	No addition of technology or development, very little research required, less impact on market and sales	Addition of flavor or variants to the existing product category. For example, a new flavor for potato chips
Reformulation of existing product	A very small research and development, less impact on market and sales	Low calorie or fat products. For example, crunchy flaming hot Cheetos
Repackaging of existing product	No change in product characteristic, depth of research and development depends on the innovativeness of new packaging, the novelty of packaging concept decides impact on the market	Seal lock snack bags, full top containers for dips, etc.
Repositioned existing product	Require product market space assessment, it causes a moderate impact on market and sales	Sorghum containing snacks repositioned as antioxidant-rich and high fiber
New form or size of existing product	Require a high level of research and development work, high impact on market and sales	Pre-peeled fruits, instant noodles, coffee, tea, dehydrated soups, etc.
Innovative products	The amount of research and development depends on the nature of the innovation, very high impact on market and sales	Frozen dinner meals, canned foods, etc.
Creative products	Extensive research and development required, very high impact on market and sales, a huge investment for industrial-scale production, new brand creation, and high risk of failure	Extruded products, plant-based meat patties, etc.

Global marketplace

The food industry is progressively becoming global due to growth in technology, communication, travel, development of global culture, and increased incomes, etc., (Mintel, 2020). Globalization eased food distribution, marketing, and communication, which leads to an increase in the number of global brands and profitability. By going global, food companies can

now access new markets and new consumers. All these factors have encouraged companies to adopt a global product developed strategy, focused on either introducing the same characteristic products across the world or launch products with modifications to fit in local/regional markets (Grunert, 2017). Examples of recently launched global product, 1) Nestlé's launched meal solutions (low carb, high protein, meatless, and gluten-free) under newest brand LIFE CUISINE with fifteen varieties of global flavors and cuisines, 2) Yasso's introduced dipped yogurt bars with four varieties under better-for-you frozen snacks, and 3) Natural Foods recently introduced a new functional superfood beverage "Organic Instant Mushroom Coffee" infused with three kinds of mushroom powders, dark coffee, beta-glucans, and chlorogenic acid (Malochleb, 2020).

Present-day researchers travel around the world in search of new ideas rather than limiting to conventional methods. Global marketplace assessment helps researchers to find white spaces or "sweet spots" in the marketplace and identify what characteristics in a product can go together to bring new consumer experiences (Moskowitz, Beckley, & Resurreccion, 2012). Developers bring different ideas from different sources (markets and cultures) and recombine the whole information to create a new product which stands a good chance of being different. Food companies often use international concepts to introduce new products into their home markets or other markets. For example, the growth of fast foods (burgers and pizzas). Murley et al. (2020), explained the process to investigate the Japanese snack food marketplace for new product inspiration.

Once researchers identify white spaces in the market, represented by either an empty product position in the marketspace or a need of the consumer. A mock-up or test products (prototypes) are presented in front of consumers for testing and feedback. Prototypes that receive consumer acceptance and fulfill consumer needs are most likely to succeed. However, only

developing a great idea doesn't guarantee product success. The quality of idea from the global marketplace is directly related to several factors, such as 1) innovative nature of the market, b) customer diversification, c) market excess, d) international exposure, and e) cultural diversity (Aschemann-Witzel, Ares, Thøgersen, & Monteleone, 2019; Rudder, Ainsworth, & Holgate, 2001; Ryynänen & Hakatie, 2014; Soares et al., 2017). Global marketplaces are great sources for information on products, consumer trends, diversity, and competition; they should be utilized for discovering potential ideas in NPD. Researchers are advised to consider cultural nuances and local market consumer requirements while implementing new food product ideas from global marketplaces (Grunert, 2017; Guiné et al., 2016).

Copy-cat or white space

The drivers of new food product success are directly related to the degree of innovation. The degree of innovation depends on the fact whether the new product is a copy, line extension, reformulation, slight modification, or a unique idea (Cooper, 2019; Grunert, 2017). "Copy-cat" or "me-too" food products are less likely to succeed over original product ideas (Loebnitz & Grunert, 2019; Mann, 2018; Nguyen & Gunasti, 2018). A product can be termed as a unique or innovative idea if it fulfills the unmet needs of consumers, i.e. those needs that cannot be satisfied completely by an existing product. Food companies often market products on the lines of previously successful products.

It is extremely risky for a food company to run, grow, or survive by simply relying on me-too products. The inventor of an original product often conducts deep market research to obtain a clear picture of consumer needs and expectations. In me-too products, makers don't have this clear picture; therefore, they are bound to have more limited success because they don't

completely understand the need of the consumer for the me-too product. The original inventor often uses a well-thought-out and planned marketing strategy to reach customers and benefits from “news” in traditional and social marketing channels about truly new products. Me-too producers have to spend more money to compete in a well-established market. The inventor holds the product's technological knowledge and distribution channels, while me-too producers run out of time in learning product technology. A leading competitor holds power to control, sway, or purchase retailers and limit shelf space for rival products (Fuller, 2016; Grunert, 2017).

Developers must study the competitor’s product, not to create copy products but to identify white spaces or to generate ideas for upcoming consumer trends. This will help food companies to capture the future market and prepare themselves for changing consumer trends. “No company can spend too much time generating ideas based on all the information that can be gleaned from all available sources” (Fuller, 2016). A comprehensive market insight can weed out bad product ideas. Food products markets can become rapidly crowded therefore, only innovative products can distinguish themselves from a large pool of products (Loebnitz & Grunert, 2019).

Role of sensory in product development

Effective use of sensory and consumer research has proven to be a significant factor in product success (Aschemann-Witzel et al., 2019; Costa & Monteiro, 2018; Grujić, Odžaković, & Ciganović, 2014; Schifferstein, 2015). In contemporary times food companies use sensory science extensively for numerous reasons such as better understanding of product properties, consumer evaluation of product properties, quality control and management, shelf life, and new idea generation, etc., (Talavera & Chambers, 2017). Product developers and marketers work in

tandem with sensory scientists at many stages in the NPD process, beginning from the very early stages such as designing consumer studies. The sensory scientist assists in data collection from consumers, experts, and interpret results, which provides invaluable guidance in decision making (Moskowitz et al., 2012).

Traditionally, food innovators have relied more heavily on experts than sensory and consumer research (Olsen, 2015). This, in part, is responsible for the high product failure rate (Dijksterhuis, 2016; Kemp & Hort, 2015) because so-called "experts" often use their own biases to predict success for products intended for people unlike themselves. Cardinal et al. (2015) showed that using food scientists or adults to predict liking of beverages for children gave incorrect responses. One of the many reasons for the high failure rate in new products is poor understanding and use of sensory and consumer research by product developers, especially at the early stages of NPD. Sensory (including consumer) analysis offers various methods and tools, both quantitative and qualitative research which are commonly used in NPD. For example, descriptive and discrimination techniques, where trained individuals with sensory known acuity describe and measure specific product attributes (e.g., aroma, flavor, texture, feel, etc.), can help in understanding whether products meet their intended sensory targets (Talavera & Chambers, 2017). Similarly, expert product assessments following appropriate evaluation techniques (ASTM International, 2020) or consumer research using targeted consumers can provide critical feedback from the early stages of product development through the launch and maintenance phases of the product life cycle (Talavera & Chambers, 2017).

Another part of the sensory analysis is consumer research, where scientists determine consumer perception, experience, expectations, emotions, preferences, and liking of product characteristics, for individuals and groups of consumers. Consumer segmentation obtained from

consumer product testing is commonly used for targeted consumer product development and marketing (Doets & Kremer, 2016; Giacalone, 2018; Sharma et al., 2020a). Sensory consumer research methods also have proven their usefulness in various cross-cultural studies (Koppel et al., 2014; Soares et al., 2017; Yang & Lee, 2019).

Sensory research participates in different stages (i.e. ideation, development, validation, final testing, and maintaining) of the NPD process in different roles. The techniques in each stage differ and understanding the sensory testing options is important to understand how and where sensory research applies. Of course, the NPD process will vary from organization to organization, and options suitable for one organization may not work within another.

To set research objectives and shape a business plan

At the inception of NPD, developers are required to collect available information to scope the project objectives. Food companies use both internal and external resources to refine project ideas, discuss internally to enhance category understanding, target consumers, and how new products can fulfill consumer needs (Talavera & Chambers, 2017). At this stage, sensory scientist fills the knowledge gaps by mapping information required to customize study plans for opportunity identification. Then all this information incorporates into a business plan that defines the market opportunity and builds a plan to exploit that opportunity (Moskowitz et al., 2012).

Evidence-based decision making

The versatility of sensory science makes it an integral part of Fast-Moving Consumer Goods (FMCG) (e.g., food, beverage, personal care, cosmetics, textile, automobile, home care, etc.). Sensory uses various consumer research methods (e.g., market survey, focus groups,

product category appraisal, etc.) to gather information for ideation, consumer needs, emotions, expectations, consumer product characteristics, trends, product communication ideas, and marketing concepts. Sensory studies collect and process all the information which helps the product development team to make evidence-based decisions that increase the product chance of success (Talavera & Chambers, 2017).

Market opportunity assessment or idea generation

Sensory research characterizes and define market requirement through consumer research and assist in identifying white spaces or "sensory gaps" in the marketplace. For example, qualitative research such as focus groups is used to begin to unearth unmet consumer needs or identify specific product characteristics that drive consumer satisfaction which is currently not available in the market. Focus groups provide real-time knowledge on product category, usage, awareness, emotions, preferences, expectations, and consumer description of the product, which scientists may miss by relying only on data. For example, Crofton and Scannell (2020), used focus groups to design snack food concepts containing brewers spent grain. Similarly, Cuny, Petit, & Allain (2020), concluded that consumers associate some textures more frequently with some flavors, termed as "implicit association" in the memory. Therefore, NPD developers must test the congruency between one texture and one flavor within the target consumer segment.

Another sensory technique for new product idea generation is termed preference mapping (Talavera & Chambers, 2017). Sensory scientist often combines descriptive and consumer research to determine in-market product space and identify main sensory attributes for a particular product category that drives consumer hedonics. This technique is also used for comparison by positioning prototypes and competitor's products on sensory space. Studies that

have used sensory research to discover new product ideas (e.g., Costa et al., 2020; Garrido-Bañuelos, Ballester, Buica, & Mihnea, 2020; González-Mohíno, Antequera, Pérez-Palacios, & Ventanas, 2019).

Microscope ideas

At the early stages of NPD, developers come up with a plethora of new ideas where most ideas remain at the granular level, lacking structure, and clear understanding. A sensory tool is known as "Conjoint Analysis" (CA) or its variation "Choice-based analysis", determines which product aspect drive consumer interest or not, how consumers differ in the way they respond to each product aspect, and how these differences assemble to form segments. CA results help developers to narrow down the number of products, and consumers reasons that maximize consumer acceptance. For example, Porretta, Gere, Radványi, & Moskowitz, (2019) used CA to appraise consumer acceptance of insect protein, De Pelsmaeker, Schouteten, Lagast, Dewettinck, & Gellynck (2017) conclude that taste had a significant influence on the consumer rating of chocolate over ingredient information, and Calegari, Barbosa, Marodin, & Fettermann, (2018) reported that Brazilian consumers preferred to have diet personalization and quality food analysis as functions in their electronic devices to customize food characteristics.

Turning a concept into a real product, product definitions, prototype development, and optimization

Often product definition requires the integration of multiple and diverging objectives. Once the product idea is finalized, then sensory scientists work with product developers to define product specifications. Generally, several prototypes with variation (intensity ranges) in sensory

attributes are developed to appeal to multiple consumer segments, and position products at multiple sensory spaces. Halagarda & Suwała (2018), characterized apple juice by a balanced sweet and sour taste, and low density of color for polish consumers.

After defining product specifications, developers produce various prototypes by manipulating ingredient quantity or type. Sensory scientist tests developed prototypes to determine the impact of ingredient type or quantity or manufacturing process on consumer sensory liking. For example, Culbert, Ristic, Ovington, Saliba, & Wilkinson (2017), evaluated the influence of wine production methods on consumer acceptance. Suwonsichon (2019) and Chambers (2019), covered a detailed list of products that were developed, refined, and optimized using sensory methods.

Benchmarking

Benchmarking is also termed as a reference point for product categories. In NPD, the reference point could be the leading product in the marketplace, or products within a specific category, or across related categories (Moskowitz et al., 2012). In NPD, benchmarking is the only way to verify if the prototype meets the desired product's sensory features. For example, in the case of a sugar-free soda drink, it is essential to determine whether the new soda drink provides similar sensory properties to the regular-sugar soda drink.

Descriptive sensory analysis is of great importance to compare any new product with a category for main sensory attributes and to quantify attribute intensities (Chambers IV, 2018). Studies that used descriptive analysis (DA) to identify sensory profiles of various products. For example, hot coffee (Adhikari, Chambers, & Koppel, 2019), thickened liquids (Chambers, Jenkins, & Mertz Garcia, 2017), coffee (Chambers et al., 2016), fresh and dried mushrooms

(Chun, Chambers, & Han, 2020), mate tea (Godoy, Chambers, & Yang, 2020), beef (Laird, Miller, Kerth, & Chambers, 2018), potato (Sharma et al., 2020b), and rye bread (Tran, James, Chambers, Koppel, & Chambers, 2019). Other sensory methods used for benchmarking are consumer surveys and tests (Busse & Siebert, 2018).

Global consumers and global products

Food companies are going global with their products. The consumer now travels or migrate more often than ever before, markets are more connected, and consumers have become global. Globalization has created the need to research different countries to understand new markets, categories, and cultural nuances in food perception among target consumers. Food companies are now exploring the global marketplace and collecting a variety of information for an enhanced and comprehensive understanding of consumer experience with food products (Grunert, 2017).

Food choices are immensely impacted by cultural nuances such as shared values, traditions, language, society, religion, and environments (Lee & Lopetcharat, 2017). Sensory research enables developers to conduct cross-cultural studies beyond borders to develop successful global products (Ares, 2018). Example of studies that have used sensory research in cross-cultural studies; Kumar & Chambers, (2019b) conducted a study to understand how consumers perceive snack food texture and terminologies used to explicit their experience in four different cultures, Spinelli et al. (2019) developed a methodology to explore global profile within processed tomato food category, and Cunha, Cabral, Moura, & de Almeida (2018) concluded that food choice questionnaire is an invaluable tool to study food choices and motivations across culture, of course with modifications for individual countries.

Marketing and communication

Sensory marketing plays a critical role in advertising. Advertisement or messaging either through imagery, haptic, olfactory, or acoustic, all affect the consumer decision-making process (Krishna, Cian, & Sokolova, 2016). Another study reported that the graphical representation of sensory attributes significantly influences consumer's satisfaction, sensory perceptions, perceived taste intensity, product evaluations, and acceptability. The study concluded that food companies could use graphic representations to convey "atypical taste combinations" in new product marketing, which not only enhances consumer acceptance but also inspires the development of concepts directly associated with flavors (Lancelot Miltgen, Pantin Sohier, & Grohmann, 2016).

Other studies investigated sensory communication ways for novel food concepts such as crackers made with earthworm flour among Italian consumers. The study reported that a label's claim focused on the nutritional qualities of products made from earthworm flour had a positive effect on male participant's responses (Russo, Songa, Marin, Balzaretti, & Tedesco, 2020). The use of sensory in product marketing and communication has also shown an influential and remarkable effect on customer's appreciation of fast-food restaurants (Ifeanyichukwu & Peter, 2018). Therefore, sensory is an invaluable research resource in NPD. If used appropriately, it can increase the product's success chances in the market.

Rapid results

With changing dynamics of market and consumer trends, food companies work very hard to get the products to the market at a much faster rate. Sensory methods can be labor-intensive, expensive, and time-consuming. They require well-trained panelists and have limitations. Global

product development has increased the momentum for rapid sensory methods (O'sullivan, 2017). Several rapid sensory methods can deliver results faster, are less expensive, more flexible, can be used with semi-trained or naïve assessors, and can deliver results very close to DA with a highly trained panel (Aguiar, Melo, & de Lacerda de Oliveira, 2019). Methods such as napping, sorting, projective mapping, HITS profiling, flash profiling, free sorting, ideal profiling, and many others are being used regularly by sensory scientists to provide faster guidance by spending minimum resources (Talavera & Chambers, 2017). However, rapid sensory methods do not provide in-depth information as classical DA methods do, but they do provide a useable broad view.

Projective mapping as a tool for product category appraisal

The developers typically go to the marketplace to understand the product category and determine the sensory characteristics of products that are already on the market. In the early stages of NPD, developers gather a broad outline to figure out white space in the product category, and design products to fit the potential opportunity (Beckley, Herzog, & Foley, 2017). Projective mapping, napping, or sorting (PM) is one of the often-used rapid sensory methods for product category appraisal. Assessors taste and smell products, similar products are put in groups on a bidimensional space, and dissimilar products are put on the opposite side (Varela & Ares, 2012).

Many sensory studies have used PM solely or in combination with other methods to categorize products, identify opportunities, and determine product sensory drivers, etc. For example, González-Mohíno et al. (2019), used napping to characterize pork loin and cod for sensory properties prepared by using different cooking methods and conditions. Another study used the modified sorting method "sequential agglomerative sorting" for sensory characterization

of large sets of products (Brard & Sébastien, 2019). Sorting was combined with quality ratings to identify drivers of wine quality (Brand et al., 2018). Napping was combined with an ultra-flash profile as a method for category identification and model system to simulate formulations for caramel corn products (Mayhew, Schmidt, & Lee, 2016). The use of PM in the early stages of NPD can help developers to arrive at a product concept or at least have a list of characteristics for the new product (Beckley, Herzog, & Foley, 2017).

Descriptive analysis as a tool for product category appraisal

DA is used to accurately describe the nature and magnitude of the sensory characteristics of the products. A wide range of descriptive analysis techniques (e.g., profiling methods, quantitative, etc.) has been developed since its inception. In the traditional approach it is typically performed by the trained panelist, but in rapid techniques (e.g., sorting, projective mapping, and polarized sensory positioning) it can be performed by untrained consumers (Chambers IV, 2018). Researchers frequently use DA in food and drink product development, categorization, ascertain sensory space, product positioning, measure changes occur in shelf life, and also to investigate the influence of changes on a product (e.g., reformulation, a new ingredient, process, packaging) (Beeren, 2018).

DA is an important part of NPD at many stages such as design, development, implementation, and compliance (Fuller, 2016). At the initial stage of NPD, developers brainstorm for ideation by looking at market trends or in-market products. To transform a new concept into an opportunity, information is usually sought from literature, the marketplace, and competitor's products. Developers get an advantage through DA in a better understanding of competitive products (e.g., sensory properties and sensory space) in the market where the

potential new product will be placed. By combining DA results with consumer hedonics, developers can determine products that are liked, the reason for liking, consumer segments for preferred sensory characteristics, and insights on potential white space in the market (Beeren, 2018).

DA helps to identify the main sensory attributes of food products which can be manipulated to create a profile of desirable sensory characteristics. It is also used to define the early-stage specifications of new products (Chambers IV, 2018). The identified key sensory attributes form the basis of technical product specifications and encourage developers to create a wide range of prototypes with different and multiple sensory profiles (Beeren, 2018). For example, hot coffee (Adhikari, Chambers, & Koppel, 2019), thickened liquids (Chambers, Jenkins, & Mertz Garcia, 2017), coffee (Chambers et al., 2016), fresh and dried mushrooms (Chun, Chambers, & Han, 2020), mate tea (Godoy, Chambers, & Yang, 2020), beef (Laird, Miller, Kerth, & Chambers, 2018), potato (Sharma et al., 2020b), and rye bread (Tran et al., 2019).

Snack foods as a product category

"Snack foods are difficult to define because the distinction between snacks and meals is often blurred" (Forbes, Kahiya, & Balderstone, 2016). A snack could be any food and beverage eaten between meals including biscuits, cake, soft drinks, ice cream, confectionery, chips, popcorn, puffs, baked/fried products, meat snacks, fruits, dairy products, and energy drinks (Kumar & Chambers, 2019a). Consumer trends such as health, lifestyles, and diet patterns have stimulated demand for many snacking options across the globe (Research, 2019). The increasing replacement of meals with snacks, along with more and more consumers asking for on-the-go,

vegan, allergen-free, and healthy snacks, are the main trends responsible for market boost (Schlinkert, Gillebaart, Benjamins, Poelman, & de Ridder, 2020).

The consumption of snack foods will continue to increase. The global snacks food category market valued at USD 439.9 billion in 2018, is expected to grow at a compound annual growth rate of 6.2% from 2019 to 2025 (Research, 2019). Similarly, the United States (US) snack food market in 2015 was estimated at USD 90 billion, and it will reach more than $100 billion by 2025 (Statista, 2020). Within the snack food category, the extruded snacks are expected to grow from USD 48.3 billion in 2019 to USD 65.2 billion by 2026, at a compounded annual growth rate of 4.4% (Markets and Markets, 2020).

Snacks are a quick source of energy, and consumers eat snacks for various motivations such as liking, need, hunger, convenience, and to socialize (Phan & Chambers, 2016). Snack foods as a category will continue to evolve as between meals, as part of main meals, or as meal replacements. Several domestic and international food companies are capitalizing on snack food growth by bringing more consumer-centric snacks (e.g., convenient packaging, increased shelf life, on the go, novel textures, etc.) (Research, 2019). Therefore, food companies need to innovate new concepts (e.g., textures, flavors, unique texture-flavor mash-up, high protein, low calorie, high vegetable content, etc.), products matching consumer needs, and lifestyles. Snacking is no longer just eating in boredom or eating for supplementary food. Today, snacking is about delivering convenience, solving problems, and providing a valuable experience to consumers. Consumer problems are potential opportunities for food companies to address their needs.

Importance of texture in snack foods

The texture is the foremost sensory characteristic of any food. It is perceived as the physical characteristics of the foods which help to identify and describe all kinds of foods (Szczesniak, 2002). Texture influences the consumer's decision-making process in assessing food quality, attitude, liking, experience, and acceptance. For example, the presence of liked characteristics will have a positive effect, and the absence of characteristics will have a negative effect on quality assessment (Szczesniak, 1991). Consumers associate texture with food quality, freshness (fruits and vegetables), health, and nutrition (tender for good quality meats, crispy and crunchy (snacks foods), (Civille, Trail, Krogmann, & Thomas, 2020). Food companies remain very vigilant to ensure the absence of defects (disliked texture attributes) and the presence of the right texture (liked texture attributes) in their products.

By definition, the texture is “the sensory and functional manifestation of the structural, mechanical and surface properties of foods discovered by the senses of sight, touch, sound and kinesthetics” (Szczesniak, 2002). In some food products, the texture is more important than flavor (Nishinari & Fang, 2018). For example, consumers like potato chips for light, crispy, and crunchy properties, peanut butter spread for smoothness, and bacon for crispy, crunchy, chewy, and fibrous aspects (Civille et al., 2020). Recent studies that have identified texture as imperative sensory property for consumers such as quinoa (Wu, Ross, Morris, & Murphy, 2017), cantaloupe (Menezes Ayres, Lee, Boyden, & Guinard, 2019), snack foods (Kumar & Chambers, 2019b, 2019a), and solid foods (Nishinari & Fang, 2018), etc. Therefore, it is imperative to look for new texture ideas in snack food product development.

What this research is about? And how it can help researchers?

This research work provides a strategic framework for the usage of sensory and consumer research tools in NPD of snack foods. The research work is divided into five separate studies, each study covers a different and significant part of NPD. The work is mainly focused on snack foods, snack food textures, consumer perception and description of snack foods textures, ideas for new texture development, identification of white spaces in the market, utilization of global marketplaces for new texture ideas, and other factors that affect NPD. Overall, all studies are interconnected to provide a holistic view of sensory strategy for NPD. Researchers can capitalize on research results in developing new texture ideas for snack foods from the global marketplace, and to identify consumer experience of snacks textures.

The first study produced methodology, challenges, and solutions for performing a product category assessment in an unfamiliar country (Murley et al., 2020). The results describe various problems such as market selection, payment, data collection, product selection, evaluation space, language barriers, and transportation which researchers might face while exploring any international market. The study also provides solutions such as setting SMART objectives, background research, product procurement strategy, and other real-time solutions to make market exploration a success. Overall, the study underlined process and specific steps which can be a valuable tool in the exploration of foreign marketplaces for new product ideas.

The second study developed a multiparameter texture lexicon for snack and snack like foods in four languages (English, Spanish, Chinese Mandarin, and Hindi), (Kumar & Chambers, 2019a). The lexicon was produced after evaluating 85 different snack foods from eight countries for 76 texture attributes. The study published attributes, definitions, and techniques in English, Spanish, Hindi, and Chinese Mandarin. The texture lexicon and other materials produced in this

study can be valuable for researchers and food companies: 1) to identify and describe similarities and dissimilarities present in textures of snack foods, 2) to ascertain main sensory characteristics of snacks foods, 3) in product development, 4) in the assessment of snack categories in various countries, and 5) applies to a wide range of products.

The third study explains the mechanism in which consumers perceive snack food textures and use terminologies to describe texture experiences. This study combined linguistic and contextual perception to generate consumer texture terminologies (Kumar & Chambers, 2019b). Sixteen consumer texture terminologies were produced in four international languages (English, Hindi, Chinese Mandarin, and Spanish). The model presented in this can be utilized to conduct cross-cultural research studies. Food companies can use the results to generate accurate consumer responses, acceptance, preference, and addressing consumer's concerns. Researchers can use the methodology in product development, product testing in international settings, consumer insights, marketing, and communication.

The fourth study demonstrates how the global marketplace can be used to generate new texture concepts for snack foods using projective mapping (PM) and descriptive sensory analysis. This research work shows how a developer can find new snack food space in the market by sorting existing market snacks using 2-dimensional PM. Descriptive analysis was used to identify the main sensory attributes of snack foods. The principal component analysis (PCA) of descriptive data allows accessing product positioning and comparison of products in the marketplace to discover white spaces. Sensory profiles obtained from a wide range of snack foods can inspire researchers to create new product concepts with different and multiple sensory profiles. This research work creates a framework to uncover white spaces in the marketplace and

nurture new snack texture concepts to fill the identified white spaces by exploiting the main sensory attributes as product characteristics.

The fifth study pinpoints an issue with results produced from various clustering methods. Researcher frequently uses various clustering methods hierarchical agglomerative clustering (HAC), k-means (KM), or fuzzy clustering (FC) to cluster either products, attributes or consumers. Also, results produced by these clustering approaches are not always stable because objects frequently change cluster associations. Researchers generally don't highlight and report how they have obtained stability in clustering patterns. This study provides a model where HAC, KM, and FC can be applied on the large descriptive data to 1) capture the frequency of object's shuffling, 2) to identify true and changing clusters, and 3) to reach stability in cluster results. A sensory scientist can use the outcome of this study to understand the nuances of cluster algorithms, and the results obtained from them. The findings of this study can help to bring robustness in cluster analysis results.

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Chapter 2 - Issues and Successes in Evaluating a Product Category in an Unfamiliar Country: A Case Study of Snacks in Japan

(The following is an early DRAFT of a paper subsequently published in the *Journal of Sensory Studies*. For the published article, see Murley, T., Kumar, R., Chambers, E. IV, Chambers, D., Ciccone, M., and Yang, G. 2020. Issues and successes in testing a product category in an unfamiliar country: a case study of snacks in Japan. *Journal of Sensory Studies, 35: e12574*. https://doi.org/10.1111/joss.12574)

Abstract

When developing new products, it is important to understand not only the category in which the products belong but also the characteristics of existing products in that category. It is common to analyze white spaces and generate ideas based on the markets in one's home country, but it is less common to look to other countries for inspiration for new product ideas. However, differences in culture and practice may create difficulties for researchers as they attempt to study and navigate around a foreign country. The objective of this study was to address the methodological challenges of conducting a product category assessment in an unfamiliar country. This was accomplished by exploring the snack food markets in Kyoto, Japan; and collecting snack food products to generate new concepts for future snack food innovation projects. Fifteen sensory experts from Kansas State University traveled to Kyoto, Japan to uncover the regional snack food markets. The researchers targeted several shops and markets in search of novel packaged snacks (with and without labeling) and street snacks. The group tasted a subset of the snacks, and discussions were held regarding product sensory attributes and any

challenges in obtaining the snacks. Issues that were found with the category evaluation included payment, data collection, product selection, evaluation space, language barriers, and transportation. Real-time problem solving and group discussion leads to solutions to overcome such challenges. The experiences and insights from the team are translatable to countries outside of Japan, and to products outside of snack foods to accomplish similar tasks in unfamiliar countries.

Introduction

As a result of increased globalization in the current century, the world is becoming more interconnected with a rise in international research and collaborations. Other factors leading to researchers seeking more cross-cultural innovation include "rapidly changing geopolitical relations," "advances in information and communications technology," "developments across social sciences," and the "relative ease of international travel" (Crossley & Watson, 2003). In seeking to enhance knowledge and increase resource sharing, innovative ideas, and diversity, international research becomes more pertinent. This is especially true if the objective is to explore new cultures and practices. Understanding product categories has been part of the sensory scientists' repertory for many years (Muñoz, Chambers IV, & Hummer, 1996). In recent years, multiple studies have been conducted examining consumer responses in multiple countries to products and concepts (e.g., Castro & Chambers, 2019a; Koppel, Chambers IV, Vázquez Araújo, Carbonell Barrachina, & Suwonsichon, 2014; Lee et al., 2010; Supartini, Oishi, & Yagi, 2018).

The Fast-Moving Consumer Goods (FMCG) market is seeing tremendous growth with increasing numbers of international brands. With this increase, it is more important that

companies understand and recognize “the role of hereditary, dietary, cultural, religious, traditional and ecological influences on consumer responses” (Muñoz & King, 2007). Therefore, for food manufacturers to compete and succeed internationally, they need to discover cultural nuances, consumers’ preferences, values, habits, and perceptions. This study is aimed at companies seeking to introduce products into new international markets. The study outcomes can help companies to use international concepts to introduce new products into their home market.

This study was conducted in Kyoto, Japan. With a population of over 130 million citizens, Japan has a tremendous effect not only on Asian culture but also on the other cultures of the world. A specific aspect of Japanese culture that has had a large impact on world markets is food. In 2015, the Japanese food and snack market was over 43.4 billion US dollars, a 4.8% increase from the previous year (TEIKOKU, 2015). Both citizens and foreign tourists enjoy Japanese cuisines. Foreign travelers are estimated to have spent over 2.5 billion dollars on food in 2015, with over 1.1 billion of these dollars being spent on snacks. Additionally, over 6 billion dollars’ worth of food was exported to other countries in 2015, with plans by the Japanese government to increase this value to 8.9 billion dollars in 2019 (The Ministry of Agriculture, Forestry, and Fisheries, Japan Tourism Agency, 2015).

With so many new products constantly being introduced in the U.S. and other markets, companies are looking for outside inspiration to grab the interest of consumers. It is becoming increasingly popular to look to international markets for new flavors, textures, packaging concepts, and products for inspiration on what the next trends might be. Several Japanese food trends, such as sushi and green tea flavorings, have already made their way to the US, but market researchers and product developers in the food industry are always looking for the next big trend. Therefore, there is tremendous interest in researching and understanding Japanese snacks

because there are many unique flavors and preparation techniques that are currently not found in other global markets. An effective way of learning information about products in a different country is to conduct on-site research, but international research can present many new challenges. This study addresses the challenges of researching an unfamiliar country to understand the most effective methods for successfully evaluating a specific product category.

Within the field of sensory and consumer science, previous research has been done to compile methodological considerations and recommendations for conducting a cross-cultural study (Ares, 2018; Buil, de Chernatony, & Martinez, 2012; Goldman, 2006; Lee & Lopetcharat, 2017). Much of the previous research focused on conducting a sensory consumer panel in a different country or culture, with suggestions for selecting the culture, obtaining samples, developing a study procedure, and translating study instructions and questionnaires. Multiple studies chose to focus only on issues surrounding the translation of study materials and sensory terms (Kumar & Chambers IV, 2019a, 2019b; Pena, 2007; Zannoni, 1997)). However, there appears to be a gap in the literature when it comes to conducting other types of sensory and consumer research in the field, such as in-market or observational studies. Other studies have discussed the importance of cross-cultural market research (Perks & Wong, 2003; Saari & Mäkinen, 2017), but few studies were found that addressed how to perform that research outside of formal consumer behavior studies and market analysis. Additionally, many of these studies focus on measuring a domestic product's international successes instead of looking for international inspiration to develop new domestic products.

This study is aimed to address the lack of information about conducting a sensory-focused product category appraisal with a research team on-site in an unfamiliar country. Also,

address the challenges of researching an unfamiliar country to the promoted understanding of effective methods for successfully evaluating a specific product category.

Research team

A diverse group of sensory food science experts (n=15, 8 male, 7 female, age range 23-63), representing nine countries and five continents, all with prior international travel experience, from Kansas State University was used for this project. The team studied background information and then immersed themselves in the snack markets of Kyoto, Japan. The group was divided into smaller teams with mixed demographics. The aim was to minimize the impact of convenience sampling of products as it compromises the reliability, validity, and generalizability of research results. The nature of differences in product composition can have a major impact on validity (Douglas & Craig, 1984). Reynolds, Simintiras, and Diamantopoulos (2003) recommended the involvement of both the selection of cultures and participants within cultures in sampling when conducting cross-cultural research.

Cross-cultural research needs additional focus and attention to achieve a diverse sampling of products. Therefore, to discourage similar product collection driven by one culture's (country or continent) researcher, individuals from the same continent were split between the teams to take advantage of the group's diversity when purchasing products. This helped to collect a diverse and large pool of snack products. Individuals with disparate cultural backgrounds were drawn to different products when searching the stores and markets culminating in a group of products with diverse sensory properties. Figure 2.1 shows the strategy developed for this project starting with the research team.

Process

Set objectives

Setting objectives is a key step in any research process. Many resources exist to help in setting objectives, but recently the setting of SMART objectives (Specific, Measurable, Assignable, Realistic, Timebound) is becoming more common in the research literature (Ogbeiwi, O., 2017). Objectives must be: a) Specific, what exactly will be accomplished, b) Measurable, what values will be obtained to determine a result, c) Assignable, who will do what, d) Realistic, what actually can be accomplished, and e) Timebound, when will each step be completed and when will a final result be available. For this project, the SMART objective was: Understand the snack food market in a major metropolitan area of Japan (Kyoto) within 3 months of the start of the project by "mapping" the snack food marketplace for various types of snacks. Mapping was defined broadly to include the geographic availability (i.e. types and locations of markets), product type, sensory, and ingredient/nutritional quality of snacks.

Background research

After finalizing the team, and setting up objectives, background research on the Japanese culture was conducted for the project. Each person in the research group was given the assignment to prepare and give a 15 min presentation to the entire group on one of the following subjects. a) Cuisine and agriculture: special foods for special occasions, varieties of foods, Japanese foods, special or typical preparation methods, eating habits, crops, animals, and farming practices, etc. b) Social and physiological habits: how people interact with each other at home, on the street, in social gatherings, special holiday rituals, the interaction between couples and people in general, and proper dining etiquette, etc. c) History and education: the influence of

other cultures, important wars and neighbors, and how these wars have influenced Japan. d) Religion: major and minor religions in Japan, how they get along with each other, dietary restrictions, temples (building, architecture, and symbolism), prayers, etc. e) Family: family hierarchy, size of typical families, respect, interaction with each other, living arrangements, marriages, businesses, etc. f) Art and textiles: textiles, type of textiles (cotton, silk, other), fabric dying, dying styles, regional differences, paper (handmade, manufacturing process), etc. g) Kimono and Dress: description of both male and female kimonos (married vs unmarried for females), parts of the Kimono, symbolism in the kimono, dresses, and thriftiness of dressing of the farmer, etc. h) Home design, both interior and exterior: description of the basic Japanese aesthetics principles. Part of the presentation was to explain how these affected everyday life in the country. Examples were presented in both words and photos. i) Ceremonies, e.g. Japanese Tea Ceremony: Japanese tea ceremony, and it is important to their culture. j) Government and Industry: governing party, type, its influence on the people, characteristics of the governing party, current political situation. Major imports, exports, large and small corporations, family businesses, etc.

The use of websites, blogs, and computer apps such as YouTube, books, travel guides, and "friends of friends" with knowledge of the culture was important to gaining background for the project. It was critical to review multiple sources because not all sources may be reliable or may conflict with one another. Thus, finding multiple sources that provide similar information helps in better understanding the true nature of the culture.

The presentations served as mini travel guides for the group. They provided a virtual background image of Japan in the scientists' minds that helped in the effective execution of the project once in Japan. The learnings were numerous. For example, the scientists learned how to

communicate, how to dress appropriately, how to navigate around the city, which places to visit, decision-making skills for various situations, understanding social gestures, maintaining safety, use of public transport, maintaining good health while in a foreign country, arranging local resources, respecting the host country, and achieving day to day objectives.

Product procurement strategy

A strategy for product procurement was developed in which the whole group was divided into small teams (three to four members) to cover a larger area and obtain a wide variety of foods from Kyoto markets (large and small grocery markets, open-air markets, department stores, specialty shops, and street vendors). The team categorized the purchase of snacks and snack-like foods into three categories; a) packaged with labels, b) packaged without labels (typical in Japan for specialty snack shops), and c) street snacks (loosely packed, unpackaged, and unlabeled). The strategy was to purchase snacks with unique appearances, textures, flavors, ingredients, and packaging features under these categories.

The purchase expeditions by the groups were conducted on three continuous days, where each day was dedicated to only one category. The rationale was to explore existing snacks from all strata of consumer use and the manufacturer's options. Each group was given a generous amount of local currency (for Kyoto this was approximately ¥10,000 or ~100 USD at the time of the study) per day for procurement of snack foods (they could get reimbursed if they exceeded this amount) and sent to a different part of Kyoto. Apart from sensory and cultural aspects, the teams also considered other important factors. For example packaging, labeling (ingredients and nutrition), health, satiety, price, safety, hygiene, and convenience that influence snack food purchase (e.g., Bilman, van Trijp, & Renes, 2010; Forbes, Kahiya, & Balderstone, 2016; French

et al., 2001; Mace, 2012; McGill & Appleton, 2009; Mintel, 2014; Salvy, Kluczynski, Nitecki, & O'Connor, 2012; Zbib, Wooldridge, Ahmed, & Benlian, 2010).

One issue that is not addressed when looking at packaging out of context is that the impact of the packaging may be culturally different (Velasco, et al., 2014). For this project, we used a large number of researchers from different countries but intentionally did not choose a Japanese researcher who might provide context but could become the "expert" that would overwhelm the opinion of other researchers. The labels on snack food are used to represent consumer related product information and claims. Labels not only provided nutritional information but also carried other pertinent information that influences consumer purchase decisions (Campos, Doxey, & Hammond, 2011; Mintel, 2014). Moreover, there are growing demands for clean labels on food products (Falguera, Aliguer, & Falguera, 2012). Because of those issues, this project used a product procurement strategy where those aspects were only influential as mediated by the assignment for the day (i.e. packaged labeled snacks on day 1).

Purchase, observe, and interview

The research was conducted in November in Japan, which means that snacks only available in summer months were not included, nor were snacks that are special to a specific holiday. However, a variety of snacks appropriate for both warm and cool weather were available during this transition season. Over three days of product procurement, the teams targeted three types of snack foods intended to represent products sold in many types of marketplaces: Day 1) only packaged and labeled snacks were purchased where the packaging had product names, ingredient statements, nutrition panels, and/or product claims directly on their packaging. Many of these products were processed snack foods produced by larger

Japanese and foreign food manufacturers, so the groups searched for them at commercial markets such as department food stores, grocery markets, and 7-Eleven, Family Mart, or Daily Yamazaki. Much of the packaging and labeling information was in Japanese, so mobile phone translation (Japanese to English) applications (apps) were used extensively during purchase. This allowed the team to get a better understanding of the ingredients, and any other claims used to influence consumer purchase of snacks.

Day 2) Teams purchased packaged snack foods "without labels". These snacks may have had a product name and price (although many did not have either on the typical clear plastic packaging), but not much other detailed information on the packaging. The teams searched for these snacks at 'Mom and Pop' snack shops and small businesses to find products not available at the larger stores and markets. These products were targeted because they are more representative of homemade or small-batch snacks that are typically made using more traditional methods. Many were traditional flavors or flavor/texture combinations that are typical of Japan and not usually found outside the country. Some products of this type also were found in department stores that had up-scale specialty snacks that were unique to that store. Yang and Lee (2019) indicated that because of globalization, ethnic products are becoming more popular outside their traditional markets. Therefore, collecting sensory information of ethnic products is critical.

Day 3) Street snacks were purchased at various markets, including Nishiki Market, a major street of small vendors that caters both to local and tourist populations and at markets near temples where many consumers visit and shop. Nishiki market is known for selling a wide variety of street snacks, ready to eat foods, specialty foods, produce, meat, fish, traditional spices, condiments, etc. Many foods found in this market were not pre-packaged, so it allowed

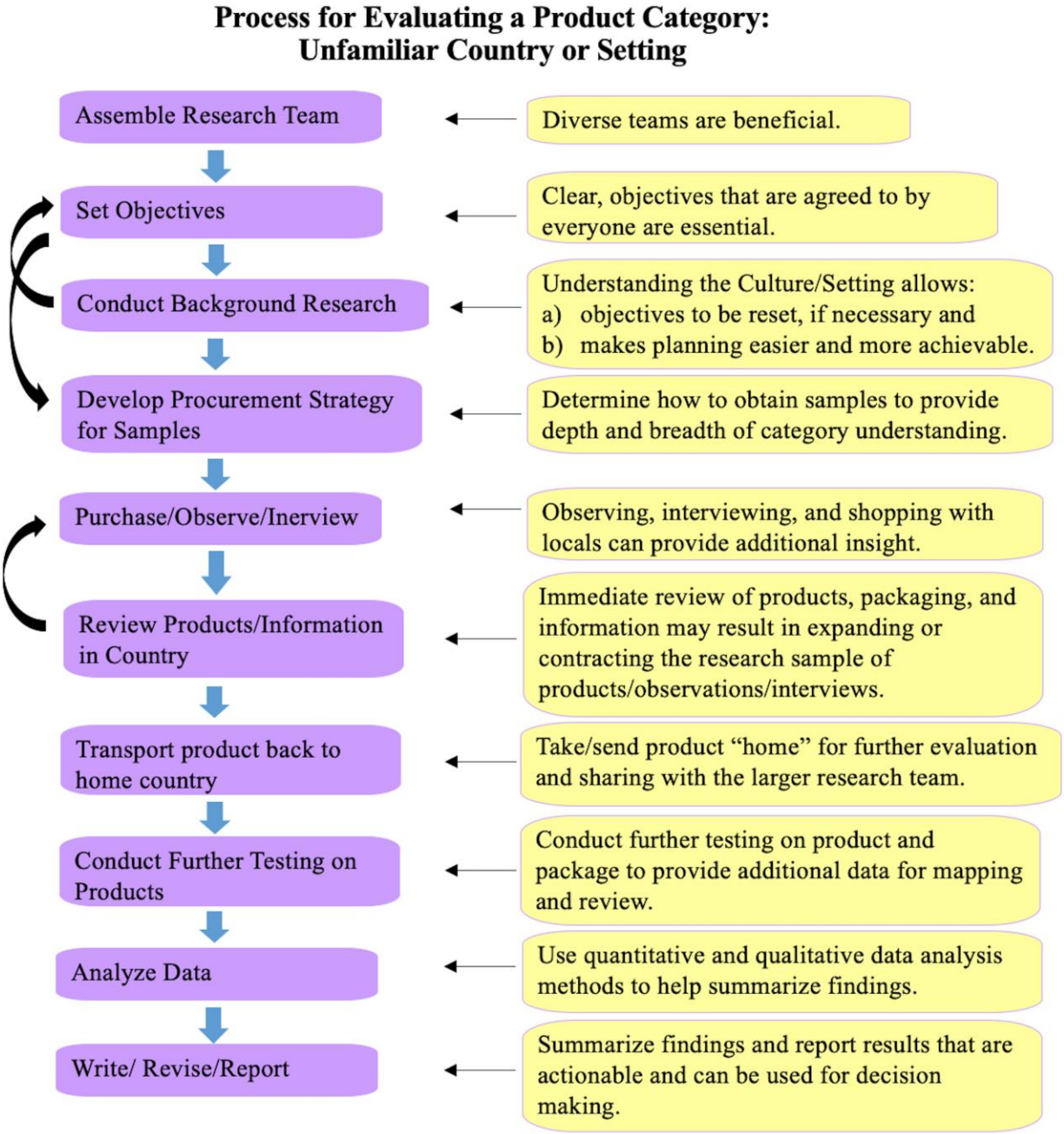
the team to examine and sample the products on-site before purchase. The products also used ingredients that cannot be used in packaged snack foods such as fresh fish or fresh bar-be-cued baby octopus with a boiled quail egg inserted in the octopus' head. These products may also be served hot or cold and required some to no degree of preparation by the vendor before consumption. This offered a different view of the snack market and provides ideas for snacks that may not currently be available except through fresh markets but might be made for the packaged snack market given the right technology.

Written notes and pictures were taken to record the product information from all three days of procurement. Each day, the teams searched for products that represented the total market.

During shopping, researchers made observations about the placement of products and shopping experience and observed consumers selecting and purchasing products. Interviews also were conducted with locals to better understand the snacking preferences and habits of Japanese consumers (Chambers & Smith, 1991). The interviews were held in public areas in Kyoto, such as malls or market streets. Interviewees were asked about their favorite snacks, when and why they snack, and what snacking means to them. The interviews were held in English with those consumers who could speak English and were held using a web-enabled translator for those who could not speak English.

Figure 2.1.

Flowchart depicting the process of evaluating a product category in an unfamiliar country.



Review products/information – in-country

The product review phase involved making and recording observations about the snacks purchased during product procurement. Each team purchased more than twenty products each day but chose a subset of their "top-ten" variations each day for the entire group to evaluate in Japan. This subset consisted of snacks with distinctive product characteristics, packaging features, and suspected processing methods. For example, shelf-stable packaged white chocolate infused strawberries were unfamiliar to most members of the team due to its unique processing technique. After taking note of the aroma, flavor, appearance, and texture sensory attributes of the snacks, the team discussed how the products might be produced and how similar products could be made and sold in the US snack food market. Each product was assessed similarly; notes, pictures, and comments were recorded during evaluation.

Some products chosen for tasting and discussion on-site had short shelf lives, and therefore would not be safe to eat by the time the products were transported back to the home country. Any products that were not discussed in Kyoto were brought back for further testing. Discussions were held at the end of each day regarding the selected products, and the successes and challenges experienced by each group during product procurement. Members from each team were assigned to keep track of all information collected, including pictures, product information, sensory attributes, and discussion notes. All product information and pictures were entered into a digital file at the end of each day.

Transport product back to home country

Shelf-stable products must be transported back to the home country for evaluation, in this case, the United States of America (USA). Before travel methods for shipping or taking product

home were explored. Besides, regulations for the import of food products were studied. Boxes were packed with snacks that are allowed into the USA (all products that were shelf-stable in this case) and were taken back by participants as checked baggage. For the USA, food must be declared to customs and may be reviewed by US Agriculture inspectors before it is allowed into the country.

Conduct further testing on products

Further testing on products then was conducted. Such testing included descriptive sensory testing of products, translation of packaging information such as ingredient statements that were not already translated, and could include physical and chemical tests. Besides, each product was examined to determine what manufacturing processes likely were used, to examining possible flavor or texture variations that might be possible, and to find other information from electronic sources that might be helpful in better understanding the products.

Analyze data

A spreadsheet of all data was made that included both quantitative and qualitative data on the products, observations, and interviews. The quantitative data can be analyzed from various perspectives: geographic data on purchase, price, ingredients, likely manufacturing process, and measures of sensory, physical, and chemical properties. Those analyses, when developed as Principal Component Analysis or other types of "map" or "plots" provide overarching information that helps to better understand the groupings, differences, and relationships among the products (Yenket, Chambers IV, & Adhikari, 2011).

Write/revise/report

The final key aspect of any project is summarizing and reporting the data. In this case, the large amount of information took considerable time and effort to analyze and to work into a focused report that identified product spaces that might provide inspiration for new products in other countries or "white spaces" that could be used to develop new products for the Japanese market (Lezama-Solano et al., 2019).

Insights related to the process

Overall

The group achieved its goal without a native Japanese member or hiring a travel guide. This was done, in part because the intent was not to use a single guide or person's pre-determined ideas of what was important and what was not. Overall, pre-travel background research not only reduced travel cost but also was helpful and effective. A local guide or native of the country could be used, but the impact of such use is unknown. A major concern of the project team was that such a person could bias the project by viewing the category through the lens of a single Japanese speaker. Of course, this also means that to some extent we also could lose a local perspective. However, this was approached by using local consumers and other helpful locals who provided some context.

Of course, challenges including differences in cultural background, understanding consumer behavior in context, developing an effective product procurement strategy, translating information into English for data collection, and product transportation could be and sometimes were encountered during the process of evaluating the snack food category in Kyoto. These challenges were interconnected to each other; a failure in one challenge could have badly

affected the whole study. In this case, none of the challenges were insurmountable. Problems were addressed by real-time solutions because not all issues could be anticipated and prepared for until the team was on-site. Flexibility is key in conducting sensory, market research, and development projects working across cultures (Lezama-Solano et al., 2019). Many of the challenges, such as language translation, navigation, "visual memories", and recording interviews were addressed by the use of technology. Others were addressed by working with the local hotel staff, asking questions, and genuinely being interested in hearing answers from willing participants. Some were handled by revamping the procedures as needed "on the fly". Details of such problems and their related solution are discussed below.

Importance of background information

Background research about the country and product category is vital in understanding cultural differences. Researchers must start collecting background research well before they leave the home country. It is important to conduct preliminary research about the host country to understand the laws, culture, people, and product category of interest. Before travel, the team learned about Japanese customs and culture to respect the country and its people. Japan, for example, is a country based on respect towards other people and their surroundings, so the team made sure to be polite and courteous towards the Japanese and its cultural values. That is not unique to the Japanese, but it may be practiced differently in various countries. Also, cleanliness is very important to the people of Japan. Unlike in America, garbage cans are not commonly found in public places, so the team used shopping bags to hold used packaging and other garbage to avoid leaving waste in public areas. Naturally, obtaining as much research on the product category in the country of interest is important. Such information often is available from public

or subscription services including government and non-governmental organization websites, research papers, and trade magazines.

Product procurement

Shops and venues in many foreign countries tend to be smaller and are more easily inundated by large groups of people. To account for this, the larger group split into teams of three or four members to avoid overwhelming shop owners. Preliminary research can also be used to increase familiarity with the geographic region to aid navigation and transportation since language translation of maps and signs can be more difficult on-site. Moreover, the research team became familiar with a few key Japanese phrases, such as those for "Please" and "Thank You," before traveling. This allowed the team members an opportunity to show politeness when asking for assistance or purchasing products.

When looking specifically for snack items, it is worthwhile to explore options beyond grocery stores because they may not stock the wide variety of snack items available. A study by Cameron et al. (2012) found that the availability of snack foods in supermarkets might vary according to country and by size. Since space in Japan is limited, stores that focus on selling convenience items, such as convenience stores, may stock a larger variety.

In practice, we found vastly different snack options in each of the types of venues we examined. Convenience stores carried an array of small packaged snack items from "brands" including major manufacturers, a few small manufacturers, and their brand. Department stores with food/grocery shops carried some major brands and multiple options of "up-scale" products. An example was a small colorfully wrapped box of colored dried, extruded pellets in the shape of leaves that when fried at home expand multifold into an edible treat that looked like fall

leaves. Traditional snack shops carried mostly unlabeled snacks that would be recognized as traditional products by most Japanese. These products were sold by the piece or by weight either in prepacked clear bags or from bulk bins and placed in similar clear bags. Fresh markets usually had a limited array of pre-packaged semi-shelf-stable snacks (e.g., fried fish bladders) or freshly made products such as sausages or unique items (e.g., barbecued baby octopus/squid with small eggs stuffed in the head to give it a round appearance).

This procurement strategy is not limited to food products. Food, beverages, or non-food items found in a large market differ from similar items found at small businesses in terms of quality, price, or product features. Shoes, for example, may be labeled similarly in all three types of markets but may not have the same selections, may be presented to the consumers differently, and/or may differ in quality, quantity, and price. Including all types of stores/markets allows researchers to gain a more complete picture of the product category.

Purchase, observe and interview

Consumers' interactions with products and with each other, both before and after purchasing, can increase understanding of a product or product category. The study of consumer behaviors can be done either actively or inactively. As active observers, the researchers can ask questions while the consumer shops and makes purchases. Additionally, the active observer can study the use or consumption of the product(s) to get an understanding of the product experience. As an inactive observer, the team studies what products are being purchased and by whom. This may allow the observer to study a larger population of consumers but limits the information that can be gathered about shopping and usage experience. An example of inactive observation is ethnography, or the observation of people's behaviors and actions in the context of the situation

being studied (Jervis & Drake, 2014). It is important to stay open-minded during data collection. Any preconceived expectations for how consumers may interact with products can bias a researcher, leading to the collection of inaccurate data.

On this project, the research teams conducted both informal (unstructured based on the context) and formal (a short set of questions prepared in advance to study shopping behavior) interviews with consumers to understand their snacking preferences and habits. The language barrier made this process a challenge because the team found that consumers with limited English skills were hesitant and not as willing to participate in the interviews. Participants in any type of research can feel uncomfortable when their cultural background or language is different from that of the interviewer (Van de Vijver, Leung, & Leung, 1997). Structured interviews were somewhat easier because the questions could be translated and provided on printed cards to the interviewee. However, this often needs to be supplemented by additional unstructured follow up questions. Younger participants had better English-speaking skills than did older participants. The young participants could be easily seen shopping in the afternoons after school. Moreover, people in groups of two or more were more comfortable participating in the interviews.

The background research helped greatly in the purchasing of snacks and interviewing consumers. The teams found solutions to several problems, for example, use of phone apps for language translation, note-taking, interacting with consumers in Japanese's gestures, asking Japanese consumers to write their response in Japanese and translating later, identification and use of local currency, choice of purchase day for maximum shop openings, and exploring ethnic food shops near shrines, etc. One issue that cannot be easily dealt with using translation apps is the difficulty of translating some terms that may seem reasonable but mean something different than the translation (Kumar & Chambers, 2019b).

The background research provided information about consumer behavior, especially certain behaviors within a culture that affect the participant's response to interviewer questions. For example, Hofstede (2001) found that people living in Asian cultures tend to agree with a majority opinion and will avoid confrontation. East Asian societies were reported to more frequently experience and describe both positive and negative emotions than people from western countries (Ishii & Eisen, 2016; Miyamoto, Uchida, & Ellsworth, 2010). Overall, Asian people have a more acquiescent response style and less extreme response style than European and American people (Chen, Lee, & Stevenson, 1995; Lee, Jones, Mineyama, & Zhang, 2002). Hence, a decision was made to interview participants on-site in groups for their comfort. We found participants tended to respect the opinions of others and, as expected, they mostly agreed with a majority opinion. Although we did interview some individuals and pairs of consumers, it might be effective to obtain more such interviews, because people might be more likely to provide their own opinion. Using local interpreters could help, but they must be trained to understand that the translations must be precise as possible without "interpretation", which may be a problem when using local interpreters who translate through a screen of their own experience. Other studies specifically studied the habits of Japanese consumers also used background information available before the studies (Gehrt & Shim, 2003; Prescott et al., 2002; Takeda & Melby, 2017).

Aside from interviewing, another way adopted for collecting information of such type is to provide consumers with money and accompany them shopping. This was suggested by a local Japanese couple (45-55 years old) who during the interview told the team they would be happy to show them what they typically bought as snacks. As a follow-up, one of the teams provided money and asked two girls dressed in school uniforms (aged between 14 and 18) to purchase

their favorite snacks from a 7-Eleven store in Kyoto. This provides a means for observing their purchases and purchase decisions. It allows them an opportunity to show the researcher their favorite snack foods that may be difficult to explain or recall on the spot. This strategy ultimately was used multiple times to determine popular snacks for various age groups. In-person shopping studies have been used in other contexts as well with success (Sigurdsson, Larsen, & Fagerstrøm, 2016; Donelan et al., 2016).

The mode of payment adopted by the research team for the procurement of snacks was cash. It was easy to distribute cash equally among teams; all types of shopping venues accepted cash payments, and it was easier to stay on budget. Credit cards can also be used to make purchases in some larger stores and convenience markets but will may not usually be as universally accepted as cash. It may be useful to determine the best payment method in the location researchers plan to visit because payment systems change over time and the researchers need to be ready. Receipts also were kept ensuring that the costs of each product were tracked for later informational analysis.

Review products/information – in-country

Once procurement was complete, the team began compiling and determining product information. Information related to products is important in consumer choice in various recent studies including Japan (Choe & Hong, 2018; Morris, Beresford, & Hirst, 2018; Chambers IV, Tran, & Chambers, 2019; Castro & Chambers IV, 2019b). The extrinsic information on products can produce expectations that shape a framework to direct sensory perception. If there is a mismatch between elicited expectation and actual sensory characteristic of food products, it can lead to product failure. Richardson, Dick, and Jain (1994) reported that products presented with

national brand names were perceived as higher quality products than generic brand names. Packaging and extrinsic information affected the experience of soft drinks and chocolate milk (Gates, Copeland, Stevenson, & Dillon, 2007), crackers and candies (Letona, Chacon, Roberto, & Barnoya, 2014; Roberto, Baik, Harris, & Brownell, 2010), and potato chips (Letona et al., 2014; McDaniel & Bakers, 1977). Therefore, researchers gathered as much extrinsic information as they could to help categorize and provide additional information on the products.

Translation

Another challenge encountered throughout all aspects of the process was the language barrier. An important goal of the project was the translation of product names, claims, ingredient statements, and nutrition panels into English to understand the nature of the products. None of the participants were native Japanese speakers and the use of a translation service on-site was prohibitively expensive for the large quantity of data collected. Unfamiliar characters hindered the interpretation of package and product information. To overcome this, on-line and downloadable language translation applications (e.g., Google Translate app) were used to gather the necessary information. Although this became a time-consuming task and the translations were not always immediately understood or reliable from a single app, preliminary translation of product details was crucial for the team. Another method of translating packaging details involved using context clues or pictures to determine the contents or sensory properties of the product (Zannoni, 1997). For example, a crunchy, savory snack found in a convenience store showed a picture of pieces of meat in a sauce with chilies and limes. Thus, an initial on-site assumption was made that the product was probably flavored like a spicy beef stew. Due to time limitations and some shops not allowing pictures, only preliminary information was recorded on

location. In many cases, simply asking the local shopkeeper provided enough information to determine our interest in the product for further evaluation. Establishing a respectful relationship with the shop owners was easy and quick in many cases, especially in grocery, specialty traditional snack markets, and fresh markets where shopkeepers were focused on "helping" customers. Full translation of the package details, nutrition labels, and ingredient lists was conducted on return to the U.S. Language translation apps also were used for on the spot translation when interviewing Japanese consumers about their snacking habits.

Of course, another option for language translation is the use of human translators. This does add expense, especially when groups are divided (in this case 3 translators would need to be hired for a minimum of 3-4 days). That can be an option for translation, communication, and even navigation. However, it also can reduce the interaction of scientists with the products because the translator does a lot of work. Similarly, when interviewing, translators may "interpret" the responses based on their personal opinions to save time and energy. That can result in reduced accuracy.

A less costly option is to ask the locals for help. With the help of the hotel staff for a nominal gratuity, interview questions were translated and written in Japanese for the interviewees. This made it easier to relay the interview questions to Japanese consumers. Conversations could then be recorded, translated, and reviewed for information. For this study, some consumers were happy to converse in English, often to practice their English skills, and translation apps again helped when needed to convey a particular point.

A further benefit of using locals was that they also can be used to help with shopping in some cases. Many local consumers were eager to show us their favorite snack foods and relay

when and how they ate it, why they liked it, and how often it was chosen. Shop-a-longs have been shown to provide valuable information (Donelan et al., 2016) about consumer behavior.

Navigation in a different language also was difficult, so when looking for specific stores or products, the team showed pictures or maps to locals to ask for directions. If one goal of the research is to conduct more formal consumer behavior surveys or interviews, it may be helpful to prepare documents before traveling. Multiple studies suggest using a double translation method to ensure that the understanding of the document in both languages is as equal as possible (Ares, 2018; Chambers et al., 2016; Lee et al., 2010; Pena, 2007).

Information gathering

The team tested each product in the subset being evaluated (top 30 each day) using a free global evaluation of individual products (open-ended within the realms of sensory perception) and held discussions on the internal and external sensory factors. The adopted methodology for collecting product information was based on the universal perception of the products (Carrillo, Varela, & Fiszman, 2012). It provides a natural, intuitive, and holistic way to describe products for both consumers and sensory experts. It was almost a replica of consumer behavior in front of the supermarket shelf with the difference being trained sensory professionals were used. That reduced the impact of the extrinsic factors on the sensory characteristics because the experts were able to identify sensory properties regardless of the extrinsic cues. In fact, in multiple cases, the scientists commented on the disconnect between expectation and the actual product. A similar methodology has been applied to other categories of various foods products with both consumers and experts (Risvik et al., 1994; Ares, Varela, Rado, & Gimenez, 2011; King, Cliff, & Hall, 1998; Nestrud & Lawless, 2008).

The information related to packaging appearance is known to have a significant effect on the consumer's perception of food categories (Becker, van Rompay, Schifferstein, & Galetzka, 2011; Schifferstein et al., 2013). Often the information for those products is both verbal and non-verbal, in the form of colors, pictures, lettering size, and type (Carrillo et al., 2012). Consumers used information displayed on eleven commercial chocolate-flavored bars such as "nutritional information, ingredients/composition, branding/uses, sensory expectations, and packaging design" as drivers for categorizing bars (Miraballes, Fiszman, Gámbaro, & Varela, 2014).

The research team collected all information to be used as inspiration for innovation-based snack product development projects. Products with sensory attributes or features that are not found in U.S. snack foods were highlighted as having potential for development in the home market. For example, many packaged and non-packed Japanese snacks used sweet potatoes or beans to create vegetable-based snacks that taste sweet. As more Americans consider the healthiness of their snack foods, snack food using these ingredients may appeal to American consumers as an indulgent snack without added calories from sugar being on the label. Manufacturers can assess competitive products sold in foreign markets using the collected product information including ingredient statements and nutrition information. The information gathered can also help to understand how their products are presented, sold, and perceived in another country.

An important step in the data collection process is the method or methods used to record the data. Resources for data collection should be considered before the study. For example, pictures and videos are valuable tools for recording observations and information, but not all vendors will allow the use of cameras or camera phones inside their shops. Therefore, multiple means of data collection should be employed. Photos, in tandem with written notes, can provide

a more complete picture of the product or category. This also allows the researcher to continue to take notes when one of the collection methods is not feasible. Since the group was split into smaller teams, record keeping became another challenge.

All notes, observations, and pictures were spread over multiple individuals on the project. This increased the risk of information being lost or misplaced before it could be shared with the group. To overcome this challenge, the group logged all collected data at the end of each day on a shared file. Selected individuals on the trip assumed the responsibility of adding to the study observations to maintain the organization of the various files. Each file contained as much information as could be gathered onsite. Not all product information could be logged onsite, and additional data was collected back home. The final set of data was compiled into one file back in the home country.

Research space

A specific challenge encountered during data collection was the lack of space to evaluate products. Unlike in the US, there is limited room to spread out in Japan. The original goal of the project was to conduct a mapping procedure using the collected products to understand the similarities and differences between products and locate any gaps in the Japanese snack food market. Using projective mapping, products are arranged in a two-dimensional space based on how similar or different they are to each other based on both intrinsic and extrinsic attributes separately (Meilgaard, Civille, & Carr, 2016; Pagès, 2005; Varela & Ares, 2012; Risvik et al., 1994). Other rapid sensory methods, like flash profiling, can be used in place of mapping or group discussion to gather data about a product or products. Smaller spaces can hinder the data collection process, especially if a mapping procedure is being used.

Due to the lack of space to gather and examine the collected products, the team could not map the products on-site and had to change the data collection strategy. Flexibility and alternative plans are essential in such cases. For this project, the team worked with the hotel to use what accessible spaces were available, such as a basement anteroom used only at certain times of the day (breakfast and dinner). In these smaller, more constrained spaces with limited time access, the team focused on group discussion of the product characteristics, both intrinsic and extrinsic. A large number of products, even in the subsets (30 per day), with 15 scientists meant the project leader had to maintain the structure and keep the flow of the discussion focused and respectful to be quick and meaningful. Notes were made and comments grouped during the sessions and agreed on summaries were discussed during this session. For packaged shelf-stable products, all remaining products were gathered and shipped back to the US for further study. If the data collection strategy or product assessment will require a large common space, research teams should contact hotels or other venues beforehand to inquire about available space and make arrangements for alternatives when needed.

Product transportation

Often products are shipped from the country back to the research base. That may occur because the product needs to undergo further analysis, complete data gathering when it could not be completed on-site, or simply to have products to show others on the research team who were unable to attend the in-country research. If the product is to be compared with existing products of another country, the sample will also need to be shipped. Thus, it is important to have the means to ship products back to the home country for further analysis. In this case, the number of researchers allowed the product to be hand-carried in luggage. This was planned, and empty

suitcases and duffle bags were taken to Japan with this in mind. Airport and import regulations were checked beforehand and followed to ensure there were no issues in bringing products back to the US. If this option is not possible, an international shipping company or simple post also can be used. In this case, a similar project in Korea required that six boxes of products were sent back by mail post. All arrived within seven days. In any case, shipping rules and requirements specific to the host and home country will need to be followed to ensure the products make it to their end destination. Shipment of perishable or agricultural items, like meat or fresh fruits, may dictate the mode of transport chosen or whether it is even legal to import the product. ASTM International has published a standard for international consumer testing which includes expectations and guidelines for consumer testing in many countries around the world (Muñoz & King, 2007). The same document also discusses shipping that can be helpful in international studies.

Nakao and Taniguchi (2007) who detailed specific shipping considerations for Japan, also suggested that shipping companies can also be contacted with additional questions and for recommendations. When transporting products internationally, products must be sufficiently protected to prevent damage during shipping. Products with packages that are "puffed" or slightly inflated, as with many highly friable snacks and those with sharp corners or edges should be wrapped or sealed with additional packaging or placed in individual containers within a larger box to avoid puncturing other items or being themselves punctured and deflated in transit. Liquid items should be properly sealed to avoid leaking and should be overwrapped to ensure that leaks are contained if they occur. It may be best to consult with the airline or mail carrier when shipping delicate products or products with specialized packagings, such as aerosol cans, to limit damage in transit. It is especially important to note that some products simply do not ship well

under certain conditions. For example, foam type products, in this case, snacks with foam centers, will need to be hand-carried in the pressurized air cabin or will need to be transported under pressurized conditions that may not be typical of all transport services if they are to be flown to another location. Such products may expand and then collapse when air pressures change. Similarly, temperature variations may be critical for some products containing high levels of fat or moisture. Additionally, some products may be considered hazardous due to the formulation or shipping conditions, such as shipping on dry ice. The laws of each country will dictate how these items should be labeled, handled, and transported.

Data analysis, summary, and reporting

The volume of information gathered in this study required careful procedures for collating and storing data. Files with pictures can become quite large and time must be allowed for downloads and uploads of such data when internet connections are slow.

Conclusion

The study of products found in countries other than one's own can be beneficial to domestic companies or research institutions for product development or other research purposes. However, differences in laws, language, customs, and culture can make international research a daunting task. The challenges associated with observational, and international product research can be made more feasible with proper preparation. Before the study, the country, people, and/or products/categories of interest should be analyzed to enhance the understanding of potential challenges. The method of data collection, product procurement, and sampling should also be considered. Determination of what products to target, what people to study, how the information

will be logged and shared, and the procedures for accomplishing such tasks should be done before traveling to avoid losing valuable time and information. The manner of product collection and feasibility of sampling the products in the host country should also be considered. Products may need to be shipped home if it is not possible to collect the necessary data in the host country. Communication, for example, is crucial to international research and can be made more manageable with the use of resources such as translation applications, fluent translators, or bilingual locals. This project illustrated that the study of a given product category in a given country is not one size fits all. By imposing models developed in one culture to other cultures "as it is", can threaten the accuracy of results, and risk the omission of culture-specific aspects that are significant for some of the cultures (Ares, 2018; Buil, de Chernatony, & Martinez, 2012). Therefore, sensory and consumer scientist are encouraged to do a background preliminary study to unearth the specific cultural concepts as explained in this study. The procedure followed will need to be tailored to fit the specifics of the experiment. However, the basic process highlighted in this study can be a valuable tool to prepare for the challenges that come with a product category analysis in an unfamiliar country.

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Chapter 3 - Lexicon for multi-parameter texture assessment of snack and snack-like foods in English, Spanish, Mandarin, and Hindi

(The following is an early DRAFT of a paper subsequently published in the *Journal of Sensory Studies*. For the published article see, Kumar, R., & Chambers IV, E. (2019). Lexicon for multi-parameter texture assessment of snack and snack-like foods in English, Spanish, Chinese, and Hindi. *Journal of Sensory Studies, 34*(4), e12500. https://doi.org/10.1111/joss.12500)

Abstract

Snack food is an important part of human life across the world due, in part, to its convenience, availability, and of course its sensory qualities. Because the texture is such a critical aspect of snack foods, a lexicon applicable to various processed and unprocessed snack foods (for example crackers, chips, vegetables, yogurt, etc.) is needed. This study also investigated how textures are experienced by vision, hand tactile, lip feel, first bite, multiple-bite, and in-throat swallowing. This study developed a texture lexicon for various snack foods. Eighty-five different food products from eight countries around the world were used to create an initial lexicon. The highly trained panel used descriptive analysis techniques to identify 76 texture attributes and develop definitions, techniques, and references for product evaluation. Fifty of the products then were selected and evaluated for intensities using references. Principal component analysis of the data shows that the developed terms differentiated the products. K-

means cluster analysis was done to find the existing clusters between attributes, and correlation analysis used to find the highest correlated and uncorrelated attributes. The article presents attributes, definitions, and techniques in English, Hindi, Mandarin Chinese, and Spanish.

Introduction

Traditionally, snack foods are defined as foods consumed outside regular meals such as breakfast, lunch, or dinner. However, there is no consistent definition of "snack food". Thus, snacks often are thought of as "hand-held" foods and could be eaten at both snacks and mealtimes. Phan and Chambers (2016a & 2016b), identified many different food products that were eaten as snacks. Food that is energy-dense, packed, or non-packed, on the go, and ready to consume (Hess et al., 2016) often are called snacks. Aroma, taste, and texture are the three most important factors predicting the overall pleasantness of foods. The perceived food texture is the most important sensory attribute of the product for the consumer. Consumers frequently use texture as an indicator of food quality (Szczesniak & Kahn, 1971). For example, soggy (not crisp) potato chips, tough (not tender) steak, wilted spinach, and shriveled grapes considered unacceptable in quality (Szczesniak & Kahn, 1971).

The texture is an important attribute to experience, describe, and identify foods. The juice sacs (visual) of orange suggests a liquid with juiciness may be present, the crispness of a potato chip (both a tactile and an auditory cue) provides a satisfactory experience, and the thickness of a milkshake (visually and tactile) differentiate that product from a fizzy soft drink. Szczesniak and Kleyn (1963) found a high percentage (over 20%) of texture-related responses as descriptors for peanut butter, celery, angel-food cake, and pie crust. Yoshikawa et al. (1970), and Rohm (1990) also found a high frequency of textural terms as descriptors for products. Therefore, the sensory

scientist should pay heed to not only the perceived aroma, taste, and color dimensions of foods but also towards the textural features.

Szczesniak (2002), defined texture as “the sensory and functional manifestation of the structural, mechanical and surface properties of foods discovered by the senses of sight, touch, sound, and kinesthetics”. In most studies, a combination of these senses is used to identify the texture of the product, whereas some studies have used one of these senses to perceive texture. The texture terms were classified into three main categories, 1) Mechanical characteristics (hardness, cohesiveness, viscosity, elasticity, and adhesiveness), 2) Geometrical characteristics (particle size, shape, and orientation), and 3) other characteristics (moisture content, oiliness, greasiness) (Szczesniak, 1963). The multi-parameter nature of texture makes it impossible to be detected by a single or specific receptor. Visual and tactile hand perceptions provide some textural assessments for particle shape, size, and orientation but the main evaluation transpires in the mouth. The initial geometrical characteristic is felt when food is first placed in the mouth. However, the majority of texture is perceived during mastication when the food is deformed between teeth and manipulated by the tongue in the oral cavity. Many tissues and receptors perceive texture sensations as touch, pressure, pain, and joint position (Christensen, 1984).

Since the development of texture classification (Szczesniak, 1963), many authors have discussed texture terms and their use. Muñoz (1986), updated Szczesniak's original list adding properties such as those felt on the lips. Similarly, Civille et al. (2010), published texture terms for almonds textures on the lips, first chew, chew-down and residual attributes. Seventy-nine texture terms from 100 panels based on 74 foods are described by Lawless and Heymann (2010). Other studies have been conducted that included the translation of terms into different languages. For example, one study translated 54 English texture terms into 22 different languages by texture

expert's proficient with English and other languages (Drake 1989). That study mentioned that some discrepancies can occur due to a) multiple meanings of several terms, especially in Japanese, b) the non-contextual background of English words when some other languages use words only in a certain context, and c) food-specific terms.

One study evaluated 12 food samples in a consumer study using a Check All That Apply (CATA) method and generated 365 texture terms in four languages; Korean, English, Chinese and Japanese (Kim & Lee 2016). English had the fewest number of texture terms and was most effective in differentiating texture characteristics of food samples, whereas Japanese was less effective with the highest number of terms. Korean did not have enough terms to completely describe some food samples. Similarly, Nishinari et al. (2008), compared texture terms in English, French, Japanese, and Chinese with both experts and consumers. They found 1) most texture terms were related to mechanical and geometrical characteristics, 2) more descriptive terms were used for solid foods than liquid foods, and 3) the terms used by texture experts and consumers were different. For the translation of terms, Cherdchu, Chambers, and Suwonsichon (2013) discussed the need to have scientists fluent in various languages work together to ensure that the translated words mean the same thing.

Studies aimed to comprehend and validate texture terms along with sensory evaluation have led to various lists of terms depending on the language. Hayakawa et al. (2013), classified 445 Japanese texture terms based on the similarities between pairs of terms. A list of German texture terms was developed and found that consumer texture awareness can be inferred from the frequency of mention, number of descriptive terms, and to consider opinions of the less-specialized local population to reduce the difference in linguistic meanings (Rohm, 1990; Rohm et al., 1994). Seventy Finnish and English texture terms were categorized (Lawless, Vanne, &

Tuorila, 1997). The categories were geometric, particle-related, degree of open structure, firmness, thickness and adhesiveness, deformability and elasticity, moisture terms, oiliness, and a category related to the presence of effervescence. The results concluded that substantial aspects of texture were more similar than different across cultures, and the difference was due to linguistic roots. Two hundred twenty-seven French texture terms were categorized into five groups (Nishinari et al., 2008). Drake (1989) concluded that for some languages a single word is sometimes used for two or more properties that are described by dissimilar terms in another language.

To date, most sensory texture studies have been limited to a few foods, are specific to a culture (countries), and usually do not attempt to measure texture perception by different senses, such as visual, tactile hand, and mouth. For Example, Kim and Lee (2016) developed texture lexicons using twelve products: apple, beef jerky, hard-boiled egg, hardtack, instant cup noodle, kimchi, potato snack, rice, rice cake, tuna, tofu, and yogurt. Similarly, texture lexicons have been developed for apples and pears (Chauvin, Ross, Pitts, Kupferman, & Swanson, 2010), cheese (Pereira, Bennett, Hemar, & Campanella, 2001), rice (Mundo & Juliano 1981), potatoes (Thybo & Martens, 1999), thickened liquids for dysphagia patients (Chambers, Jenkins, & Garcia, 2017), fresh processed tomatoes (Hongsoongnern & Chambers IV, 2008), milk desserts (Bruzzone, Ares, & Giménez, 2012), and lip products (Dooley, Adhikari & Chambers, 2009). Several studies have examined either visual and mouth texture characteristics (Irie et al., 2018), hand and mouth texture (Drake, Gerard, & Civille 1999). In that case, the authors found no difference between hand and mouth evaluations.

This study was designed to 1) develop a texture lexicon useful for evaluating many foods during the process of eating including visual, hand, lip, first bite, chew, and swallowing, and 2)

to translate the texture terms and definitions from English into three other widely used languages: Chinese (Mandarin), Hindi and Spanish. The definitions were translated to provide a clear understating of attributes by sensory panelists.

Materials and methods

Descriptive panelists

Four highly trained professional sensory panelists (two females and two males) were used to help generate and define terminology. That number of highly trained panelists is sufficient to differentiate among samples (Chambers IV, Bowers, & Dayton, 1981). The panelist had completed 120 hr. of general descriptive analysis training that includes techniques and practice in attribute identification, terminology and definition development, and intensity scoring. Each panelist had more than 2000 hr. of testing experience with a wide range of products including beverages and food. For this project, the panelist received additional training and orientation to ensure they understood the concept of evaluating products at all stages of sensory perception.

Snack product screening

To develop a texture lexicon, a total of 85 different foods manufactured in eight different countries (United States, China, India, Malaysia, Japan, Taiwan, South Korea, and Italy) were used (Table 3.1). Note that although the samples were manufactured in 8 countries, they typically are sold in many more countries. All the samples were purchased in the United States to ensure that we could obtain more samples if needed. The products used to develop a lexicon that offers a widespread range of textures, although the primary focus was on foods that usually could be eaten held in the hand because hand evaluation of texture was included. Thus, liquids

generally were excluded as were fresh meat and mixed dishes. However, multi-textured products were included.

Sample preparation

The samples used in the study were ready to eat without preparation thus, were served "as is" to preserve the natural order of consumption. The samples were served in 3.25 oz (plastic) and 8 oz (Styrofoam) cups (based on the size, and shape of the samples) and covered with a lid. One sample at a time was served in random order. Panelists cleaned their palates between samples with freshly cut cucumbers, Mozzarella cheese (manufactured by Kroger, Cincinnati, Ohio), water, and a washcloth for cleaning of lips and hands.

Categorization of texture perception

Because food texture can be determined using various senses and at different stages of consumption, six different stages of texture assessment were used: visual (V), hand-feel (H), lip feel (L), first-bite (FB), multi-bite (chewing/mastication) (MB), and Swallowing (throat) (TH). Potential textural attributes were developed for each stage. Each food sample was evaluated for each stage (Table 3.2).

Table 3.1.

Listed products are used for texture lexicon. Product names with an asterisk (*) are used for validation purposes.

Sr. No	Product Name	Manufacturer
1	Laughing Cow Cheese*	Fromageries Bel
2	Yoplait Original Yogurt*	General Mills and French dairy Co. Sodiaal
3	Dried Turkish Apricots*	Multiple manufacturers
4	Gummy Worms*	Ferrara Candy Company
5	Matador Original Beef Jerky*	Frito-Lay
6	Baby Carrots*	Grimmway Farms
7	Taro Parsnip Chips*	The Hain Celestial Group
8	Stacy's Pita*	Frito-Lay
9	Lay's Classic Potato Chips*	Frito-Lay
10	Cheetos Crunchy*	Frito-Lay
11	Prawn crackers	Multiple manufacturers
12	Seaweed Chips*	Annie Chun's
13	Maltesers*	Mars
14	Jet Puff Original Marshmallow*	Kraft foods
15	Nutri-grain Fruit Bar Strawberry	Kellogg's
16	Egg Meringue*	Lab prepared
17	Pop Rocks	Zeta Especial
18	Soft Baked Montauk Cookies	Pepperidge Farm
19	Loacker Wafers	Loacker (Italian company)
20	Skippy PB Bites*	Hormel Foods
21	Mashed Potatoes*	Basic American foods
22	Triscuit	Mondelez
23	Nature Valley- crunchy granola bars*	General Mills
24	Mission white corn tortillas (super soft) *	Gruma corporations
25	Snyder's of Hanover- sourdough hard pretzels*	SL snacks national LLC
26	Sara Lee 100% whole wheat bread*	Bimbo Bakeries
27	Trident-bubble gum*	Mondelez
28	Hershey's Milk chocolate	The Hershey Company
29	Werther's Original chewy caramels*	August Storck
30	Shelled walnuts*	Diamond foods
31	Musselman's unsweetened apple sauce	Knouse foods
32	JIF creamy peanut butter	The J M Smucker company
33	Snack pack pudding	ConAgra foods
34	Green Giant asparagus spears*	B&G foods North America
35	Mezzetta imported cocktail onions	G L Mezzetta Inc.
36	Mt Olive Petite snack crunchers*	Mt. Olive Pickle company
37	Sea Salt & Peppercorn Rice Crisps*	The Quaker Oat Company
38	Bin-Bin Rice Crackers Original flavor	Namchow ltd
39	Lotte Choco Pie cacao	Lotte confectionery co ltd
40	Strawberry Puff	I-MEI food co ltd

Sr. No	Product Name	Manufacturer
41	Bread balls	Thomas & Friends
42	Yuki & Love Green tea Mochi*	Taiwan SAN SHU gong foods co
43	Party Wafers coconut*	Lago group
44	Moroll-wafer rolls with chocolate fillings*	Win-Win Food Industry
45	Quail Eggs*	KSU dairy bar
46	Bagel crisps- sea salt	B&G foods Inc
47	Bananas*	Purchased Dillons
48	Fritos corn chips	Frito Lays
49	Apple chips	Bare foods co
50	Glazzed Apple fritters	Archer Farms
51	Coconut chips	Dang Foods LLC
52	Fruit Strips- mango	Target corporations
53	Lara bar*	Small planet food Inc
54	Oreo chocolate candy bar	Mondelez Global LLC
55	Smarties-Candy rolls	Smarties candy company
56	Jumbo pears*	Everhills foods Inc
57	Fruit Gushers	General Mills
58	Dark chocolate whole grain clusters	Kind LC
59	Figgy Pops Super snack	Made -n Nature
60	Mr. Cheese O's	Sonoma creamy
61	State Fair 100% Beef corn dogs	The Hillshire brands company
62	Frozen edamame*	The Pict sweet Company
63	Uncrustables*	Smucker's
64	Garden Lites Superfood Veggie cakes*	New Classic Cooking’s LLC
65	Jackfruit*	Flying Horse
66	Cocktail Samosas*	Deep Foods
67	Soan Papdi*	Mo'plleez
68	Rasagulla*	Mo'plleez
69	Quinoa with Artichoke and Pepper Medley*	World Gourmet
70	180̊ snacks Almond Cashew Pops with Mango	180° Snacks
71	Coconut Cashew Crunch	Anastasia Confections
72	Ginger chews*	Chimes
73	Dried Figs*	Prana Bio vegan Inc
74	Caber Wine salami*	Milan Salami Co Inc
75	Mochi Roll*	Yuki & Love
76	Egg Tofu	Tiffany food Corp
77	Fish Tofu Snack*	Yankershop food co ltd
78	Chinese food snack WEI-LONG	WEI-LONG Konjac
79	Natori Surimi Product	Nan Jing Ming Hong Foods Ltd
80	Almond chocolate sticks	Lotte confectionary
81	Mixed Congee- Canned Instant Cereal*	TAISUN Enterprise
82	Moon Pie*	Chattanooga bakery
83	Dried Okra chips*	Distributed by Johnvince foods
84	GFB- Gluten free bites*	West Thomas Partners LLC
85	Baby bottle pop lollipop with popping powder*	The Topps company

Lexicon development

The texture terminologies were developed initially using all 85 products. Fifteen 2hr sessions were conducted to create the initial attributes and descriptive references. The literature review, panelist previous work, and experiences, input from the scientists were used to develop and refine initial attributes, and others were added during lexicon development and review. The panelists were allowed to add attributes to the lexicon if new textures were found in the samples they tested. A consensus methodology (Chambers IV, 2018) was employed in the lexicon development on the appropriateness of attributes, their definition, and references. Throughout the study, a product frame of reference was collected to generate terms, followed by a review of references, examples, and determining the final descriptor list. Similar methodology has been used in other recent studies (e.g., Chambers IV, Jenkins, & Garcia 2017; Griffin, Dean, & Drake 2017; Kim, Lee, & Kim 2017; Belisle et al., 2017).

Lexicon testing and validation

A total of 50 products were selected from the set of 84 products for further testing. The selection was based on panelist and scientist input and an attempt was made to include a wide range of products that were believed to offer unique textures for scaling attributes and reference development.

Fifteen 2 hr. sessions were held for evaluation of the 50 screened snack food samples. A consensus profile method with a scale ranging from 0 to 15.0 with 0.5 increments where 0 represents none and 15 extremely strong was used (Chambers IV, Jenkins & Garcia, 2017). Separate panelists were to evaluate different aspects of the products to ensure that panelists did not simply use similar scores for attributes in a halo effect. Thus, visual, lip-feel, and first bite

textures were evaluated by two panelists, and hand, multi-bite, and in-throat swallow textures were evaluated by two different panelists. Each panelist independently allocated intensities to the attributes and then the intensities were discussed within a panel for a consensus score by the panel. A list of 76 textural attributes over the six different stages was developed and scaled for intensities (Table 3.3)

Data Analysis

Scores for each attribute for each of the 50 samples were clustered using k-means, and principal component analysis (PCA), cluster analysis (CA), and correlation analysis was also performed (Yenket, Chambers, & Adhikari, 2011; Muñoz, Chambers, & Hummer, 1996). Data analytical software R-studio version 3.5.1 (R Foundation for Statistical Computing, Vienna, Austria; URL https://www.R-project.org/) was used for all statistical analyses. The program was run 25 times for each cluster number (k) starting with K=5 with an increment of 5 until the explained variability plot flattened out with increasing numbers of clusters and then reduced by half and increased by 1 until an optimum solution was found. Clusters were individually inspected to examine results as suggested by (Yenket, Chambers, & Johnson 2011). The number of clusters for 76 attributes was 28 based on the trials and residual errors. A similar approach was used for product clustering where the number of clusters was set at 50 because of the widespread distinction between products (See the Appendix-A, Figure A.5).

Table 3.2.

Techniques or standard procedures used in this study to evaluate texture by different senses. English is highlighted simply to make it easier to differentiate techniques.

Language	Type	Description
English	**Visual Texture**	**Visual observations of entire product by looking at the product. You can turn the product if required.**
Hindi	खादय पदार्थ (फ़ूड प्रोडक्ट) के टेक्सचर को सिर्फ देख कर अनुमान लगाना	देख कर खादय पदार्थ (फ़ूड प्रोडक्ट) की सम्पूर्ण संरचना (टेक्सचर) का पता लगाना. यदि आवश्यक हो तो उत्पाद को पलट कर देख सकते है
Mandarin	视觉质感	通过视觉观察整个产品来进行品评，需要时可翻转产品。
Spanish	Atributos visuales de textura	Observaciones visuales de todo el producto. El producto se puede voltear si se requiere.
English	**Hand feel Texture**	**Evaluated by manipulating product between thumb and fingers (press lightly).**
Hindi	खादय पदार्थ (फ़ूड प्रोडक्ट) के टेक्सचर को हाथों से महसूस करना	अंगूठे और उंगलियों के बीच में (प्रोडक्ट) को पकड़ कर या हल्का दबा कर मूल्यांकन किया जा सकता है
Mandarin	手部质感	通过用拇指和其他手指轻轻挤压产品来进行品评
Spanish	Textura en la mano	Evaluado por la manipulación del producto entre el dedo pulgar y los demás dedos (presionando suavemente).
English	**Lip feel Texture**	**Blot lips with napkin before testing. Evaluate products by placing between the lips and pressing lightly.**
Hindi	खादय पदार्थ (फ़ूड प्रोडक्ट) के टेक्सचर को होटों से महसूस करना	मूल्यांकन से पहले होठों को रूमाल से साफ़ करें। होठों के बीच रखकर और हल्के से दबाकर उत्पादों का मूल्यांकन करें।
Mandarin	唇部质感	测试前用纸巾擦干嘴唇，将产品放在嘴唇之间，通过轻轻挤压来品评产品
Spanish	Textura en los labios	Limpie los labios con una servilleta antes de evaluar. Evalué el producto posicionándolo entre los labios y presionando suavemente.
English	**First Bite Texture**	**Biting (single bite only) into the product with molar or your natural preferred tooth just once. Evaluate product based on first bite experience.**

Language	Type	Description
Hindi	सिर्फ एक बार दातों या दाढ़ से तोड कर खादय पदार्थ (फ़ूड प्रोडक्ट) के टेक्सचर का पता लगाना	(फर्स्ट बाईट) सिर्फ एक ही बार दातों या दाढ़ से टूटने के अनुभव के आधार पर उत्पाद के टेक्सचर का मूल्यांकन करना ।
Mandarin	第一口质感	用磨牙或其他你习惯使用的牙齿咬一口产品。 根据第一口的体验，品评产品。
Spanish	Textura en el primer mordisco	Mordiendo (una única vez) el producto con los molares o los dientes que usted naturalmente prefiera. Evalúe el producto basado en el primer mordisco.
English	**Multiple bite Texture**	**Mastication (chewing) of product in natural manner (breaking down the product in mouth, making it ready for swallow). Evaluate perception of product textural attributes during mastication process.**
Hindi	एक से अधिक बार दाढ़ से चबा कर खादय पदार्थ (फ़ूड प्रोडक्ट) के टेक्सचर का पता लगाना	खदया पदार्थ को प्राकृतिक तरीके से चबाना, पदार्थ को चबा चबा कर तोडना ताकि वो निगलने के लिए उपयुक्त बने। चबाने की प्रक्रिया के दौरान उत्पाद के टेक्सचर की विशेषताओं का मूल्यांकन करें।
Mandarin	反复咀嚼感	用平常咀嚼的方式（在嘴里咀嚼磨碎产品直到可以正常吞咽）。在反复咀嚼的过程中根据质感的词汇品评产品。
Spanish	Textura en múltiples mordiscos	Masticación del producto de forma natural (rompiendo el producto en la boca, preparando el mismo para tragarlo). Evalúe la percepción de los atributos de textura del producto durante el proceso de masticación.
English	**Swallow/ in throat Texture**	**Swallow the product after mastication. Evaluate the textural experience while you swallow the product flowing down through throat.**
Hindi	गले के भीतर या निगलने कि क्रिया के समय खादय पदार्थ (फ़ूड प्रोडक्ट) कि संरचना (टेक्सचर) का मूल्यांकन करना	चबाने के बाद उत्पाद को निगलने कि क्रिया में गले के भीतर अनुभव किए गए टेक्सचर की विशेषताओं का मूल्यांकन करें।
Mandarin	吞咽（喉部）感	在咀嚼后吞下产品时的感觉。根据吞咽时喉部的感官词汇品评样品。
Spanish	Tragar/ textura en la garganta	Tragar el producto tras la masticación. Evalué la experiencia de texturas mientras traga el producto que fluye a través de la garganta.

Table 3.3.

Seventy-six attributes clustered into twenty-eight clusters using the k-mean clustering method.

Cluster-1	Waxy-V Waxy Mouthfeel-MB	Waxy-H Waxy mouth coat-TH	Waxy-L
Cluster-2	Residuals Mouth-TH	Residuals Throat-TH	
Cluster-3	Roughness of surface- V	Roughness of surface- H	Roughness of surface-L
Cluster-4	Slickness during swallow-TH		
Cluster-5	Adhesive-H	Adhesive-L	
Cluster-6	Moistness -V Moistness-FB	Moistness-H	Moistness-L
Cluster-7	Mealy-MB		
Cluster-8	Fracturability-FB	Initial crispness-FB	
Cluster-9	Fibrous-FB	Fibrous-MB	
Cluster-10	Astringent-MB	Chalky Mouthfeel -MB	Chalky mouth coat-TH
Cluster-11	Flaky-V		
Cluster-12	Powdery-V	Powdery-H	Powdery-L
Cluster-13	Cohesiveness-FB	Uniformity of bite-FB	Moistness of mass-MB
Cluster-14	Cohesiveness-TH	Pressure on throat-TH	Swallowability-TH
Cluster-15	Dissolvability-MB		
Cluster-16	Heat burn- L Heat burn-MB	Sting bite-L Heat burn-TH	Heat burn-FB
Cluster-17	Springiness-H		
Cluster-18	Greasy-V Oily-L	Oily-V Oily-H	Greasy-H Greasy-L
Cluster-19	Smoothness-V Smoothness-L	Uniformity of surface-V	Smoothness-H
Cluster-20	Particle amount-V		
Cluster-21	Melt in Hand-H Doughy-MB Tongue Tingle-MB	Effervescence-FB Effervescence-MB	Cooling-MB Sting bite-MB
Cluster-22	Firmness-FB	Chew count-MB	Cohesiveness of mass-MB
Cluster-23	Adhesive to teeth-FB	Adhesive to teeth-MB	
Cluster-24	Gritty-H	Gritty-L	Particle amount- L
Cluster-25	Fibrous-V		
Cluster-26	Sustained crispness-MB	Sustained Fracturability-MB	
Cluster-27	Oily Mouthfeel-MB	Oily mouth coating-TH	
Cluster-28	Particles amount-MB	Roughness of mass-MB	Roughness of swallow-TH

Results and discussion

The results were explained by the PCA plot (Figure 3.1) and CA (Table 3.3). The product space explained by the first two principal components (PCs) represented only 36.4% of the explained variability. The texture terms that contributed most to PC1 were smoothness (V and H), uniformity of surface (V) (Figure 3.3), and for PC2 the main contributing terms were greasy (V and H) and oily (V and H) (Figure 3.4). Additional figures are provided in the Appendix-A for PC3 (Figure A.1), PC4 (Figure A.2), PC5 (Figure A.3), and PCA scree plot (Figure A.4).

It is interesting to remember that the first principal components tend to show those aspects that are most differentiating among the products, in this case, visual and hand aspects such as smoothness, uniformity, greasiness, and oiliness, which suggests the importance of those aspects when examining textural characteristics. Yet, visual and hand aspects of texture are rarely evaluated. Both PC1 and PC2 terms were found in clusters 18 and 19 in the cluster analysis (Table 3.3). Because of the diversity of texture characteristics in products, 38 PCs would be needed to explain about 99% of the variability. The CA of products demonstrated that the selected products were so divergent in texture that even with 45 clusters 97% of the variability was explained (data not shown). The developed texture terms were effectively used to address each product's diversity.

CA helped dive deep into the existence of clusters among attributes, a total of 28 clusters explaining 87% variability were identified from 76 terms (Figure 3.2). The terms associated with each cluster described similar texture characteristics experienced by vision, hand, and lips. Attributes measured with non-oral senses (sight, hand, and lips) such as waxy, adhesive, roughness of surface, moistness, powdery, heat burn, greasiness, oiliness, smoothness, and grittiness were similar for each non-oral sense. Therefore, those attributes could be measured by

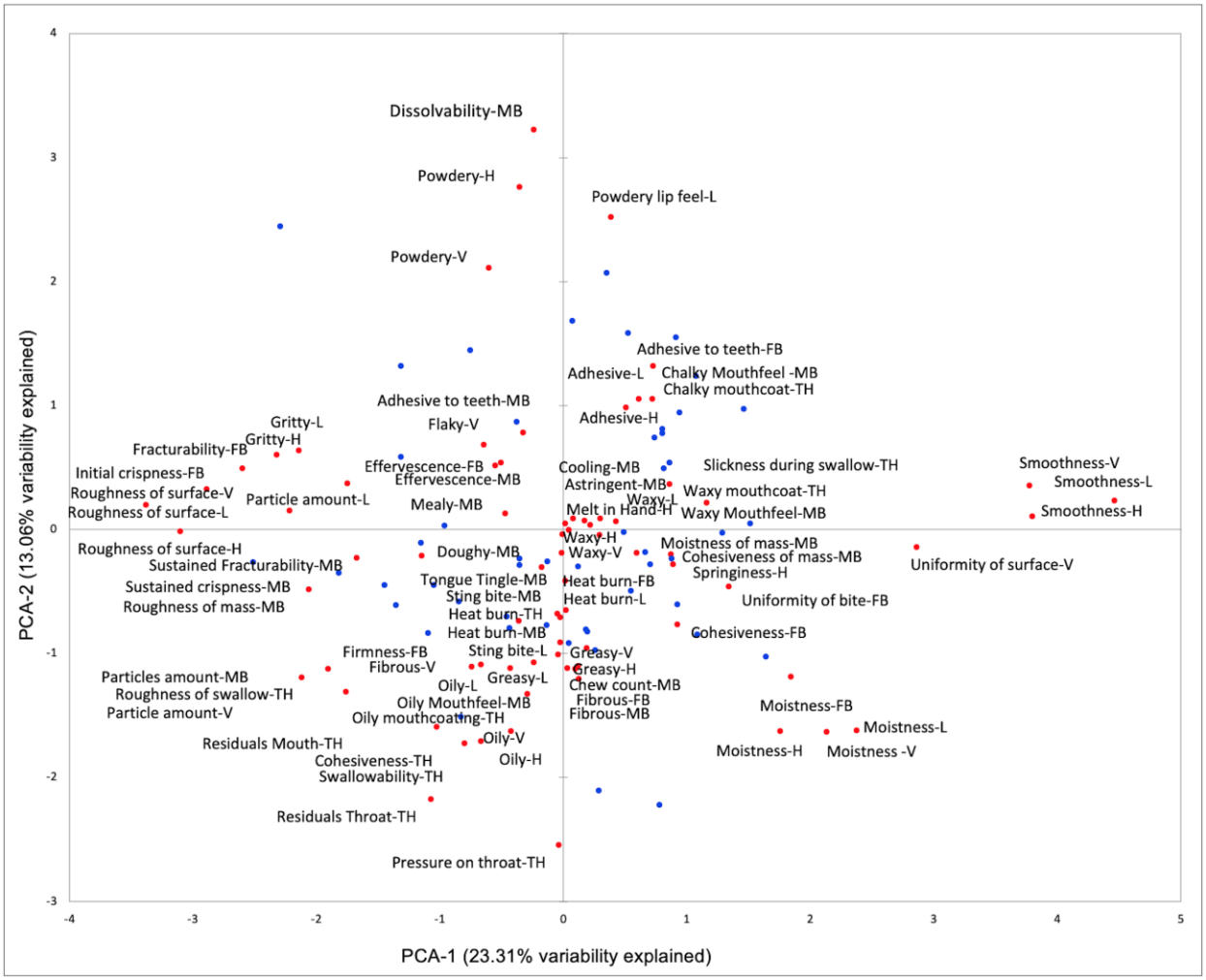
only one sense to save resources and time. It must be remembered that visual and lip were measured by a separate panel than hand, thus this is not simply a case of a halo effect.

The ability of various textural attributes to be measured using different senses also means that it may be possible to change the way we measure attributes across various foods or cultures. For example, if the oral evaluation of a food results in substantial "carry-over" from sample to sample, it may be possible to measure the texture attributes using visual or hand assessments that may be less intrusive. Besides, evaluation of the texture of products that may be a problem for some people to taste because of disgust, religion, or health issues, such as insect-based products (Chambers et al., 2018) might be evaluated only visually or by hand.

Other attributes measured with oral senses (first bite, multiple-bite and in-throat) that clustered together were waxy mouthfeel MB and TH; residual mouth TH and residual throat TH; initial crispiness FB and fracturability FB; fibrous MB and FB; effervescences FB and MB; oily mouthfeel/ coating MB and TH. The dryness caused in the mouth by the product with characteristics such as Astringent MB, chalky mouthfeel MB, and chalky mouth coating TH may be the reason for having these attributes in the same cluster. The low swallowability of cohesive products appeared to exert pressure in the throat during swallowing, which clustered (#14) swallowability, pressure on the throat, and cohesiveness experienced by the throat. Particle amount (MB), roughness of mass (MB), and roughness of swallow (TH) were also clustered (#28). A highly crisp (related to the noise) product also is highly fracturable (shatters easily), which led to the clustering (#26) of sustained crispiness (MB) and sustained facturability (MB). Attributes that didn't cluster with any other attribute were dissolvability (MB), springiness (H), and slickness during swallow (TH).

Figure 3.1.

Principal component analysis plot of texture attributes and products evaluated by a trained panel. Where blue dots represent products and red dots represent textural attributes. (Note: Only attributes are identified on the figure).

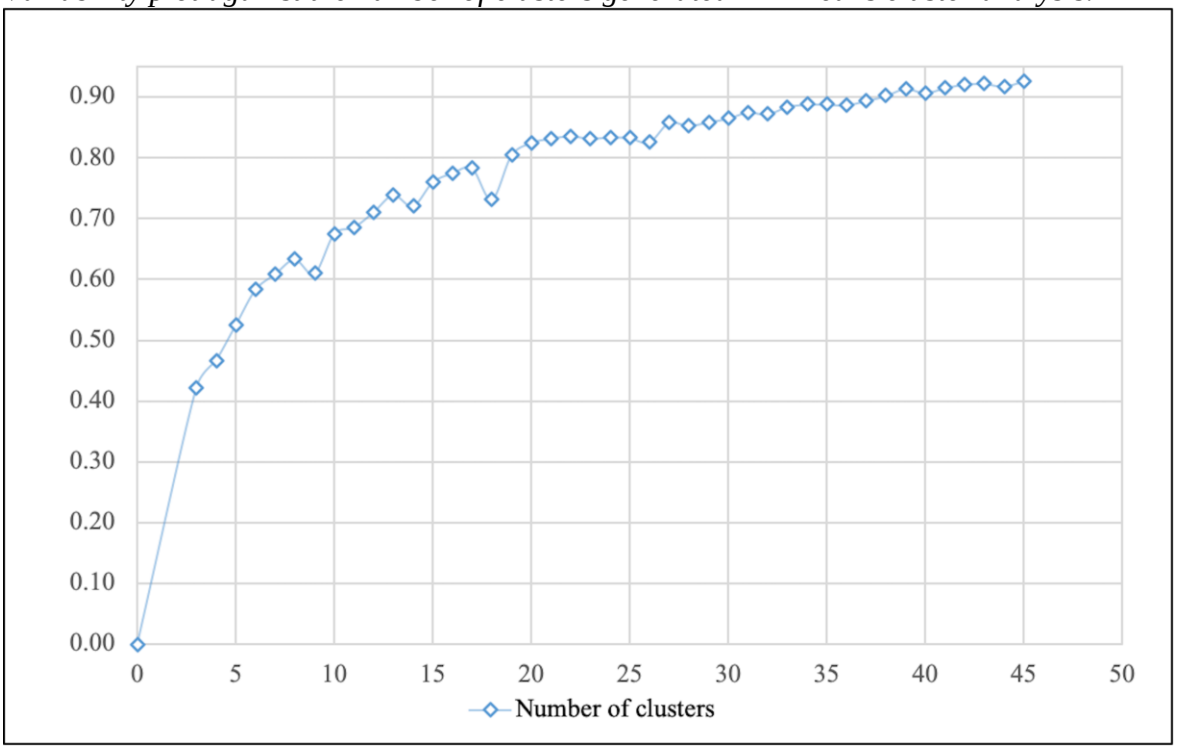


The results suggest that the set of descriptors was appropriate for defining the general texture space of many solid food products perceived by any of the five senses studied in this research. For example, this texture lexicon covered all the nineteen texture terms described for fifty pasta samples (Irie et al., 2018). Similarly, terms developed in other studies for various products were also included in this lexicon. For example, four texture terms to describe 18

different cashew samples (Griffin et al., 2017), seventeen out of twenty attributes for twenty-four French bread samples (Hayakawa, Ukai, Nishida, Kazami, & Kohyama, 2010), twelve out of fourteen texture descriptors for eight commercial red sufu products (He, Chen, & Chung, 2018), all seven texture attributes for twelve commercial plain sufu products (Chen & Chung, 2016), and six of seven attributes for fresh peaches (Belisle et al., 2017).

Figure 3.2.

Variability plot against the number of clusters generated in k-means cluster analysis.



All nineteen texture terms provided for almonds by Civile et al. (2010) were included in this texture lexicon. Terms not included in this lexicon found in the other lexicons mentioned

include such terms as creamy (red sufu), a multidimensional term that our panel broke into individual component terms, and juicy (peaches) terms that we described as moisture. Thus, we believe the developed lexicon is comprehensive, but not redundant (at least within a texture phase such as visual or lip) where each term has a related reference to help interpretation for all future sensory studies. The lexicon can be used for various applications such as product testing, product development, quality control, discrimination, and identification of products.

Correlated attributes

From correlation analysis results, ten attributes were found to be highly correlated (Table 3.4), attributes with correlation values more than 0.90 are presented. Some texture characteristics generated the same information in several ways (like lip feel, hand feel, etc.). For example, greasiness in hand and greasiness on lips were highly correlated (0.98). Other highly correlated attributes experienced by hands and lips were greasy, oily, waxy, roughness of surface, and gritty. Similarly, a high correlation was reported between mouth terms (firmness, cohesiveness, stickiness to teeth, elasticity, adhesive between teeth, slipperiness of mass, and smoothness of mass), and hand terms (rubbery, firmness, brittleness, sticky, and slipperiness of film) (Drake et al., 1999). To avoid data redundancy only one attribute among the highly correlated could be measured if these relationships are found in future studies.

The correlation between moistness observed by visual, hand, lips, and fist bite were moderately correlated (r =0.71 to 0.77). The moistness experienced inside the mouth and by lips was higher than hand tactile for the same products. The possible reasons could be the difference in the sensing perception of organs. For example, fingers tips may be rougher and drier in comparison to oral tissues that may be smoother and have high moistness. Overall, the moistness

of mass in mastication had the highest values for moisture even for dry products. This probably is the result of saliva being released during mastication to allow for chewing and swallowing of dry products. The fibrous nature of the product was experienced more during multiple bites than the first bite probably because the fibers begin to break apart and break down during continued chewing. However, both attributes were highly correlated (r = 0.92).

Table 3.4.

Highly correlated attributes with correlation values.

Sr. No	Attributes		Correlation values
1	Fibrous- MB	Fibrous-FB	0.92
2	Greasy-H	Greasy-L	0.98
3	Greasy-H	Oily-H	0.90
4	Waxy Mouthfeel-MB	Waxy Mouth coat-TH	0.95
5	Waxy-H	Waxy-L	0.95
6	Roughness of surface- H	Roughness of surface- L	0.92
7	Gritty-Hand feel	Gritty-L	0.94
8	Smoothness-V	Smoothness-L	0.90
9	Heat burn-MB	Heat burn-TH	0.99
10	Effervescence-FB	Effervescence-MB	1.00

As expected, some attributes were negatively correlated such as roughness of surface with smoothness (r > -0.70), chew count with dissolvability (r = -0.64), dissolvability with pressure on the throat (r = -0.54), roughness of mass with slickness during swallow (r = -0.50), adhesive to teeth with residual throat (r = -0.50), slickness during swallow with roughness of swallow (r = -0.56), roughness of swallow with smoothness (r = -0.59), roughness of swallow with uniformity of surface (r = -0.47), cooling with swallowability (r =-0.55), and powdery with

swallowability (r =-0.47). These negatively correlated attributes represent the contrasting nature of textural attributes.

The mouth is a very special somatosensory system, the oral sensation provides an important interface experience of the object and its state in the mouth (Haggard & de Boer, 2014). Whereas, the hand sensation often is visually guided and remains subservient to vision (Hartcher-O'Brien, Gallace, Krings, Koppen, & Spence, 2008). Attributes measured by sight and hand feel, and their intensities that did not differ much were fibrous, powdery, waxy, greasy, roughness of surface, and smoothness. Perhaps these attributes might be sensed better by the hand guided by vision instead of the oral sensorimotor process.

Attributes such as oiliness, moistness of mass, particle amount, and adhesiveness were experienced most during mastication (multiple bites). Some attributes with reasonably high intensities in the mouth such as residuals, cohesiveness, and heat burn (a trigeminal sensation that is not really a texture but is sometimes treated as one) were felt more in the throat during swallowing.

Translations of terms and definitions

For a lexicon to be useful in many contexts (e.g., across products, cultures, and countries), the lexicon must be understood. Cherdchu et al. (2013), showed that it was possible to develop a joint lexicon between panels who spoke two different languages when they were able to discuss the terms and provide examples of what they were des describing. In this case, that was not possible, but the translations of terms were done by sensory professionals who were natives of India, China, Costa Rica, and Spain. The translators were fluent in both English and their native language in reading and writing. Translations and back translations were done by

different personnel. During back translation, the original English version was not shared with translators who were asked to translate directly from the native language back to English. Usually, any differences were simply editorial differences. For any differences that appeared to be substantive, the translators met together to determine if there was a misinterpretation, better wording, or the terms needed to be changed in some way. Only minor differences were found and those were adjusted easily.

The translations covered multiple words from languages that represent the same attribute. Example moistness can be represented by three different words in Hindi (नमी / गीलापन / सीलन). The translated definition and terms into four languages English, Hindi, Mandarin (Chinese), and Spanish are presented in Table 3.5 (visual), Table 3.6 (tactile), Table 3.7 (lip feel), Table 3.8 (first bite), Table 3.9 (multiple bites), Table 3.10 (swallow-in), and techniques in Table 3.2.

Conclusion

A comprehensive texture lexicon including attributes, references, and intensities was developed for a broad range of snack and snack-type foods that exist today by a highly trained descriptive sensory panel. The developed lexicon is non-redundant within a texture phase, but some terms might be redundant from one phase to the next (e.g., visual, hand-feel, to first-bite) and provides an opportunity to describe product texture characteristics using attributes from the large pool of terms. The lexicon is useful in product development, quality control, shelf life, and other related applications. Future studies are needed to validate this lexicon with products from various parts of the world that offers unique textures. The developed lexicon opens for addition or modification overtime when needed. Attributes such as fibrous, powdery, waxy, greasy, roughness of surface, and smoothness were evaluated similar both visually and by hand feel.

However, attributes such as residuals and cohesiveness were perceived most in the throat while others such as oiliness, moistness of mass, particle amount, and adhesive were experienced most during mastication. The use of sight, hand, mouth, or throat for texture evaluation must be based on the specific attribute. There is no requirement to use all the different senses for evaluation, the determination of what attributes to use must be based on the objectives of the study. This study suggests that researchers may be able to use selected attributes from each of the 28 clusters to avoid data redundancy. The developed lexicon also allows researchers to observe the "white spaces" that may be available for new texture combinations with a specified marketplace.

Figure 3.3.

Texture attributes loadings for principal components 1.

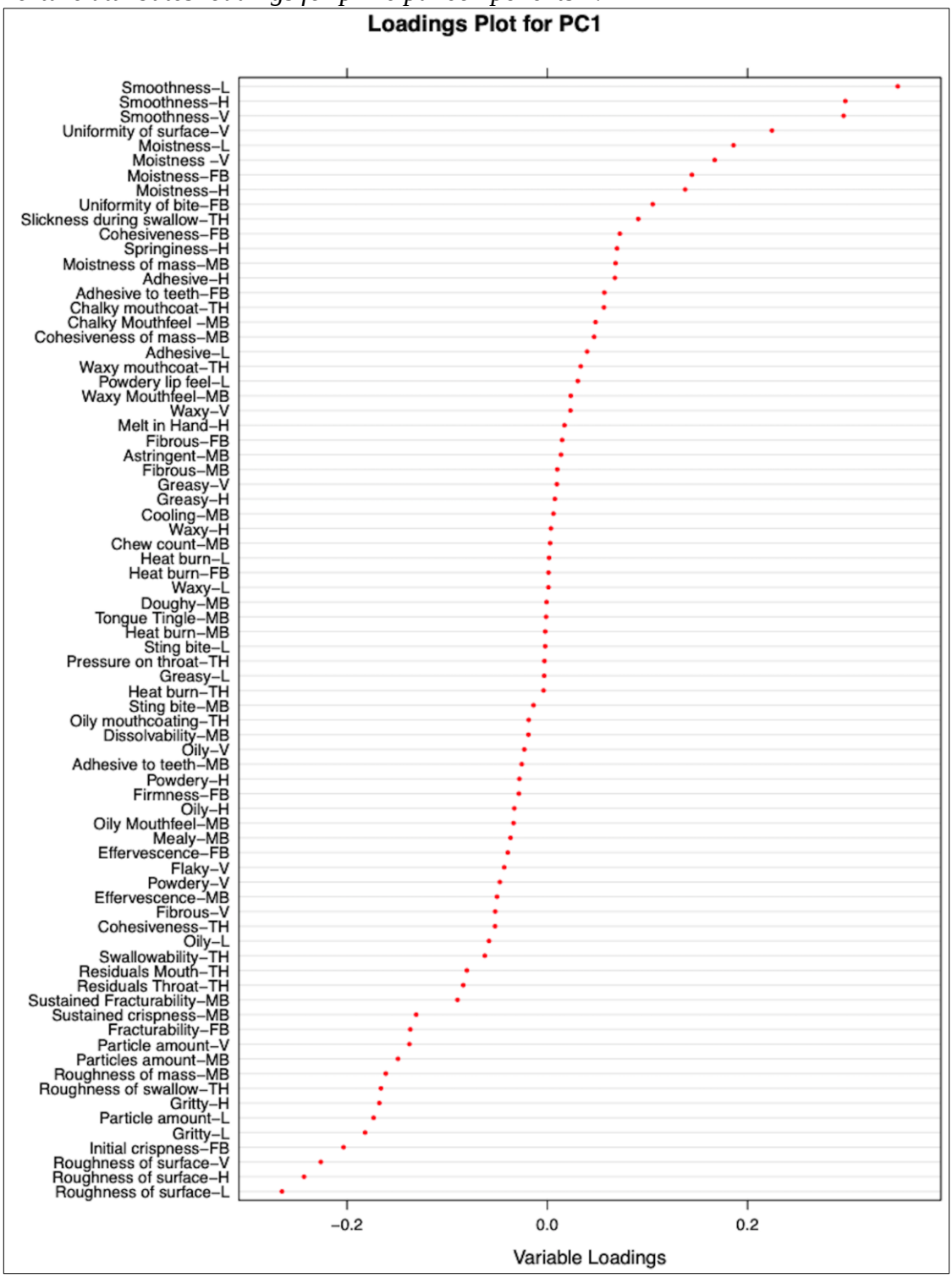


Figure 3.4.

Texture attributes loadings for principal components 2.

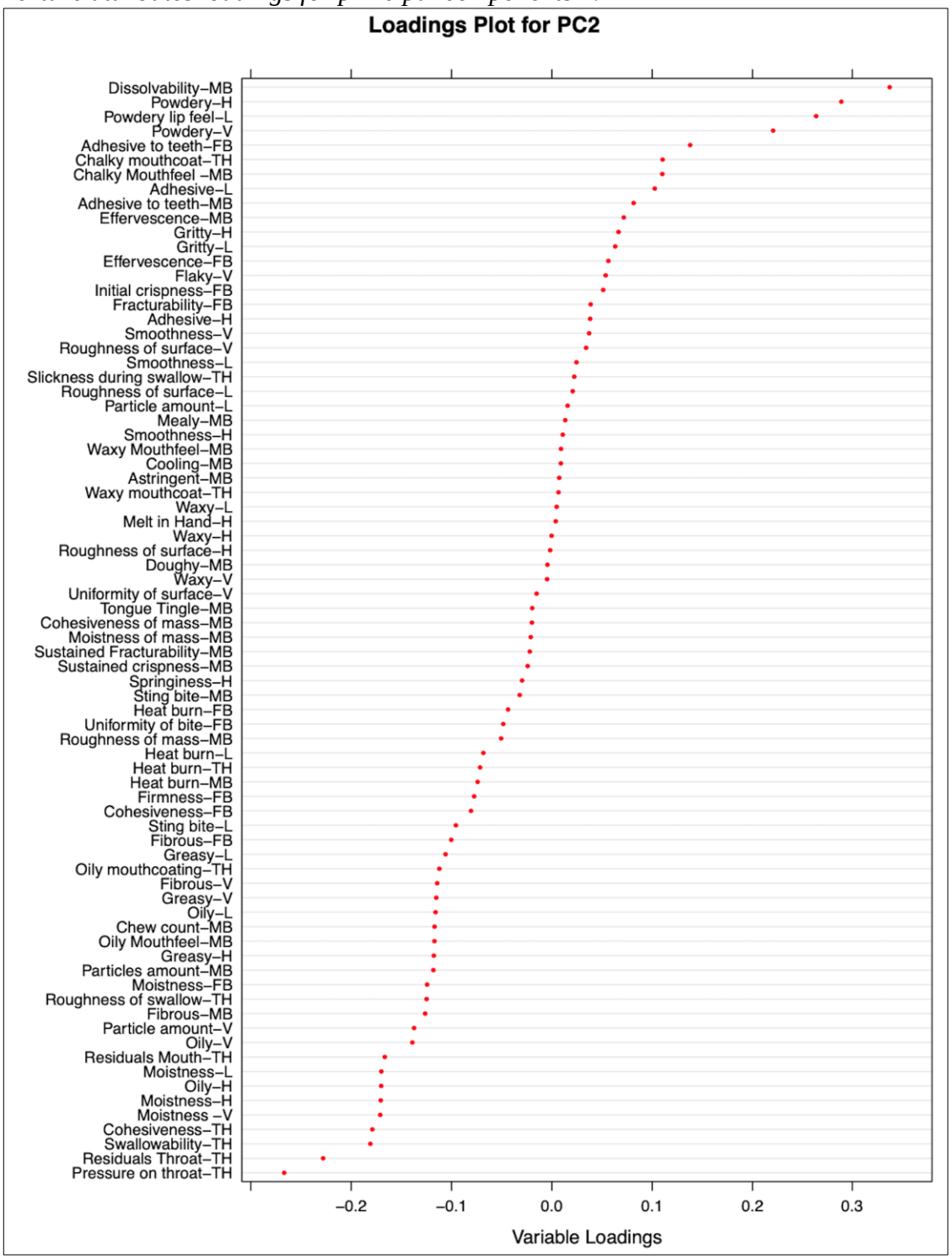


Table 3.5.

Visual texture attributes with their translations into Hindi, Mandarin, and Spanish. English terms are highlighted simply to make it easier to differentiate new attributes.

Language	Texture terms	Definitions
English	**Fibrous-V**	**The perception of filaments or strands of muscle tissue or plant fiber**
Hindi	रेशेदार / तंतुमय / रेशेवाला	खादय पदार्थ का रेशेदार दिखना / या खादय पदार्थ के भीतर रेशे दिखना
Mandarin	纤维**状的**	对肌肉组织或植物纤维的细丝或股线的感知
Spanish	Fibroso - V	Percepción de filamentos o hebras provenientes de tejidos musculares o fibras de plantas.
English	**Flaky-V**	**The impression of individual layers within the product**
Hindi	पपड़ीदार/ परतदार	खादय पदार्थ का परतदार दिखना
Mandarin	**片状的**	产品中各个层的印象
Spanish	Escamoso–V (hojaldrado)	Impresión de capas individuales en el producto.
English	**Greasy-V**	**The appearance of a fat or oily coating on the surface of the product**
Hindi	चिकनाई / चिकना / चिकनाई में सना हुआ / चिकनाईयुक्त	खादय पदार्थ की सतह पर तेल कोटिंग या चिकनाई दिखना
Mandarin	**油腻状的**	**在**产品表面上出现脂肪或油性涂层
Spanish	Grasoso-V (grasiento)	Apariencia de grasa o aceite que cubre la superficie del producto
English	**Moistness -V**	**The perceived amount of moisture in the product (dry to wet).**
Hindi	नमी (पानी की मात्रा) / गीलापन / सीलन	खादय पदार्थ में नमी (पानी की मात्रा) का दिखना
Mandarin	**湿润状的**	产品的整体湿润程度（从干到湿）
Spanish	Humedad – V	Humedad percibida en el producto (de seco a húmedo).
English	**Oily-V**	**Perception of oil on the surface of the product**
Hindi	सतह पर तेल दिखना / तेलमय / तैलीय / वसा / तेलिया	खादय पदार्थ की सतह पर तेल या तेल की परत का दिखना
Mandarin	**油状的**	对产品表面的油的感知
Spanish	Aceitoso-V	Percepción de aceite en la superficie del producto
English	**Particle amount-V**	**The perception of small pieces relatively harder than surrounding product**
Hindi	कणमय/ किरकिरा / कणिकीय	खादय पदार्थ में कणो की मात्रा का परतीत होना

Language	Texture terms	Definitions
Mandarin	颗**粒状的**	对小颗粒比周围产品相对较硬的感知
Spanish	Cantidad de partículas-V	Percepción de partículas pequeñas relativamente más grandes que el resto del producto.
English	**Powdery-V**	**Perception of a powdery substance/ coating on the product**
Hindi	पाउडर / पाउडर कोटिंग/ पाउडर से ढका होना / पाउडर से पुता हुआ / पाउडर लगा हुआ	खादय पदार्थ की सतह पर पाउडर या पाउडर के कणो का दिखना
Mandarin	**粉末状的**	对产品中粉末状物质/**涂**层的感觉
Spanish	Polvoso-V (polvoriento)	Percepción de una sustancia/cobertura polvosa en el producto.
English	**Roughness of surface-V**	**The amount of indentations/bumps and surface abrasions which can be perceived by gently manipulating one piece between the thumb & fingers, lips, palate and/or tongue**
Hindi	खुरदरी सतह (खुरदरापन)/ कर्कशता	खादय पदार्थ की सतह पर खुरदरापन दिखना
Mandarin	**表面粗糙度**	**关于凹陷，凸起和表面摩擦的感知，可以通**过使用拇指和其他手指，以及嘴唇，上下颚与舌头的接触来感受
Spanish	Aspereza de la superficie-V	Cantidad de abolladuras y abrasiones en la superficie que se pueden percibir al manipular gentilmente una porción entre el dedo pulgar y demás dedos, labios, paladar, y/o lengua.
English	**Smoothness-V**	**Degree of to which the sample feels smooth and free of lumps/particulates as opposed to lumpy, rough, grainy, gritty, and/or sandy**
Hindi	समतल सतह / समतलता	खादय पदार्थ की सतह का समतल (समूथ) दिखना
Mandarin	**光滑度**	样品感觉光滑并且没有块状物/颗粒，没有块状，粗糙，颗粒状，砂质和/**或沙**质
Spanish	Lisura-V (liso)	Grado en que el producto se siente liso y libre de grumos o partículas, contrario a grumoso, áspero, granuloso, rasposo, y/o arenoso.
English	**Uniformity of surface-V**	**Perceived degree of evenness of all product surfaces. The absence of valleys, raised areas, cracks, blisters, etc. (from least to most)**
Hindi	सतह की एकरूपता/ सतह का एक समान जैसा होना/ एक-रूप	खादय पदार्थ की सभी सतह का एकसमान (एकसा) दिखना
Mandarin	**表面均匀度**	**关于**产品表面均匀度的感知, **没有凹陷、凸起**、**裂**缝和水泡等（从最少到大多数）

Language	Texture terms	Definitions
Spanish	Uniformidad de la superficie - V	Percepción del grado de uniformidad de la superficie del producto. Ausencia de valles, relieves, grietas, burbujas, etc. (de menos a más).
English	**Waxy-V**	**The perception of a wax like coating on the product**
Hindi	मोम जैसा / मोम जैसा / मोमी	खादय पदार्थ की सतह पर मोम के जैसी परत दिखना
Mandarin	**蜡状的**	对产品上的蜡状涂层的感知
Spanish	Ceroso – V	Percepción de cobertura cerosa en el producto.

Table 3.6.

Texture attributes measured by hand feel with their translations into Hindi, Mandarin, and Spanish. English terms are highlighted simply to make it easier to differentiate new attributes.

Language	Texture terms	Definitions
English	**Adhesiveness to fingers-H**	**Degree to which the product sticks/adheres to the fingers. The sample is placed between the fingers and compressed once lightly and released to assess adhesiveness. None -> very**
Hindi	चिपचिपा / चिपचिपाहट	खादय पदार्थ का चिपचिपापन उंगलिओं पर महसूस करना
Mandarin	**手指粘附感**	产品粘附在手指上的程度。将样品置于手指之间并轻轻压缩并释放以评估粘附性。没有->**非常**
Spanish	Adhesividad a dedos-M	Grado en que el producto se pega/adhiere a los dedos. Para evaluar la adhesividad, la muestra se coloca entre los dedos, se comprime suavemente una vez y se libera. Nada-> Mucho
English	**Greasy-H**	**The appearance of a fat or oily coating on the surface of the product**
Hindi	चिकनाई / चिकना / चिकनाई में सना हुआ / चिकनाईयुक्त	खादय पदार्थ की सतह के चिकनेपन या चिकनी परत को हाथो से महसूस करना
Mandarin	**油腻感**	**在**产品表面上出现脂肪或油性涂层
Spanish	Grasoso-M	Apariencia de grasa o cobertura aceitosa en la superficie del producto.
English	**Gritty-H**	**The perception of small, hard, sharp particles reminiscent of sand, or granules in pears**
Hindi	किरकिरा / किरकिराहट	खादय पदार्थ की सतह पर रेत के कणो जैसा किरकिरापन महसूस करना
Mandarin	**沙砾感**	细小，坚硬，尖锐的颗粒感让人想起沙子或梨子中的颗粒感
Spanish	Granuloso-M	Percepción de partículas pequeñas, duras y afiladas similar a la arena o los gránulos en peras.
English	**Melt in Hand-H**	**Rate and degree to which products dissolves in the hand**
Hindi	हाथ में पिघलना/ पिघल जाना	खादय पदार्थ का हाथो में पिघल जाने की मात्रा को महसूस करना
Mandarin	**手中融化感**	产品溶解在手中的速度和程度
Spanish	Derretimiento en mano-M	Grado en que el producto se disuelve en la mano.

Language	Texture terms	Definitions
English	**Moistness-H**	**The perceived amount of moisture in the product (dry to wet)**
Hindi	नमी (पानी की मात्रा) / गीलापन / सीलन	खादय पदार्थ में नमी को हाथो से महसूस करना
Mandarin	**湿润感**	产品的整体湿润程度（从干到湿）
Spanish	Humedad-M	Cantidad de humedad percibida en el producto (seco a húmedo).
English	**Oily-H**	**Perception of oil on the surface of the product**
Hindi	तेलमय/ हाथ में तेल लगना/ / तेलमय / तैलीय / वसा / तेलिया / तेल सा / तेल भरा / तेलयुक्त	खादय पदार्थ की सतह पर तेल या तेल की परत को हाथो से महसूस करना
Mandarin	**油腻感**	对产品表面油的感知
Spanish	Aceitoso-M	Percepción de aceite en la superficie del producto.
English	**Powdery-H**	**Perception of a powdery substance/ coating on the product**
Hindi	पाउडर / पाउडर कोटिंग/ पाउडर से ढका होना / पाउडर से पुता हुआ / पाउडर लगा हुआ	खादय पदार्थ की सतह पर पाउडर या पाउडर के कणो को हाथो से महसूस करना
Mandarin	**粉末感**	对产品的粉状物质/**涂**层的感**知**
Spanish	Polvoso-M	Percepción de una sustancia/cobertura polvosa en el producto.
English	**Roughness of surface-H**	**The amount of indentations/bumps and surface abrasions which can be perceived by gently manipulating one piece between the thumb & fingers, lips, palate and/or tongue**
Hindi	खुरदरी सतह / खुरदरापन	खादय पदार्थ की खुरदरी सतह को हांथों से महसूस करना
Mandarin	**表面粗糙感**	**关于凹陷，凸起和表面摩擦的感知，可以通**过使用拇指和其他手指，以及嘴唇，上下颚与舌头的接触来感受
Spanish	Aspereza de la superficie-M	Cantidad de abolladuras y abrasiones en la superficie que se pueden percibir al manipular gentilmente una porción entre el dedo pulgar y demás dedos, labios, paladar, y/o lengua
English	**Smoothness-H**	**Degree of to which the sample feels smooth and free of lumps/particulates as opposed to lumpy, rough, grainy, gritty, and/or sandy**
Hindi	हांथों में समतलता महसूस करना / समतलता	खादय पदार्थ कि सतह कि समतलता को हाथों से महसूस करना

Language	Texture terms	Definitions
Mandarin	**光滑感**	样品感觉光滑并且没有块状物/颗粒，没有块状，粗糙，颗粒状，砂质和/**或沙**质
Spanish	Lisura-M	Grado en que el producto se siente liso y libre de grumos o partículas, contrario a grumoso, áspero, granuloso, rasposo, y/o arenoso.
English	**Springiness-H**	**The degree to which the sample returns to its original shape after compress**
Hindi	उछालपन/ वस्तु का लचीलापन / पलटाव	हलके दबाव के बाद खादय पदार्थ का अपने मूल रूप में वापस आ जाने की मात्रा
Mandarin	弹**性度**	样品被压缩后恢复其原始形状的程度
Spanish	Elasticidad-M	Grado en que la muestra vuelve a su forma original tras la compresión
English	**Waxy-H**	**The perception of a wax like coating on the product**
Hindi	मोम जैसा / मोम सा / मोमी	खादय पदार्थ कि सतह पर मोम के जैसी परत को हांथों से महसूस करना
Mandarin	**蜡状感**	对产品上的蜡状涂层的感知
Spanish	Ceroso-M	Percepción de cobertura cerosa en el producto.

Table 3.7.

Lip feel texture attributes with their translations into Hindi, Mandarin, and Spanish. English terms are highlighted simply to make it easier to differentiate new attributes.

Language	Texture terms	Definitions
English	**Adhesiveness -L**	**Degree to which the product sticks/adheres to the lips. The sample is placed between the lips, compressed once lightly and released to assess adhesiveness. None -> very**
Hindi	चिपचिपापन / चिपचिपा / चिपचिपाहट	खादय पदार्थ का चिपकना या होठों पर चिपक जाने की मात्रा
Mandarin	**唇部粘附感**	产品粘在嘴唇上的程度。 **将**样品置于唇缘之间，轻轻压缩并释放以评估粘附性。 **没有** - > **非常**
Spanish	Adhesividad a labios-L	Grado en que el producto se pega/adhiere a los labios. Para evaluar la adhesividad, la muestra se coloca entre los labios, se comprime suavemente una vez y se libera. Nada-> Mucho
English	**Greasy-L**	**The appearance of a fat or oily coating on the surface of the product**
Hindi	होठों पर चिपक जाने की मात्रा / चिकनाई / चिकना / चिकनाई में सना हुआ / चिकनाईयुक्त	खादय पदार्थ की सतह पर तेल की परत को होठों से महसूस करना
Mandarin	**唇部油**腻**感**	**在**产品表面上出现脂肪或油性涂层
Spanish	Grasoso-L	Apariencia de grasa o cobertura aceitosa en la superficie del producto.
English	**Gritty-L**	**The perception of small, hard, sharp particles reminiscent of sand, or granules in pears**
Hindi	किरकिरा / किरकिराहट /	खादय पदार्थ की सतह का किरकिरापन (रेत के कणो जैसा) होठों पर महसूस करना
Mandarin	**唇部沙**砾**感**	细小，坚硬，尖锐的颗粒感让人想起沙子或梨子中的颗粒感
Spanish	Granuloso-L	Percepción de partículas pequeñas, duras y afiladas similar a la arena o los gránulos en peras.
English	**Heat burn-L***	**Burning sensation on the lips in the oral cavity and throat, resulting from exposure to substance such as capsaicin or hot peppers. The sensation tends to persist after the stimulus is removed.**

Language	Texture terms	Definitions
Hindi	मिर्च जैसा/ मसालों से भरा/ तीखा	खादय पदार्थ को होठों पर रखते ही जलन (मिर्च जैसा) या मसालों से भरा तीखापन महसूस करना
Mandarin	**唇部灼**热**感**	**由于接触辣椒素或辣椒等物**质而在口腔和喉咙的嘴唇上产生灼烧感。 **刺激消除后**，**感**觉往往持续存在
Spanish	Picante-L	Sensación quemante en los labios, en la cavidad oral y en la garganta, resultado de la exposición a sustancias como la capsaicina o pimiento picante. La sensación tiende a perdurar una vez que el estímulo ha sido removido.
English	**Moistness-L**	**The perceived amount of moisture in the product (dry to wet).**
Hindi	नमी (पानी की मात्रा) / गीलापन / सीलन	खादय पदार्थ में नमी (पानी की मात्रा) को होठों से महसूस करना
Mandarin	**唇部湿**润**感**	产品中感知的水分量（干燥至湿润）
Spanish	Humedad-L	Cantidad de humedad percibida en el producto (seco a húmedo).
English	**Oily-L**	**Perception of oil on the surface of the product.**
Hindi	तेलमय/ तेल को महसूस करना	खादय पदार्थ की सतह पर तेल या तेल की परत को होठों से महसूस करना
Mandarin	**唇部油脂感**	对产品表面的油的感知
Spanish	Aceitoso-L	Percepción de aceite en la superficie del producto.
English	**Particle amount-L**	**The perception of small pieces relatively harder than surrounding product.**
Hindi	कणमय/ किरकिरा / कणिकीय	खादय पदार्थ में कणो की मात्रा को होठों से महसूस करना
Mandarin	**唇部颗粒感**	对小颗粒比周围产品相对较硬的感知
Spanish	Cantidad de Partículas-L	Percepción de partículas pequeñas relativamente más grandes que el resto del producto.
English	**Powdery-L**	**Perception of a powdery substance/ coating on the product.**
Hindi	पाउडर या पाउडर कोटिंग को महसूस करना / पाउडर से ढका होना / पाउडर से पुता हुआ / पाउडर लगा हुआ	खादय पदार्थ की सतह के पाउडर को होठों से महसूस करना
Mandarin	**唇部粉末感**	对产品的粉状物质/**涂**层的感**知**
Spanish	Polvoso-L	Percepción de una sustancia/cobertura polvosa en el producto.

Language	Texture terms	Definitions
English	**Roughness of surface-L**	**The amount of indentations/bumps and surface abrasions which can be perceived by gently manipulating one piece between the thumb & fingers, lips, palate and/or tongue**
Hindi	खुरदरी सतह/ सतह का खुरदरापन	खादय पदार्थ की सतह के खुरदरेपन की मात्रा को होठों से महसूस करना
Mandarin	**表面粗糙感**	**关于凹陷，凸起和表面摩擦的感知，可以通**过使用拇指和其他手指，以及嘴唇，上下颚与舌头的接触来感受
Spanish	Aspereza de la superficie-L	Cantidad de abolladuras y abrasiones en la superficie que se pueden percibir al manipular gentilmente una porción entre el dedo pulgar y demás dedos, labios, paladar, y/o lengua.
English	**Smoothness-L**	**Degree of to which the sample feels smooth and free of lumps/particulates as opposed to lumpy, rough, grainy, gritty, and/or sandy.**
Hindi	समतलता / समतल सतह	खादय पदार्थ की सतह की समतलता (समूथनेस) को होठों से महसूस करना
Mandarin	**光滑感**	样品感觉光滑并且没有块状物/颗粒，没有块状，粗糙，颗粒状，砂质和/**或沙**质
Spanish	Lisura-L	Grado en que el producto se siente liso y libre de grumos o partículas, contrario a grumoso, áspero, granuloso, rasposo, y/o arenoso.
English	**Sting bite-L**	**The sharp, biting, stinging sensation on the tongue or lips.**
Hindi	जलन महसूस करना	खादय पदार्थ के भीतर मिर्ची या जलन्ता की मात्रा को जीभ या होठों पर महसूस करना
Mandarin	针**刺感**	**舌**头或嘴唇上尖锐，刺骨，刺痛的感觉
Spanish	Picadura punzante-L	Sensación aguda, cortante y punzante en la lengua o labios.
English	**Waxy-L**	**The perception of a wax like coating on the product.**
Hindi	मोम जैसा / मोम सा / मोमी	खादय पदार्थ की सतह पर मोम के जैसी परत को होठों से महसूस करना
Mandarin	**蜡**样**感**	对产品上的蜡状涂层的感知
Spanish	Ceroso-L	Percepción de cobertura cerosa en el producto.

*Heat-Burn actually is a trigeminal sensation, not a texture attribute, but is treated as such in many studies, and is included here simply by convention.

Table 3.8.

First Bite texture attributes with their translations into Hindi, Mandarin, and Spanish. English terms are highlighted simply to make it easier to differentiate new attributes.

Language	Texture terms	Definitions
English	**Adhesive to teeth-FB**	**Degree to which the product sticks/adheres to the teeth. The sample is placed between the teeth and compressed once lightly and released to assess adhesiveness. None -> very.**
Hindi	दांतों पर चिपकना / चिपचिपापन / चिपचिपा / चिपचिपाहट	खाते समय पदार्थ की मुंह के भीतर चिपकने की मात्रा
Mandarin	**粘牙感**	产品粘附/**粘附于牙**齿的程度。将样品置于牙齿之间并轻轻压缩并释放以评估粘附性。**没有 - >非常**。
Spanish	Adhesividad a los dientes-PM	Grado en que el producto se pega/adhiere a los dientes. Para evaluar la adhesividad la muestra se coloca entre los dientes y se comprime levemente una vez y se libera. Nada-> Mucho (Técnica: Después de tragar la muestra, sienta la superficie de los dientes con la lengua)
English	**Cohesiveness-FB**	**The degree to which the sample deforms prior to breaking apart when compressed once between the molar teeth (least to most).**
Hindi	संसक्तिशील (वस्तु के इकठा रहने की क्षमता) / संगतता	खाते समय पदार्थ की मुंह के भीतर टूटने से पहले विकृत होने की क्षमता
Mandarin	**粘聚感**	**当在臼**齿之间压缩一次（最少到最多）时，样品在断开之前变形的程度。
Spanish	Cohesividad-PM	Grado en que la muestra se deforma previo a que se quiebre cuando se comprime una vez entre los molares (menos a más).
English	**Effervescence-FB**	**The gaseous/ fizzy sensation produced upon the introduction of the products into the mouth.**
Hindi	बुलबुलेदार / बुदबुदाहट / छनछनानेवाला	खादय पदार्थ को मुँह में रखने के बाद या खाते समय बुलबुलेदार (बुलबुलों का बनना) महसूस करना
Mandarin	**气泡感**	**在将**产品放入口中时产生气泡/**汽水感**
Spanish	Efervescencia-PM	Sensación gaseosa producida con la introducción de productos a la boca.
English	**Fibrous-FB**	**The perception of filaments or strands of muscle tissue or plant fiber.**

Language	Texture terms	Definitions
Hindi	रेशेदार / तंतुमय / रेशेवाला	खादय पदार्थ का खाते समय उसमे रेशे या उसके रेशेदार होने की मात्रा
Mandarin	纤维感	对肌肉组织或植物纤维的细丝或股线的感知
Spanish	Fibroso-PM	Percepción de filamentos o hebras provenientes de tejidos musculares o fibras de plantas.
English	**Firmness-FB**	**The force required to bite completely through the sample with the molar teeth. Evaluate on first bite down with the molars.**
Hindi	मज़बूती / स्थिरता	खादय पदार्थ का खाने क़े लिए मुँह क़े भीतर जबड़ो से लगाए गए बल की मात्रा
Mandarin	结实度	用臼齿完全咬住样品所需的力。用臼齿评估第一口
Spanish	Firmeza-PM	Fuerza requerida para morder completamente la muestra atravesando la con los molares. Evalúe el primer mordisco con los molares.
English	**Fracturability-FB**	**The force with which the sample ruptures. Evaluate on first bite down with the molars.**
Hindi	कोई वस्तु जो आसानी से नष्ट हो जाय (टुकड़े टुकडे होना)/ टूट जाना	खादय पदार्थ का खाते समय तोड़ने क़े लिए मुँह क़े भीतर लगाए गए बल की मात्रा
Mandarin	脆度	样品破裂需要的力。用臼齿评估第一口
Spanish	Fracturabilidad-PM	Fuerza con que la muestra se rompe. Evalúe en el primer mordisco con los molares.
English	**Heat burn-FB***	**Burning sensation on the lips in the oral cavity and throat, resulting from exposure to substance such as capsaicin or hot peppers. The sensation tends to persist after the stimulus is removed.**
Hindi	मिर्च जैसा/ मसालों से भरा/ तीखा	खादय पदार्थ को खाते समय मुँह क़े भीतर जलन (मिर्च जैसा) या मसालों से भरा तीखापन महसूस करना
Mandarin	灼热感	由于接触辣椒素或辣椒等物质而在口腔和喉咙的嘴唇上产生灼烧感。刺激消除后，感觉往往持续存在
Spanish	Picante-PM	Sensación quemante en los labios, en la cavidad oral y en la garganta resultado de la exposición a sustancias como la capsaicina o pimiento picante. La sensación tiende a perdurar una vez que el estímulo ha sido removido.

Language	Texture terms	Definitions
English	**Initial crispness-FB**	**The intensity of audible noise at first bite with molars.**
Hindi	प्रारम्भिक करारापन व प्रारंभ का करारापन	खादय पदार्थ का खाते समय (केवल फर्स्ट बाईट) मुँह क़े भीतर उसके टूटने की आवाज व ध्वनि की तीव्रता (करारेपन के कारन)
Mandarin	**初始响脆度**	**用臼**齿咬合产品时听到的声音强度
Spanish	Crujencia inicial-PM (crujibilidad inicial)	Intensidad del sonido en el primer mordisco con los molares.
English	**Moistness-FB**	**The perceived amount of moisture in the product (dry to wet).**
Hindi	नमी (पानी की मात्रा) / गीलापन / सीलन	खादय पदार्थ में नमी (पानी की मात्रा) को खाते समय महसूस करना
Mandarin	**湿**润度	产品的整体湿润程度（从干到湿）。
Spanish	Humedad-PM	Humedad percibida en el producto (seco a húmedo).
English	**Uniformity of bite-FB**	**Degree to which the product changes from start to finish in the bite. If the force necessary to bite through the sample changes during bite, the product is non-uniform. The more consistent force, the more uniform.**
Hindi	टूटने की समानता	खादय पदार्थ को खाते समय तोड़ने क़े लिए मुँह क़े भीतर लगाए गए बल की समानता
Mandarin	**咬合力均匀度**	产品在一次咬合中从开始到结束的程度。**如果在咬合期**间咬合样品所需的力发生变化，则产品不均匀。 **力越一致，越均匀。**
Spanish	Uniformidad de la mordida-PM (uniformidad de mordisco)	Grado en que el producto cambia desde el inicio hasta el final de la mordida. Si la fuerza necesaria para morder atravesando la muestra cambia durante la mordida, el producto no es uniforme. Entre más consistente la fuerza, más uniforme.

*Heat-Burn is a trigeminal sensation, not a texture attribute, but is treated as such in many studies, and is included here simply by convention.

Table 3.9.

Multiple bit (also called chew down) texture attributes with their translations into Hindi, Mandarin, and Spanish. English terms are highlighted simply to make it easier to differentiate new attributes.

Language	Texture terms	Definitions
English	**Adhesive to teeth-MB**	**Degree to which the product sticks/adheres to the teeth. The sample is placed between the teeth and compressed once lightly and released to assess adhesiveness. None -> very.**
Hindi	दांतों पर चिपकना / चिपचिपापन / चिपचिपा / चिपचिपाहट	खाते समय पदार्थ का मुंह के भीतर चिपकना व चिपकने की मात्रा
Mandarin	**黏牙感**	产品粘附/**粘附于牙**齿的程度。 **将**样品置于牙齿之间并轻轻压缩并释放以评估粘附性。（**没有** - >**非常**）
Spanish	Adhesividad a los dientes-MM	Grado en que el producto se pega/adhiere a los dientes. Para evaluar la adhesividad la muestra se coloca entre los dientes y se comprime levemente una vez y se libera. Nada-> Mucho (Técnica: Después de tragar la muestra, sienta la superficie de los dientes con la lengua)
English	**Astringent-MB**	**During puckering or tingling sensation on the surface and/ or edges of the lips, tongue and mouth.**
Hindi	मुँह का सुखना	खादय पदार्थ का खाते समय मुँह/ जीभ/ होठों का सुखना या सूखेने को महसूस होना
Mandarin	涩感	**在嘴唇**，**舌**头和嘴巴的表面和/**或**边缘上起皱或刺感**。**
Spanish	Astringencia-MM	Sensación de sequedad, hormigueo y aspereza en la superficie o la comisura de los labios, lengua y boca.
English	**Chalky Mouthfeel -MB**	**A perception of a thin, even powdery coating on the tongue and mouth surface during mastication.**
Hindi	पाउडर जैसा महसूस करना	खादय पदार्थ को खाते समय मुँह क़े भीतर पाउडर या पाउडर कोटिंग को महसूस करना
Mandarin	颗粒**感**	**在咬碎**产品时**你舌**头和口腔表面上感受到的**薄而均匀的粉末涂层**。

Language	Texture terms	Definitions
Spanish	Sensación bucal gredosa-MM	Percepción de una capa fina, uniformemente polvosa en la lengua y la superficie de la boca durante la masticación.
English	**Chew count-MB**	**Number of chews required to hydrate sample and bring to a state ready to swallow. The sample is chewed on one side of the mouth only.**
Hindi	निगलने से पहले पदार्थ को चबाने की संख्या	खादय पदार्थ को खाते समय निगलने जैसा बनाने क़े लिए चबाने की निम्न आवश्यक संख्या
Mandarin	咀嚼度	经过多次的咀嚼使样品达到足够湿润准备吞咽的状态时所需的咀嚼次数。仅在口腔的一侧咀嚼样品。
Spanish	Conteo de mordidas-MM	Número de mordidas requeridas para hidratar el producto y llevarlo al estado de listo para tragar. La muestra se mastica únicamente en un lado de la boca.
English	**Cohesiveness of mass-MB**	**The degree to which the mass holds together during mastication after 5-7 chews.**
Hindi	चबाते समय वस्तु के इकठा रहने की क्षमता	चबाते समय पदार्थ क़े इकठा रहने (ना टूटना) की क्षमता
Mandarin	紧实度	在咀嚼 5-7 次样品后保持凝结的程度。
Spanish	Cohesividad de masa-MM	Grado en que la masa se mantiene unida durante la masticación tras 5 a 7 mordidas.
English	**Cooling-MB**	**A cool sensation in the oral and nasal cavities.**
Hindi	ठण्डक/ ठण्डा महसूस करना	खादय पदार्थ को खाने क़े बाद मुख क़े भीतर ठंडा / ठण्डक महसूस करना
Mandarin	清凉感	口腔和喉腔感受到清凉的程度.
Spanish	Refrescante-MM	Sensación refrescante en las cavidades oral y nasal.
English	**Dissolvability-MB**	**Rate and degree to which product dissolves in the mouth during mastication.**
Hindi	गलाऊ (गलने योग्य) / घुलना	खादय पदार्थ को खाते समय मुँह में घुल जाने की क्षमता
Mandarin	溶解感	样品在咀嚼过程中溶解的速度和程度。
Spanish	Disolubilidad-MM	Grado en el que el producto se disuelve en la boca durante la masticación.
English	**Doughy-MB**	**A moist, under baked impression associated with grain product.**
Hindi	गूंथा हुआ आटा जैसा / अधपक्का	खादय पदार्थ को खाते समय मुँह में अधपके आटे जैसा स्वाद आने की मात्रा
Mandarin	面团感	与谷物产品相关的潮湿，低温烘烤的感觉。

Language	Texture terms	Definitions
Spanish	Masoso-MM (subhorneado, crudo)	Impresión de producto húmedo y subhorneado, asociado con productos a base de granos.
English	**Effervescence-MB**	**The gaseous/ fizzy sensation produced upon the introduction of the products into the mouth.**
Hindi	बुलबुलेदार / सनसनाहट / सुरसुराहट / गैस निकलने की फुफकार	खादय पदार्थ को खाते समय मुँह में बुलबुलेदार (बुदबुदानेवाला) व सनसनाहट / सुरसुराहट / गैस निकलने की फुफकार का महसूस होना
Mandarin	冒气泡感	样品刚送入口中时产生的气态/汽水感。
Spanish	Efervescencia-MM	Sensación gaseosa producida con la introducción de productos a la boca.
English	**Fibrous-MB**	**The perception of filaments or strands of muscle tissue or plant fiber.**
Hindi	रेशेदार	खादय पदार्थ को खाते समय उसमे रेशे या उसके रेशेदार होने का अनुभव होना
Mandarin	纤维感	一缕缕类似肌肉纤维或者植物纤维的感觉。
Spanish	Fibroso –MM	Percepción de filamentos o hebras provenientes de tejidos musculares o fibras de plantas.
English	**Heat burn-MB***	**Burning sensation on the lips in the oral cavity and throat, resulting from exposure to substance such as capsaicin or hot peppers. The sensation tends to persist after the stimulus is removed.**
Hindi	मिर्च जैसा/ मसालों से भरा/ तीखा	खादय पदार्थ को खाते समय मुँह क़े भीतर जलन (मिर्च जैसा) या मसालों से भरा तीखापन महसूस करना
Mandarin	灼热感	由于接触辣椒素或辣椒等物质而在口腔和喉咙的嘴唇上产生灼烧感。 刺激消除后，感觉往往持续存在。
Spanish	Picante-MM	Sensación quemante en los labios, en la cavidad oral y en la garganta, resultado de la exposición a sustancias como la capsaicina o pimiento picante. La sensación tiende a perdurar una vez que el estímulo ha sido removido.
English	**Mealy-MB**	**The perception of fine, soft, somewhat rounded smooth particles very evenly distributed within the product itself. Perceived as the product is broken down during mastication but is a geometrical attribute within the product and is not created by the mastication.**

Language	Texture terms	Definitions
Hindi	मुलायम / आटा सा / चुरमुरा / फुसफसा	खादय पदार्थ को खाते समय उसके भीतर क़े सभी कणो /अंशो/ संघटको का सामानरूप होने को महसूस करना
Mandarin	**米粒感**	**感受**细微，柔软，略微圆滑的颗粒**且非常均匀地分布在**产品本身**内。品**评样品在咀嚼过程中被分解时感知的立体几何属性，然而这种属性并非由咀嚼产生的。
Spanish	Harinoso-MM	Percepción de partículas finas, suaves, algo redondas y lisas, muy uniformemente distribuidas dentro del producto. Percibido conforme el producto se rompe durante la masticación. Sin embargo, es un atributo geométrico dentro del producto, es decir, no es creado por la masticación.
English	**Moistness of mass-MB**	**The perceived amount of wetness of the product in the mouth following 5-7 chews.**
Hindi	नमी (पानी की मात्रा) / गीलापन / सीलन	मुँह के भीतर पांच-छे बार चबाने के बाद वस्तु (खादय पदार्थ) में नमी की मात्रा
Mandarin	**湿**润度	**感知** 5-7 **次咀嚼后口腔中**产品的湿润**度。**
Spanish	Humedad de la masa-MM	Humedad del producto percibida en la boca tras 5-7 mordidas.
English	**Oily Mouthfeel-MB**	**The sensation of oily coating on mouth surface during mastication.**
Hindi	मुँह का तेलमय हो जाना	खादय पदार्थ को खाने (चबाने) के दौरान मुंह की सतह पर तेल की कोटिंग महसूस करना
Mandarin	**油感**	**在咀嚼**过程中口腔表面产生的油性层**的感**觉。
Spanish	Sensación bucal aceitosa-MM	Sensación de cobertura aceitosa en la superficie de la boca durante la masticación.
English	**Particles amount-MB**	**The perception of small pieces relatively harder than surrounding product.**
Hindi	कणमय/ किरकिरा / कणो की मात्रा	खादय पदार्थ को खाते समय मुँह में कणो की मात्रा या किरकिरापन को महसूस करना
Mandarin	颗粒**程度**	**在**样品中**可被感受到的小的**坚硬的颗粒的整体感**受**
Spanish	Cantidad de partículas-MM	Percepción de partículas pequeñas relativamente más grandes que el resto del producto.
English	**Roughness of mass-MB**	**The degree of abrasiveness of particles perceived when gently manipulating the mass of against the palate after 5-7 chews.**

Language	Texture terms	Definitions
Hindi	कणो का खुरदरापन / खादय पदार्थ का खुरदरापन	खादय पदार्थ में खुरदरेपन की मात्रा को मुँह के भीतर चबाते समय महसूस करना
Mandarin	**粗糙感**	5-7 **次咀嚼后感受**颗粒在口腔里造成的摩擦感，粗糙感。
Spanish	Aspereza de la masa-MM	Grado de abrasividad de partículas percibido cuando la masa se manipula contra el paladar tras 5-7 mordidas.
English	**Sting bite-MB**	**The sharp, biting, stinging sensation on the tongue or lips.**
Hindi	मुँह के भीतर जलन होना / स्वाद के तीव्रता	खादय पदार्थ को खाते समय मुँह के भीतर जलन या स्वाद की तीव्रता को महसूस करना
Mandarin	针刺感	舌头或嘴唇上尖锐，刺骨，刺痛的感觉。。
Spanish	Picadura punzante-MM	Sensación aguda, cortante y punzante en la lengua o labios.
English	**Sustained crispness-MB**	**The perceived duration of crispiness (audible noise) maintained that is equal to the first bite crispness.**
Hindi	करारेपन का लगातार बने रहना / करारेपन का ना जाना / करारापन	खाते समय खादय पदार्थ के करारेपण का बने रहना
Mandarin	**持**续性**清脆感**	**从咬下第一口开始，感受清脆感（声音）的持久性**。
Spanish	Crujencia sostenida-MM (crujibilidad sostenida)	Duración percibida de la crujencia (sonido audible) sostenida que es igual a la crujencia inicial en el primer producto.
English	**Sustained Fracturability-MB**	**The duration of force with which sample ruptures that is equal to the first bite.**
Hindi	टूटते रहने की क्षमता	खाते समाये खादय पदार्थ को तोड़ने के लिए लगाए गए बल की समानता का बने रहना
Mandarin	**持**续性脆度	**从咬下第一口开始，用同**样的力度咀嚼样品，直到样品破碎，品评这个过程所用时间。
Spanish	Fracturabilidad sostenida-MM	Duración de la fuerza con la que la muestra se rompe que es igual a la del primer mordisco.
English	Tongue Tingle-MB	A feeling of an increased sensation on the tongue that may be due to chemical stimulation, intense carbonation, or other causes. Evaluate during first 3-5 seconds after sample is placed in the mouth.
Hindi	जीभ का झनझनाना / जीभ का सनसनाना/ झनझनाहट व सनसनाहट महसूस करना	खादय पदार्थ को खाते समय मुँह या जीभ में झनझनाहट व सनसनाहट महसूस करना

Language	Texture terms	Definitions
Mandarin	**舌刺感**	**感**觉舌头持续性**的受到刺激。刺激主要来源于化学刺激，二氧化碳刺激等。在**样品放入口腔 3-5 **秒后品**评。
Spanish	Hormigueo en la lengua-MM	Percepción de una sensación que se incrementa en la lengua, se puede deber a un estímulo químico, intensa carbonatación, u otras causas. Se evalúa durante los primeros 3-5 segundos posteriores a la colocación de la muestra en la boca.
English	**Waxy Mouthfeel-MB**	**The sensation of waxy coating on mouth surface during mastication.**
Hindi	मोम सा / मुँह के भीतर मोम सा महसूस करना	खादय पदार्थ को खाते समय मुँह के भीतर मोम की परत सा महसूस करना
Mandarin	**蜡**质感	**在咀嚼**过程中口腔表面蜡质般光滑的感觉
Spanish	Sensación bucal cerosa-MM	Sensación de cobertura cerosa en la boca durante la masticación.

*Heat-Burn is a trigeminal sensation, not a texture attribute, but is treated as such in many studies, and is included here simply by convention.

Table 3.10.

Texture attributes in the throat during swallowing with their translations into Hindi, Mandarin, and Spanish. English terms are highlighted simply to make it easier to differentiate new attributes.

Language	Texture terms	Definitions
English	**Chalky mouth coat-TH**	**A measure of the dry, powdery sensation in the mouth after swallowing.**
Hindi	मुँह के भीतर पाउडर जैसा महसूस करना	खादय पदार्थ को निगलने के बाद मुंह में पाउडर जैसा महसूस होना
Mandarin	**口腔干粉感**	**吞咽后口腔中干粉的感**觉
Spanish	Cobertura bucal gredosa-TG	Medida de la sensación seca y polvosa en la boca tras la deglución.
English	**Cohesiveness of throat-TH**	**A measure of how much the product holds together while swallowing. High spread to no spread.**
Hindi	संगठित रहना / खादय पदार्थ का निगलते समय संगठित रहना	खादय पदार्थ के निगलते समय संगठित रहना या उसके विपरीत फैल जाने की मात्रा
Mandarin	**喉部**紧实感	**衡量吞咽**时产品保持在一起的程度。**从高分散度到不分散**。
Spanish	Cohesividad en garganta-TG	Medida de cuanto se mantiene unido el producto mientras se traga. Gran esparsión a no esparsión.
English	**Heat burn-TH***	**Burning sensation on the lips in the oral cavity and throat, resulting from exposure to substance such as capsaicin or hot peppers. The sensation tends to persist after the stimulus is removed.**
Hindi	मिर्च जैसा/ मसालों से भरा/ तीखा	खादय पदार्थ को निगलते समय गले में जलन (मिर्च जैसा) या मसालों से भरा तीखापन महसूस करना
Mandarin	**灼**热感	**由于接触辣椒素或辣椒等物**质而在口腔和喉咙的嘴唇上产生灼烧感。**刺激消除后**，**感**觉往往持续存在。
Spanish	Picante-TG	Sensación quemante en los labios, en la cavidad oral y en la garganta, resultado de la exposición a sustancias como la capsaicina o pimiento picante. La sensación tiende a perdurar una vez que el estímulo ha sido removido.
English	**Oily mouth coating-TH**	**A measure of an oily like sensation in the mouth after swallowing.**

Language	Texture terms	Definitions
Hindi	मुँह व गले का तेलमय हो जाना	खादय पदार्थ को निगलते समय या निगलने के बाद तैलमय (तेल जैसा) महसूस करना
Mandarin	**油余感**	**吞咽**样品后口腔中的油腻的量度。
Spanish	Cobertura bucal aceitosa-TG	Media de una sensación aceitosa en la boca tras la deglución.
English	**Pressure on throat-TH**	**The amount of pressure felt on throat while swallowing. The perception of a squeezing on or a tightening sensation at the back of the throat. None to high.**
Hindi	गले पर दबाव महसूस करना	खादय पदार्थ को निगलते समय गले पर दबाव महसूस करना
Mandarin	**喉部**压迫感	**吞咽**时喉咙上感受到的压力。 **在喉**咙后部感觉到挤压或紧绷的感觉**。感**觉从无到**高**
Spanish	Presión de garganta-TG	Cantidad de presión percibida en la garganta al tragar. Percepción de un apretón o contracción en la parte posterior de la garganta. Nada a alto.
English	**Residuals Mouth-TH**	**Sample remaining in or on surfaces of mouth after swallowing that triggers the need for subsequent swallows to clear.**
Hindi	खादय पदार्थ का मुंह की सतहों के ऊपर या मुँह के भीतर बचे रहना	निगलने के बाद भी खादय पदार्थ के अवशेष का मुँह की सतहों के ऊपर या मुँह के भीतर बचे रहना
Mandarin	**口腔残留感**	样品被吞咽后残留在口腔中的样品引起后续需要被**吞咽清除的感受**。
Spanish	Residual en la boca-TG	Muestra remanente en o sobre la superficie de la boca tras la deglución que impulsa la necesidad subsecuente de tragar para limpiar.
English	**Residuals Throat-TH**	**Sample remaining in back of mouth or throat area after swallowing that triggers the need for subsequent swallows to clear mouth/throat.**
Hindi	गले में अवशेष का बचा रह जाना	खादय पदार्थ निगलने के बाद मुंह में या गले में अवशेष का रह जाना, जिस की बाद मुंह या गले को साफ़ करने की आवश्यकता पड़े!
Mandarin	**喉部残留感**	样品被吞咽后残留在喉腔中，使品评者感觉必须继续吞咽下剩余物质的感受。
Spanish	Residual en la garganta-TG	Muestra remanente en la parte posterior de la boca o la garganta tras la deglución que impulsa la necesidad subsecuente de tragar para limpiar la boca/garganta.

Language	Texture terms	Definitions
English	**Roughness of swallow-TH**	**The degree of abrasiveness of the product while being swallowed. Smooth to rough.**
Hindi	निगलते समय उत्पाद की घर्षण या खुरदरापन	खादय पदार्थ को निगलते समय उत्पाद के घर्षण या खुरदरेपन को गले में महसूस करना
Mandarin	**吞咽粗糙感**	**吞咽**过程中样品表面粗糙摩擦口腔的感觉。从光滑到粗糙
Spanish	Aspereza al tragar-TG	Grado de abrasividad del producto mientras se traga. Liso a aspero.
English	**Slickness during swallow-TH**	**The slippery feel of the sample while being swallowed.**
Hindi	फिसलकर निगल जानेवाला वाला उत्पाद/ पदार्थ का फिसलकर निगलना	पदार्थ को निगलते समय गले में फिसलन महसूस करना
Mandarin	**吞咽滑溜度**	**被吞下**时样品的光滑**感**。
Spanish	Viscosidad al tragar-TG	Sensación resbalosa de la muestra mientras se traga
English	**Swallowability-TH**	**A measure of the effort required to swallow the sample after mastication.**
Hindi	निगलने के लिए लगने वाला प्रयास व जोर	चबाने के बाद उत्पाद को निगलने के लिए लगने वाले प्रयास व जोर की मात्रा
Mandarin	**吞咽欲**	**咀嚼后吞咽**样品所需**的工作量度**。
Spanish	Tragabilidad –TG	Medida del esfuerzo requerido para tragar la muestra tras la masticación.
English	**Waxy mouth coat-TH**	**A measure of a wax like sensation in the mouth after swallowing.**
Hindi	मोम जैसा महसूस होना	खादय पदार्थ को निगलने के बाद मुंह में मोम जैस जैसा महसूस होना
Mandarin	**口腔蜡**质感	**在吞咽完后口腔中的蜡**质感。
Spanish	Cobertura bucal cerosa-TG	Medida de la sensación de cera en la boca tras la deglución.

*Heat-Burn is a trigeminal sensation, not a texture attribute, but is treated as such in many studies, and is included here simply by convention.

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Chapter 4 - Understanding the Terminology for Snack Foods and Their Texture by Consumers in Four Languages: A Qualitative Study

(The following is an early DRAFT of a paper subsequently published in the journal *Foods*. For the published article, see Kumar, R., & Chambers, E. (2019). Understanding the Terminology for Snack Foods and Their Texture by Consumers in Four Languages: A Qualitative Study. *Foods, 8*(10), 484. https://doi.org/10.3390/foods8100484)

Abstract

The choice of food products is affected by the combination of food properties, consumer motives, emotions, and context, especially in cross-cultural studies. The designs of cross-cultural studies involve several limitations such as conceptual perception and linguistic and cultural differences in response style. These factors confine the validity and generalizability of such study models. In this study, we have combined linguistic and contextual perception to generate consumer texture terminologies. Four focus group discussions were conducted with consumers from nine different countries in English, Hindi, Mandarin, and Spanish. Vocabularies for sixteen texture terms were generated. Consumers provided a single consensus term that they typically use to describe contextual sensory perception. The results show that consumers use several terms to describe the texture, and terms are very specific to product and related perception. The English translation of words like “snack”, “texture”, and other sensory texture terms are meaningless for

non-English speaking cultures. Researchers are encouraged to validate (test) the structure of cross-cultural study models before application.

The findings of this study present a model that can be utilized to conduct cross-cultural research studies. The results can contribute to generate accurate consumer responses, acceptance, preference, and addressing consumer's concerns. Food industries could leverage these by using our methodology in product development, finding consumer insights, effective communication, and product testing in international settings.

Introduction

Cross-cultural understating of sensory terminologies is a major need of today's global world where the same products are tested and marketed internationally. The growing demand for standards to describe products on a global scale makes it more important to define and understand sensory terminologies, either in analytical sensory description with trained panelists or with consumers to investigate human perception (Kumar & Chambers IV, 2019; Lawless, Vanne, & Tuorila, 1997). Sensory profiling can help to achieve a better understanding of products and meet objectives (Talavera & Chambers IV, 2017). However, cross-cultural sensory studies become complicated when understanding food perceptions. Issues such as language and culture can promote frustration when trying to understand the same products across multiple countries. For descriptive sensory analysis, such problems can be overcome by training and good communication among researchers and panels (Cherdchu, Chambers IV, & Suwonsichon, 2013). This may be less easy to do with consumers, who may have high variability in their use of consumer terms, a problem aggravated by differences in language and culture. For effective

communication across cultures, particularly when consumers are involved, it is vital to understand how people of different languages and cultures describe the same perception.

Texture is an important multi-parameter sensory property stimulating consumers' attitudes towards foods (Szczesniak & Kahn, 1971). In some products, texture is more important than flavor (Szczesniak & Kleyn, 1963). It is essential to comprehend the structure of texture vocabulary (terms) from the consumers' point of view, instead of just simply translating them into other languages. Exploring appropriate consumers' texture terms, describing particular texture perceptions of the consumers in daily life, can help to: (a) better design food products to meet specific needs; (b) address consumer texture concerns; (c) avoid misunderstanding that can occur from simple translations; (d) accurately measure the sensory meaning of consumer perception; and (e) help promote marketing that directly speaks to consumer needs. Szczesniak (1963), and other researchers gave importance to developing texture lexicons and classifying texture terms in various languages (Szczesniak & Kleyn, 1963). Since those early days of texture studies, translations, and comparisons of texture terms among different languages have been an important topic for research. Nevertheless, languages contain many nuances in words, and the topic can quickly become complicated.

Drake (1989), developed a list of 54 English texture terms and had approximately 50 English proficient collaborators with texture expertise to translate those terms into 22 other languages. The results indicated that some languages use a single word for multiple texture attributes (for example, katai in Japanese corresponds to rigid, stiff, hard, firm, or tough in English). Although the English terms were described by distinguishable terms in another language, the author concluded that translations might result in misunderstanding and inconsistencies because English words were presented out of context. The other drawback was

the exclusion of consumers, and the use of highly qualified sensory expertise completely differs from consumers in contextual textural perception. For example, one paper had an English panel to generate descriptors for chocolate, which were then translated into Norwegian and used by a panel (Risvik, Colwill, McEwan, & Lyon, 1992). The panels used the attribute "fruity" differently. The authors concluded that the fundamental perceptual dimensions were similar across cultures, but the underlying sensory dimension and vocabulary differed.

The problem in simply translating terms was highlighted in a study comparing English and Finnish texture terms (Lawless, Vanne, & Tuorila, 1997). Because terms can have multiple meanings, inconsistency can arise. The researchers provided pre-selected texture terms to consumers, which might have restricted consumers' vocabularies. Besides, food samples were not provided for the textural experience. Several other studies emphasized the differences in the use of textural terms among cultures (Antmann et al., 2011; Kim & Lee, 2016; Nishinari et al., 2008; Tu et al., 2007; Varela, Salvador, Gámbaro, & Fiszman, 2008). The majority of studies either compared existing texture vocabularies or used direct translation of terms into different languages without consideration of specific products or the nuances that exist among languages. However, the consensus was that the major dimensions of texture vocabulary are consistent across cultures and languages.

Some studies have compared texture vocabularies for specific foods among different languages. French and Vietnamese panels individually generated and defined a set of texture descriptors to profile jellies (Blancher, Lê, Sieffermann, & Chollet, 2008). The lexicons that were developed were then assessed against preselected sensory descriptors, which allowed successful translation and transfer of attributes to panels in their respective countries. Son et al. (2012), used cooked rice as a model product to develop a lexicon to describe rice texture in four

countries, i.e., France, Japan, Korea, and Thailand. Lists of terms were generated by naïve panels, and the authors noted that the wealth of vocabulary for texture and aroma was influenced by culture. The most texture terms were generated by Thai panelists, but all terms were semantically similar when translated into English. Zannoni (1997), highlighted that while translating texture terms, it is essential to focus mainly on stimuli rather than on words. These results established that direct translation of texture terms isolated from their context could be very problematic. Hence, it can be hypothesized that the consumer understanding of texture is strongly related to the sensory perception experience.

One way to better understand consumer terminology is through focus groups. Focus groups typically involve a roundtable discussion centered on particular issues. The groups must be led by qualified moderators. Focus groups are best suited for clarification of problems, consumer perspectives, attitudes, reactions, motivations, and emotions (Chambers IV & Smith, 1991; Krueger & Casey, 2009; Stewart & Shamdasani, 2014). A "laddering" probing style that leads to a deeper understanding of the reasons behind participants' responses or comments can be used to provide a depth of information (Krystallis, Maglaras, & Mamalis, 2008). The focus group method is a unique method to capture significant sensory information that could be otherwise missed (Marlow, 1987; Moskowitz, Beckley, & Resurreccion, 2012). Focus groups have been used successfully to generate consumer descriptive sensory terms for mung beans (Galvez & Resurreccion,1992), mayonnaise (Cardinal, Flores, Contarini, & Hough, 2003), pudding (Elmore, Heymann, Johnson, & Hewett, 1999), and peanut butter (McNeill, Sanders, & Civille, 2000). Qualitative methodology is a well-practiced technique to explore consumers' knowledge systems, vocabularies, beliefs, and the phraseology that they use to talk about foods.

The overall objective of this study was to determine consumer terminology that corresponds to descriptive sensory terminology for selected characteristics of snack food texture in four languages: English, Mandarin (Chinese), Spanish, and Hindi. Specific objectives of this study were (1) to obtain a consumer meaningful texture vocabulary for key aspects of snack foods, (2) provide positive and negative connotations associated with texture vocabulary, and (3) determine whether simple translations of sensory terms to consumer language would be appropriate. Additional information on the role that snacks play was collected too.

Materials and methods

Participant profile

This study was conducted at the Center for Sensory Analysis, Kansas State University, Manhattan, KS, USA. The city is a hub of international communities living, working, and studying at Kansas State University. It also has a substantial population of military families, many with spouses from foreign countries, and immigrants who have settled in the multicultural community. The consumers were recruited via an established database of community participants using an online screener with predetermined quotas. To qualify for the study, all consumers had to eat snacks at least once a week, have no food allergies or dietary restrictions, and could not have an educational background in food/nutrition, dairy, or sensory sciences. Participants for the focus groups in the specific languages (Hindi, Mandarin, and Spanish) had to be a native speaker of the language and had to have been living in the United States (US) of America for less than two years. All non-US participants also had to have a basic understanding of English, but fluency was not required. US consumers had to be native English speakers and have lived in the US for more than 10 years. Hindi-speaking consumers were residents of India. Mandarin-speaking

consumers were residents of China. Spanish-speaking consumers were from Mexico, Costa Rica, Argentina, Ecuador, Colombia, and Uruguay. Female participants were at least 50% or more for each group (Table 4.1).

Table 4.1.

Participants' demographic details.

By Age	English	Hindi	Mandarin	Spanish
18-24	2	3	4	1
25-34	4	4	4	5
35-44	1	1	1	4
45-54	1			
Total	8	8	9	10
By Gender				
Female	6	5	7	5
Male	2	3	2	5

Products

The list of representative foods served to consumers to establish textural context and to help in determining consumer term options was based on the descriptive sensory analysis results produced by Kumar and Chambers IV (2019), who used a trained panel and expert translators to describe textural terms in various languages (Table 4.2). The samples used in the study were ready to eat without any preparation and, thus, were served "as is". The samples were served blind (no label information) in 3.25 oz (plastic) or 8 oz (Styrofoam) cups (based on the size and shape of the samples) and covered with a lid. One sample at a time was served to consumers for tasting. Participants cleaned their palates between samples with water. Paper napkins were provided for cleaning of lips and hands.

Table 4.2.

A list of food samples served to consumers for each texture attribute.

Sample No.	Descriptive Attribute	Products	Manufacturer
1	Firmness	Gummy Worms	Ferrara Candy Company
2	Smoothness	Brach's chocolate balls	Ferrara Candy Company
3	Moistness	Frozen jack fruit	Flying Horse
4	Roughness of surface	Sourdough Hard Pretzels	SL Snacks National LLC
5	Adhesive	Werther's Original chewy caramels	August Storck
6	Cohesiveness	Sourdough Hard Pretzels	SL Snacks National LLC
7	Crispiness	Cheetos Crunchy	Frito-Lay
8	Uniformity of bite	Lay's Classic Potato Chips	Frito-Lay
9	Astringency	Yoplait original yogurt	General Mills/Sodiaal
10	Oiliness/ Oily	Lay's Classic Potato Chips	Frito-Lay
11	Chew count	Werther's Original chewy caramels	August Storck
12	Residuals in mouth	Sourdough Hard Pretzels	SL Snacks National LLC
13	Powdery	Mochi roll	Yuki & Love
14	Dissolvability	Jet Puff Original Marshmallows	Kraft foods
15	Heat Burn	Seaweed chips	Annie Chun's
16	Particle amount	Nature Valley crunchy granola bars	General Mills

Focus group methodology

Professionally trained moderators, whose native language was that of the consumer group, led and conducted four focus group discussions. The moderator's guide was prepared in English (Table 4.3) and moved from more general to complex, and on to detailed questions. After discussions with industry colleagues, it was translated into three languages by the moderators, who also had excellent skills in English. Whenever a question arose about possible options for translation, other native speakers of that language were consulted. All sessions were conducted in the native language of the representative consumer group and were video recorded to review later. Each focus group session lasted for 90 min. The study was approved by the Committee on Research with Human Subjects at Kansas State University.

Table 4.3.

An abbreviated interview guide with introduction and themes covered by the moderator in the focus group discussion.

Section	Interview guide for focus group sessions
Introduction	Welcome note, guidelines, and purpose Participants introduce themselves
Opening questions	How often do you eat snacks in a week?
General questions	When you think of snacks, what is the first thing that comes to your mind? What are some of the brands that come to your mind about snacks? What are the things you look for in snack foods to make a purchase? What features make a snack food special from your point of view?
Texture theme	What do you understand by "texture" of snack food? How important is texture for you? What other textures you have experienced so far? What terms do you usually use for snacks or snack-like foods? (This question was asked to Hindi-, Mandarin-, and Spanish-speaking consumers) What terms do you usually use for texture of snacks or snacks like foods? (This question was asked to Hindi-, Mandarin-, and Spanish-speaking consumers) Do snack occasions impact the textures you want? If yes, how? Are oily, waxy, and greasy the same or different in your understanding? (This question was asked to Hindi-, English-, and Spanish-speaking consumers only—it was untranslatable in Mandarin)
Texture attributes	What are the words you use to describe these texture terms? (*1) Firmness: The force required to bite completely through the food sample with the molar teeth.* *(2) Smoothness: Degree to which the sample feels smooth and free of lumps/particulates as opposed to lumpy, rough, grainy, gritty, and/or sandy.* *(3) Moistness: The perceived amount of moisture in the product.* *(4) Roughness of surface: The amount of indentations/bumps and surface abrasions which can be perceived by gently manipulating one piece between the thumb & fingers, lips, palate, and/or tongue.* *(5) Adhesive: The degree to which the product sticks to the hands or mouth.* *(6) Cohesiveness: The degree to which the sample deforms before breaking apart when compressed once between the molar teeth.* *(7) Crispiness: The intensity of audible sound when the sample is compressed between the molar teeth.* *(8) Uniformity of bite: Degree to which the product changes from start to finish in the bite. If the force necessary to bite through the sample changes during the bite, the product is non-uniform. The more consistent the force, the more uniform.* *(9) Astringency: Drying sensation on the surface and/or edges of the lips, tongue, and mouth.*

	(10) Oiliness: The appearance of a fat or oily coating on the surface of the product. *(11) Chew count: Number of chews required to hydrate sample and bring to a state ready to swallow.* *(12) Residuals in mouth: Sample remaining in or on surfaces of the mouth after swallowing.* *(13) Powdery: A measure of the dry, powdery sensation in hand or mouth.* *(14) Dissolvability: Rate and degree to which product dissolves in the mouth during mastication.* *(15) Heat burn: Burning sensation on the lips, in the oral cavity, and in the throat, resulting from exposure to a substance such as capsaicin or hot peppers. The sensation tends to persist after the stimulus is removed.* *(16) Particle amount: The perception of small particles relatively bigger than surrounding product.*
Closure	When and where do you often eat your snack food?
Additional groups questions	Only to English speaking American consumers Do you think emotions have anything to do with snack eating? How would you design a snack food if provided an opportunity? Only to Hindi speaking Indian consumers People who eat snacks at home. Why do you eat snacks at home?

Each participant was provided with printed handouts that included the trained descriptive panel texture terms of interest (Table 4.3) with definitions in both the native language and English (Kumar & Chambers IV, 2019). The terms and definitions were provided one at a time, at the time the term was discussed. To provide context, participants were served representative snack foods for each attribute listed in Table 3. Recent authors have shown that simple changes in the flavor of products where texture is maintained can still show differences in consumer emotional response to the product, clearly indicating the importance of tasting to provide context (Bell et al., 2017).

The participants were asked to read the textural term and definition, followed by the tasting of the products for the textural experience. Then, participants were asked to describe the textural attribute using consumer terms in their native language that they thought was the best

representative of the attribute, definition, and experience during the tasting. Multiple terms were requested from the participants; the moderator obtained at least three terms before exploring the meanings of those words and discussing them. Once the list was developed, discussion on the meanings of those terms and how they compared were held to begin developing consensus for the one best consumer term, if possible, that was most representative of the descriptive texture term developed by a trained panel. The strategy was to get the most appropriate term that consumers usually use to define these textures in their daily life.

Results

Snacks and texture

The basic concept of the term "snack food" was the same among participants from all countries: Convenient, something that is small, quick, packaged ready to eat, eaten between meals, and not considered healthy. While enquiring about the terminology's consumer use for a snack and snack-like foods, we found that no specific word or term exists for snacks in the Spanish, Mandarin, and Hindi languages. Also, no translation terms exist for "snacks" in these languages. However, consumers used product names and/or some related terms. For example, the Chinese group used terms like "passing time, tasty food, and potato chips". Indian consumers used terms such as *nashta* (evening breakfast), namkeen (trail mix), time pass, and *alpahar* (small amount of food) for snacks. Out of seven, five Hindi speakers voted for the term "namkeen" and two voted for the term "*alpahar*" for snack food in Hindi. The Spanish speakers used a plethora of terms, such as *aperitiv*o (side dish), *colación* (a meal that is considerably smaller in calorific content than lunch or dinner), *refrigerio* (snacks, Central America, usually served in meetings/formal gatherings), picada (a snack in Argentina consisting of cheeses and

usually cured meats), *merienda* (snack), botana (a snack usually for parties in Mexico), *piqueo* (snacks, South America), tapas (appetizer or snack in Spain), and bocas (snack for parties only, Central America). All of the terms used were different and specific to culture, country, occasion, and kind of snack.

There were some differences among groups; for example, the English and Spanish speakers considered snack foods to be something in between meals but not necessarily a meal replacement. In contrast, Hindi and Mandarin speakers suggested that snacks could be used in place of a meal. While defining snack foods, Indian consumers used product names as identifiers, such as potato chips, nuts, and namkeen (Hindi name for "trail" mixes), and sensory attributes such as fried, crispy, groundnuts, chocolaty, etc. Snacks have been identified and defined by other researchers based on eating occasion (Duffey, Pereira, & Popkin, 2013; Duffey, Rivera, & Popkin, 2014; Garriguet, 2007; Mercille, Receveur, & Macaulay, 2010; Ovaskainen, Tapanainen, & Pakkala, 2010), type of food (Lipoeto, Lin, & Angeles-Agdeppa, 2013), amount of food consumed, location of food consumption, or a combination of several of these factors (Garriguet, 2007; Nicklas, Yang, Baranowski, Zakeri, & Berenson, 2003; Ovaskainen et al., 2006; Wang, Zhai, Zhang, & Popkin, 2012). Phan and Chambers IV (2016a, 2016b), had consumers identify snack foods based on the morning, afternoon, and late-night eating, and then determined the types of snacks consumers ate during each of those occasions. Breakfast cereals, dairy, egg products, and baked products were preferred in the morning. Fruit, nut, and seed snacks were mostly consumed during mid-morning snacking compared to any other occasion. Legumes and legume-based products were for mid-afternoon and late-night snacking. Sweets were mainly consumed as late-night snacks (Phan & Chambers IV, 2016b). Phan and Chambers IV (2016a) also reported snacking as indulgent and part of daily meals among US consumers.

Participants related to snack food purchase and consumption to liking and their cultural background and previous experiences. Cost, package size, packaging (attractiveness and information), nutrition, calories, labeling, and brand names were mentioned as common factors among groups. The other important aspects that influence snacks purchase were health, fat content, calories, protein content, emotions, family members, and resealability. Similar motivations, such as liking, convenience, energy need, hunger, and health, were reported as primary drivers for snacking among US consumers by Phan and Chambers (2016a). Only English speakers (US group) mentioned texture as a driving factor for snack purchases. Other consumer groups did not mention texture explicitly. However, the terms used by these groups, such as fried, crispy, and crunchy, were texture terms, but consumers did not associate them with texture or failed to relate these terms as texture properties of snack foods. Hindi and Spanish speakers also talked about flavor (taste) attributes—for example, sweet, spicy, and salty.

We found no specific word or terminology for the term "texture" in Spanish, Mandarin, or Hindi—and no translation terms exist for "texture" in these languages. Consumers used both terms and phrases to define texture, and some of these terms cannot be translated well into English. The three terms provided by Hind speakers were *sanrachna* (structure), *upari parat* (upper layer), and *haath se chuu kar pata lagana* (hand feel). Consumers rarely use these terms because they are complex and uncommon in the culture. The Mandarin Chinese group gave the terms 口感 (mouth feel or how food feels in the mouth) and 触感 (hand feel).

The English speakers from the US were the only group that related sensory perceptions to the term "texture" and explained "texture" explicitly as a terminology. For example, "a crunchy texture of an apple is an indicator of freshness, whereas mushy apple is stale", "I do not eat crunchy textured foods because it's noisy", and "yogurt is too thin to experience, not my jam,

rather I like hummus because it is more substantial". Hindi, Mandarin, and Spanish speakers had difficulty with "texture" as a translated term and used different methods to describe what "texture" was.

General comments made by Hindi speakers on snack texture were "ruffle texture, the structure of food, rough surface, crispy, and indentions on chips". They were not able to understand the English term "texture" as terminology for snacks, and their responses were mainly based on individual experiences. Some direct comments were "hardness depends on the chip, kettle-cooked is different from normal chips", said, 26-year-old women. Indian consumers frequently used product names and associated sensory attributes such as namkeen mixture, *bhujia*, roasted groundnuts, *bhel puri*, salty, spicy, crispy, crunchy, sweet, etc. Similarly, Chinese speakers frequently used product names to establish textural concepts in terms of specific products. For example, "peanut candy should be crispy but not hard, and I will be disappointed if it is very hard", "softness of the bread, it should not be dry or hard", "creaminess and thickness of yogurt texture", "liquid texture of yogurt stimulates the feeling of low quality" etc. "A cracker needs to be crunchy", said a 32-year-old Spanish speaker. The Spanish-speaking group related textures to snacking occasion. For example, "what texture I eat depends on the time of the day and the event" and "cereal bars for the office consumption". A few Spanish speakers noted that texture was a quality, freshness, and purity indicator. For example, "fruits with certain textures are too perfect, it makes me think if it has something extra".

All groups had experienced multi-textured snack foods before, but not all were as adept at describing the textural aspects of such products. For example, Hindi speakers often attributed their prior experience to multi-sensory characteristics, including flavor (i.e., taste and aroma). For example, "*rasagulla* (sweet dumpling) liked for sponge feel, sweet taste and rose flavor", a

product “layered in cookies and *ladoos* (sweet dish) coated with coconut flakes offers a variety of soft and hard bite experiences”, said a 26-year-old woman. Other examples provided for multi-textured experiences were “ice cream as soft, apple as crispy, and banana as soft”, suggesting again that the concept of the term “texture” was associated with specific products. Spanish speakers talked about combining different snacks with alcoholic “beer” and non-alcoholic “coffee and tea” beverages. For example, “flour or grain-based snacks pair well with coffee or tea” and “meat snacks go well with alcohol”. The US group shared widespread multi-textured experiences such as “soft yogurt with crunchy granola”. Some snacks were preferred for their specific features, such as “crispy and flaky pretzel stick for their crunch and thick bite experience” and “buffalo pretzels for crispness”.

Snacking occasion, texture, and emotions

We found a strong association between snacking occasions, textures, and emotions. The format of association remained consistent across cultures and genders. Consumers want to start their day with a soft-textured snack or food, and as the day progressed, consumers tend to move towards more crispy, hard, and noisy textures. Besides, consumers prefer to eat something healthier or something close to nature, like fruits, particularly in the morning and early in the day. Consumers want to avoid noisy snacks in public places. For example, “in office, I don’t like crispy stuff because it is super loud”, “I prefer soft texture like chocolate or fruits like banana. I have an issue with apple because it is still noisy to eat”, said a 24-year-old Indian woman. “Usually I eat fruits in the morning, it is culture to eat fruits in the morning and savory snack in the evening”, said a 26-year-old Indian woman. Similar responses were received from the Chinese- and Spanish-speaking groups.

Consumers associated occasions to snack eating, for example, “sometimes I need sweet in the morning more like fruit or other sweet, and in the afternoon more crunchy or salty”, said a Spanish speaker. A pattern of starting the day with something sweet, soft, less or no crisp or crunch at all was also observed among non-English speakers. The Indian group preferred to eat fruits, milk, puff pastry, croissants, bread, and soft-textured foods, giving the reason as tradition and culture. Some specific comments included “I eat soft-textured food in the morning, even if I eat rusk (sweet toast) like food, I dip that in milk or tea to make it soft, little hard during lunch but likes crispy in the evening”, said a 26-year-old woman. “I do not like to eat a spicy or savory snack in the morning, prefer to eat something that gives me a less stomach fill experience”, said a 30-year-old man. The majority of Indian consumers eat savory, crispy, crunchy, and hard-textured snacks in the evening or late at night to re-energize themselves. At night, they prefer to eat sweet, semi-liquid snacks like chocolate. A 30-year-old Indian consumer said, “I want to eat something in the night where I do not waste energy to chew or eat”. One or two consumers in each group did not have a texture preference at all. The number of consumers who had “no texture preference at all” was higher in the US group than others, but still in the minority.

Consumers mentioned some specific textures that are preferred at certain places. For example, all groups want to avoid eating crispy and crunchy textures in public (like offices) due to noise generation. For example, “In the office, I don’t like crispy stuff because it is super loud, I prefer soft texture like chocolate, fruits like banana, have an issue with apple too because it is still noisy”, said a 25-year-old Indian woman. A 28-year-old US woman said, “I don’t like to eat crumbly, easily breakable, sticky, and oily snacks in the car”. Chinese consumers also shared similar comments about avoiding eating snacks in public places that make noise. Spanish consumers prefer to eat creamy textures at home due to the spreading process. US consumers

usually eat snacks in all places, but mostly prefer to eat only at home. Alike, Indian consumers mostly eat snacks at home.

We found a strong association of snacking with emotions. When stressed, some consumers prefer to snack, whereas others said they lose their appetite. Consumers, especially women, prefer to eat sweet and soft-textured snacks (like ice creams and cookies) when feeling sad. Specific comments made by the US group were “if it’s a bad day, that’s an excuse to get ice cream or cookies”, “when frustrated I eat crunchy and loud to get steam out”, “if sad, eat ice cream”, “If sad or down, I eat ice cream”, and “if stressed, I do not eat anything”. In the comments, “taste” (such as sweet) dominated over texture preference for most emotions, at least among women. For example, a 34-year-old US woman in the English group stated “my snacking preference in a sad emotional state is more related to taste and flavor than texture. I do not eat savory foods when feeling sad”.

A contrasting pattern was found for male consumers. Almost all male consumers either eat anything (texture does not matter) or prefer to eat crunchy, savory, and hard-textured snacks when they feel angry, saying it helps to get the anger out, and potentially exhaust themselves. US consumers were found very assertive for their emotions and snacking behavior, whereas Spanish, Chinese, and Hindi speaking consumers were more assertive for occasion (different times in a day), places, and snacking behaviors than emotional associations.

Table 4.4.

Consumer texture terms provided by the English-speaking group (US).

Descriptive Attributes	Consumer Terms	Final Consumer Term
Firmness	Chewiness Toughness Hardness	Toughness
Smoothness	Sleek Creamy Silky Clean Clear Hard Surface	Smooth*
Moistness	Wet Slimy Juicy Tender	Juicy*
Roughness of surface	Coarse Abrasive Gritty Jagged	Rough*
Adhesive	Sticky Chewy Gummy Tacky	Chewy
Cohesiveness	Chewy Gummy Crumbly Spongy Uniform when biting down Change in shape but stay as a whole	Gummy/ Spongy**
Crispiness	Crunchy Crackly	Crunchy
Uniformity of bite	Consistency of texture Hardness Brittle One bite Disintegrate Smooth consistent bite or consistency	Consistent
Oiliness	Oily	Oily

Descriptive Attributes	Consumer Terms	Final Consumer Term
Astringency	Dry Tabasco Chaps your lips Bitter Sour Salty Spicy Thirsty Thick	Dry
Chew Count	Chewy Gummy	Chewy
Residuals in mouth	Gritty Chewy (if it stuck in teeth) Grainy	Gritty
Powdery	Chalky Dry Powdery	Powdery
Dissolvability	Disintegrate Airy Melts Dissolves	Melts
Heat Burn[1]	Spicy Hot Real hot Hot-hot (for Spanish foods) Flaming (for Cheetos) Lips burning Chili powder (chili sounds like cold) Chili pepper (chili sounds like cold)	Spicy
Particle Amount	Crumbly Grainy Gritty	Grainy

[1]Heat/burn technically is a trigeminal sensation part of the flavor, separate from the texture. However, it is included here because people often refer to it as part of texture because of its seemingly physical effect in the mouth. * Closest term for the product tasted but no single term because it depends on the product. ** Equal number of consumers voted for these terms.

Table 4.5.

Consumer texture terms provided by the Hindi speaking group (India).

Attributes	Consumer Terms	English Translation	Consensus Consumer Term
Firmness	सख्त (Sakkt)	Toughness	सख्त (Sakkt)
	कड़क (Kadak)	Hard	
	ज़्यादा ज़ोर लगाने वाला (Zyada jor lagane wala)	Something that requires more power to bite	
	ज़्यादा चबाने वाला (Zyada chaabane wala)	More number of bites to eat	
Smoothness	लिस्सापन (Lissapan)	Gluey	
	चिकनापन (Chiknapan)	Smoothness/slickness	
	मृदु (Mradu)	Soft-touch (closet meaning)	
	कोमल (Komal)	Soft feel	
	चिकना (Chikna)	Smooth/ slippery	चिकना (Chikna)
	नरम (Naram)	Soft feel	
Moistness	पानी पानी (Pani-Pani)	Water like	
	पिलपिला (Pilpila)	Flabby	
	भेजवाला (Bhejwala)	No English term	
	पनियाल (Paniyaal)	Water like	
	गीला (Geela)	Wet	गीला (Geela)
Roughness of surface	कड़क (Kadak)	Hard	
	खुरदरा (Khurdara)	Rough/ Abrasive	खुरदरा (Khurdara)
	कुरकरा (Kurkara)	Crisp	
Adhesive	चिपचिपा (Chipchipa)	Sticky	चिपचिपा (Chipchipa)
	चिपकना (Chipakna)	Stickiness	
	चिकना (Chikna)	Smooth	
Cohesiveness	मज़बूती (Majbuti)	Strong	
	कडा (Kadaa)	Tough	
	पकड़ के रहने वाला (Pakad ke rehne wala)	Something that holds together	
	न टूटने वाला (Na tutane wala)	Something that doesn't break	
	न बिखरने वाला (Na bikharne wala)	Something that doesn't scatters	न बिखरने वाला (Na bikharne wala)
	जुड़ा हुआ (Juda hua)	Remains together	
Crispiness	कुरकुरा (Kurkura)	Crispy	कुरकुरा (Kurkura)

Attributes	Consumer Terms	English Translation	Consensus Consumer Term
Uniformity of bite	हल्का (Halka)	Light	
	तोड़ने में आसान (Todne me assan)	Easy to break/bite	
	टूटने की समानता (Tutane ki samanta)	Uniformity of bite	
	चबाना आसान है (Chabana assan hai)	Easy to bite	चबाना आसान है (Chabana assan hai)
Oiliness	तेल बहुत ज्यादा है (Tael bahut jyada hai)	High amount of oil	
	तला हुआ (Tlaa) hua	Fried	
	चिकनाई (Chiknaye)	Oily	चिकनाई (Chiknaye)
Astringency	सूखापन (Sukhapan)	Dryness	सूखापन (Sukhapan)
Chew count	बहुत चबाना पड़ता है (Bahut chabana padtha hai)	Something that requires more numbers of chews to eat	बहुत चबाना पड़ता है (Bahut chabana padtha hai)
Residuals in mouth	दांतो के बीच में रह जाना (Danto ke beech me reh jana)	Stuck in between teeth	
	मुँह में रह जाता है (Muh me reh jata hai)	Leftover in mouth	मुँह में रह जाता है (Muh me reh jata hai)
Powdery	पाउडर जैसा (Powder jaisa)	Powder-like	पाउडर जैसा (Powder jaisa)
	आटे जैसा (Aatte jaisa)	Flour-like	आटे जैसा (Aatte jaisa)
Dissolvability	पिघलना (Peghalna)	Melts	पिघलना (Peghalna)
	घुलना (Ghulna)	Dissolves	घुलना (Ghulna)
Heat burn[1]	तीखा (Tekha)	Peppery hot	तीखा (Tekha)
	मिर्ची वाला / मिर्ची लगी (Mirchi wala /Mirchi lagi)	Spicy	
	तेज़ (Tej)	Peppery tang	

Attributes	Consumer Terms	English Translation	Consensus Consumer Term
Particle amount	मुरमुरा (Murmura)	Crisps	
	किरकिरा (Kirkira)	Gritty	
	भुरभुरा (Bhurbhura)	Crumbly	भुरभुरा (Bhurbhura)

[1]Heat/burn technically is a trigeminal sensation part of the flavor, separate from the texture. However, it is included here because people often refer to it as part of texture because of its seemingly physical effect in the mouth.

Table 4.6.

Consumer texture terms provided by the Spanish-speaking group.

Attributes	Consumer Terms	English Translation	Consensus Consumer Term
Firmness	Consistencia	Consistency	Resistencia
	Dureza	Hardness	
	Resistencia	Resistance	
Smoothness	Plano	Flat	Liso (Smooth)
	Terso	Smooth	
	Suave	Soft	
	Liso	Smooth	
	Homogéneo	Homogeneous	
Moistness	Jugosidad	Juiciness	Jugosidad
	Aguado	Watery	
	Mojado	Wet	
Roughness of Surface	Rugosidad	Roughness	Aspereza
	Superficie heterogénea	Heterogeneous Surface	
	Superficie Irregular	Irregular Surface	
	Rasposo	Rough	
	Lijoso	Pieces with sharp edges (example, rough surface of a nail filer)	
	Aspereza	Roughness	
Adhesive	Pegajoso	Sticky	Pegajoso
	Chicloso	Taffy	
	Gomoso	Gummy	
Cohesiveness	Elasticidad	Elasticity	Elasticidad
	Suavidad	Softness	
	Consistencia	Consistency	
	Firmeza	Firmness	
	Quebradizo	Brittle	

Attributes	Consumer Terms	English Translation	Consensus Consumer Term
Crispiness	Crujencia	Crunchiness	Crujencia
	Crocancia	Crunchiness	
Uniformity of bite	Homogeneidad de la mordida	Homogeneity of bite	Homogeneidad de la mordida
	Uniformidad	Uniformity	
	Consistencia de la mordida	Consistency of bite	
	Resistencia de la mordida	Resistance of bite	
Astringency	Aspereza	Roughness	Astringencia
	Sensación de sequedad	Dryness sensation	
	Astringencia	Astringency	
Oiliness	Aceitoso/grasoso	Oily/greasy	Aceitoso/grasoso
Chew count	Masticabilidad	Chew ability	Número de masticadas
	Número de masticadas	Number of chews	
Residuals in mouth	Sabor de boca	Flavor in mouth	Residuo en boca
	Sensación de boca	Sensation in mouth	
	Residuo en boca	Residual in mouth	
Powdery	Arenoso	Sandy	Polvoroso
	Granuloso	Grainy	
	Harinoso	Floury	
	Polvoso	Dusty	
	Polvoroso	Dusty	
Dissolvability	Solubilidad	Solubility/solvability (melts)	Solubility/ solvability
	Disolubilidad	Dissolvability	Solubilidad
Heat burn[1]	Picante	Spicy	Picante
	Picosidad	Spicy (Mexican)	
	Enchiloso	Spicy (Mexican)	
Particle amount	Granuloso	Grainy	Granuloso

1Heat/burn technically is a trigeminal sensation part of the flavor, separate from the texture. However, it is included here because people often refer to it as part of texture because of its seemingly physical effect in the mouth.

Table 4.7.

Consumer texture terms provided by the Mandarin-speaking group (Chinese).

Attributes	Consumer terms	English Meaning of Consumer Terms	Consensus Consumer Term
Firmness	有嚼劲	Chewy	有嚼劲
	韧性	Toughness	
Smoothness	圆润度	Roundness	圆润度
	圆 滑	Smooth	圆滑感
	顺滑	Smooth	
Moistness	多汁	Juicy	多汁
	水润	Moist	
Roughness of surface	凹凸不平	Rugged	凹凸不平
	磨砂	Roughness	
Adhesive	黏牙	Teeth sticky	黏牙
	粘稠	Viscous	
Cohesiveness	韧性	Tenacity (something that does not break or recover in shape, like a sponge)	韧性
Crispiness	脆性	Crispy	脆性
	嘎嘣	Crunchy	
Uniformity of bite	口感均匀	Even texture	口感均匀
	均匀的	Evenly	
Astringency	发涩	Dry	发涩
	麻	Numbing	
Oiliness	油腻	Greasy	油腻
	油乎乎的	Oily	
	冒油	Oily	
Chew count	嚼劲	Chewy	嚼劲
	下咽度	Easy of swallowing	
Residuals in mouth	渣	Residual	渣
Powdery	面	Powdery	面
	绵	Powdery	
	面面的	Powdery	
Dissolvability	入口即化	Dissolve directly when put in mouth	入口即化
Heat burn[1]	烧灼	Burning	烧灼
	辣	Spicy	
	冲	Pungent	
Particle amount	碎	Granular	碎
	酥	Crisp	

[1]Heat/burn technically is a trigeminal sensation part of the flavor, separate from the texture. However, it is included here because people often refer to it as part of texture because of its seemingly physical effect in the mouth.

Table 4.8.

Final consumer texture terms provided by each different language consumer.

Attributes	English Speaking group	Spanish Speaking group	Hindi Speaking Group	Mandarin Speaking Group
Firmness	Toughness	Resistance	Toughness	Chewy
Smoothness	Smooth*	Smooth	Smooth	Roundness/ smoothness**
Moistness	Juicy*	Juiciness	Wet	Juicy
Roughness of surface	Rough*	Roughness	Rough/ abrasive**	Rugged
Adhesive	Chewy	Sticky	Sticky	Teeth sticky
Cohesiveness	Gummy/ Spongy**	Elasticity	Something that doesn't scatters	Tenacity
Crispiness	Crunchy	Crunchiness	Crispy	Crispy
Uniformity of bite	Consistent	Homogeneity of bite	Easy to bite	Even texture
Astringency	Dry	Astringency	Dryness	Dry
Oiliness	Oily	Oily/greasy**	Oily	Greasy
Chew Count	Chewy	Number of chews	Numbers of chews	Chewy
Residuals in mouth	Gritty	Residual in mouth	Leftover in mouth	Residual
Powdery	Powdery	Dusty	Powder/ flour-like**	Powdery
Dissolvability	Melts	Solubility/ solvability**	Melts	Dissolve
Heat Burn[1]	Spicy	Spicy	Peppery hot	Burning
Particle amount	Grainy	Grainy	Crumbly	Granular

[1]Heat/burn technically is a trigeminal sensation part of the flavor, separate from the texture. However, it is included here because people often refer to it as part of texture because of its seemingly physical effect in the mouth. * Closest term for the product tasted but no single terms because it depends on the product. ** Equal number of consumers voted for these terms.

Consumer texture terms

Table 4.4 (English), Table 4.5 (Hindi), Table 4.6 (Spanish), and Table 4.7 (Mandarin) represent all consumers' descriptors used for each texture attribute and final terms (Table 4.8) on which each group agreed. We used the closest English meaning of each term to explain the results. Original terms in native languages can be found in Table 4.4, Table 4.5, Table 4.6, and Table 4.7.

Gummy Worms were used as a reference food for "firmness". US consumers described "force required to bite completely through the food sample with the molar teeth" as chewiness, toughness, and hardness. The Hindi-speaking group used the same terms, the Chinese group used chewy and toughness, and the Spanish group described firmness as consistency, hardness, and resistance. Only "hardness" was consistent among all four groups. The US and Indian groups described "toughness" as the most suitable descriptor for firmness, based on the (1) tough structure of the Gummy Worms, and (2) the force required to bite through the Gummy worms. The Spanish and Chinese groups preferred terms that translated as resistance and chewy as their final descriptors (Table 4.8). The reason was the high number of chews required to breakdown the food.

Brach's chocolate balls were used as a reference food for "smoothness". The descriptors used by US consumers were sleek, creamy, silky, clean, clear, hard surface, and smoothness. The group explained that the terms might change with the product. For example, "creamy goes for cheese spreads and silky for milk-based drinks". The Indian group used six terms to describe smoothness, but not all terms could be used similarly. The terms were gluey, slickness, soft feel (कोमल), slippery/smooth (चिकना), soft feel (नरम), and soft-touch (मृदु). The terms largely mean smoothness, but terms were specific to certain products. Spanish speakers used flat, smooth

(terso), soft, smooth (*liso*), and homogeneous. There is no term for smoothness (only smooth) in the Spanish language. The Chinese group used roundness and smoothness. Only smooth/smoothness was common among cultures. Due to the smooth surface of chocolate balls, all groups felt smooth was the most suitable final term (Table 4.8). The final terms may change to other terms if the product is different. For example, Chinese consumers used "smoothness" for hard-textured products and "roundness" for soft-textured products.

Frozen jackfruit was used as a reference product for "moistness". US consumers used wet, slimy, juicy, and tender as descriptors and stated that they use tender for moist meat food and slimy for oyster-like watery foods. Indian consumers used descriptors such as water-like (पानी पानी), water-like (पनियाल), flabby, भेजवाला (no English term), and wet. Spanish speakers used juiciness, watery, and wet. The Chinese group used only two terms, i.e., juicy and moist (wet). The term "wet" was common among the four cultures, and "juicy" was common in three of the cultures but not in the Indian group. The term "juicy" in Hindi explicitly reflects fruit or vegetable juice perception. Therefore, Indian consumers used "wet" as a term for the most perception of jackfruit. Whereas, other cultures used "juiciness/juicy" for dripping-moistened jackfruit. The perception of "juiciness" as a fruit juice, not as moist, was the dominant driving force here. Again, the final terms may change if the product is changed.

Sourdough pretzels were used as a reference product for "roughness of surface". US consumers used coarse, abrasive, gritty, and jagged as descriptors, while the Hindi-speaking group used hard, rough/abrasive, and crisp. The Spanish group used six descriptors, i.e., roughness (*rugosidad*), heterogeneous surface, irregular surface, rough, *lijoso* (sharp-edged products), and roughness (*aspereza*). The Chinese group used rugged and roughness, with "rugged" as the final term (Table 4.8). The Spanish and US consumers settled with "rough" as

the final term. Indian consumers determined that both rough and abrasive were equally good (Table 4.8). The rough perception was due to the top surface of the pretzels. Both the US and Indian consumers may use other terms for "roughness of surface" if the product is different.

For "adhesive" perception, chewy caramels were used as a reference product. US consumers used descriptors such as sticky, chewy, gummy, and tacky. Indian consumers used sticky (चिपचिपा), sticky (चिपकना), and slippery (चिकना). Spanish consumers used sticky, taffy, and gummy, and Chinese consumers used teeth sticky and viscous. The US consumers commented that "the product is chewy, and it sticks on teeth because it is chewy" and chose "chewy" as the final term. The other three cultures used "sticky" (teeth sticky) as the final term (Table 4.8). "Adhesive" was too technical, as consumers use "adhesive" to describe adhesive glues for pasting things but not as a food sensory descriptor.

US consumers described "cohesiveness" by terms such as chewy, gummy, crumbly, spongy, uniform bite, and "change in shape but stay as a whole". There was no agreement on the use of a single term, so no conclusion was reached. Indian consumers used strong, tough, "something that holds together" (न टूटने वाला), "remains together" (जुड़ा हुआ), "something that does not break", and "something that does not scatter". They agreed to use the phrase "something that does not scatter" as the final term. Spanish consumers used terms such as elasticity, softness, consistency, firmness, and brittle; the final term was "elasticity" (Table 4.8). The Chinese used only one term, "tenacity" (something that does not break or recover in shape, like a sponge). Cohesiveness is a complex term that encompasses multiple aspects.

The US consumers described "crunchiness" as crunchy and crackly. Spanish consumers used crunchiness (*crujencia*) and crunchiness (*crocancia*), with "crunchiness" (*crocancia*) as the final term. Similarly, Indian consumers also used crispy as the final term. Hindi speakers used

only one Hindi term to describe both crispy and crunchy, i.e., कुरकुरा (*Kurkura*), it does not translate well into English). Chinese consumers used descriptors crispy and crunchy, with "crispy" as the final term (Table 4.8).

Lay's classic potato chips were used as a reference product for "uniformity of bite". The US consumers used descriptors such as consistency of texture, hardness, brittle, one bite, disintegrate, smooth, and consistency (of bite); the final consensus term was "consistency of bite" (Table 4.4). Indian consumers used light, easy to break (bite), uniformity of bite, and easy to bite; the final term chosen was "easy to bite", although this may not be the same concept. Spanish consumers used descriptors like homogeneity of bite, uniformity, consistency of bite, and resistance of bite; the final terms agreed was "homogeneity of bite". Chinese consumers used a single term, "even texture", to describe "uniformity of bite". The consumers associated the perception as "the way a product breaks inside mouth", which was described as "evenness of bite".

Oiliness was measured on Lay's classic potato chips. Both "oily" and "greasy" were used as the final terms (Table 4.4). The Indian group provided the additional term "fried" for oiliness, but it is generally used as an identifier for fried foods. The moderators inquired to know if consumers perceive oily, greasy, and waxy as the same or different. Spanish consumers used waxy and greasy interchangeably, observing only a small difference that they could not explain. O'Mahony and Alba (1980), found inconsistencies among Spanish and English speakers in their choice of descriptive terms for sour/acid or bitter foods. "Oiliness (*aceitoso*) is more related to the surface properties, and more appropriate for snacks", explained Indian and US consumers. The consumers understand oily, waxy, and greasy as different, and provided examples to back their opinions: "Waxy is like a coat to cover a product or coating on the skin, and waxy is thick

and hard, waxy does not drip, and does not leave any residue on fingers". Examples mentioned were "fruit covered with wax (apple skin), "*Laffy Taffy*" (a brand of thick hard chewy candy), a layer of cheese, and a solid-state of butter is waxy like pastry dressing". "Greasy is liquid, might drip, and leaves a residue on fingers". "Greasy is like ghee (milk fat), a molten state which sticks in mouth, has an after taste, and stays in the mouth even after swallowing". Examples were "greasy hot cheese dripping on pizza that comes up on a napkin", and "*Suji ka Halwa*" (a sweet dish made from semolina and ghee). Oily was defined as a thin layer of oil observed on the surface of foods. Overall, the consumer experience of greasy, oily, and waxy was mainly of visual and tactile perception.

Yoplait strawberry yogurt was used as a reference product for "astringency" perception. Terminologies used by US consumers were dry, tabasco, chaps your lips, bitter, sour, salty, spicy, thirsty, and thick. Taste attribute sensations dominated the perception, which may be common with astringency perception of yogurt. Astringency is referred to in the sensory literature both as a part of flavor (trigeminal sensation) and as a texture. Indian consumers used dryness, and Chinese consumers used dry and numbing as descriptors. The Spanish group used astringency as the final term, and the additional terms were roughness and dryness. None of the consumers felt astringency (drying/puckering) in the sample food, whereas a trained descriptive panel found a very high intensity of astringency in Yoplait strawberry yogurt (Kumar & Chambers IV, 2019). The possible reason could be that the untrained profile of consumers failed to identify the astringency sensation.

For "chew count", all four cultures used chewy (high number of chews required to breakdown food) as the final term (Table 4.8). Other terminologies, for example, US consumers

used gummy; Spanish consumers used chew-ability, and Indian consumers used “ease of swallowing”. As for Indian consumers, “if something is chewy that it is not easy to swallow”.

US consumers described “residuals in the mouth” as gritty and grainy, and Chinese consumers used residuals (indicated the need to drink water to clear teeth). Spanish consumers’ use of terms was based on the lingering sensation, i.e., flavor in the mouth, sensation in the mouth, and residuals in the mouth. Similarly, Indian consumers also used phrases such as “leftover in the mouth” and “stuck in between teeth”. The US consumers concentrated on the nature of the food, i.e., “gritty”, and other cultures selected “leftover in the mouth” as the final term (Table 4.8).

The Spanish consumers described the term “powdery” as “dusty”, but other cultures used “powdery” as the final term (Table 4.8). Multiple terminologies were provided by each group of language speakers, with US consumers using chalky and dry; Indians using flour-like; and Spanish using sandy, grainy, floury, dusty (*Polvoso*), and dusty (*Polvoroso*). Although powdery is an English term, all four cultures understood it fairly well.

Consumers found it difficult to relate to “dissolvability” as a term for food texture sensory perception. The US consumers used terms such as disintegrate, airy, melt, and dissolve; Indian consumers used melt and dissolve; Spanish consumers used solubility (melt) and dissolvability; and Chinese consumers used a single term, “dissolve”, as the descriptor. All other groups preferred to use “melt” as a generic texture term for “dissolvability”.

Heat burn was noted by consumers to be more of a taste sensation rather than texture. The terms used by US consumers were spicy, hot, real hot, hot-hot (for Spanish foods), flaming, lips burning, chili powder, and chili pepper. Indian consumers used peppery hot, spicy, and peppery tang; Spanish consumers used spicy (picante), spicy (*picosidad*), and spicy (*enchiloso*);

Chinese consumers used burning, spicy, and pungent. The terms spicy (picante) (used by both Spanish and US consumers), peppery hot (Indian consumers), and burning (Chinese consumers) were used as the final terms (Table 4.8).

A crunchy granola bar was used as a reference product for "particle amount". The terms generated were crumbly, grainy, and gritty (by US consumers); crisp, gritty, and crumbly (by Indian consumers); grainy (by Spanish consumers); and granular and crisp (by Chinese consumers). The final terms were grainy (by both Spanish- and English-speaking consumers), crumbly (by Indian consumers), and granular (by Chinese consumers) (Table 4.8).

Discussion

Consumers related texture with quality, freshness, taste, ease of handling, and good experience. Consumers had certain texture benchmark expectations for each snack food, which must be met for acceptance of that particular snack food. The consumer benchmark expectations were completely based on experiences from previous consumption of those snack foods. For example, a benchmark for chips (crisps) is that there must be a certain level of crispness without the chip being either limp or too hard, and the chip must shatter without being powdery or breaking into pieces with sharp edges. Consumers had positive and negative connotations with textures. Consumers considered snacks that are too hard, too floury (starchy), too gummy, or oily as negative textures that discourage them from eating or handling snacks. However, airy and crunchy (an indicator of freshness, good quality) are positive textures. For example, "good texture also tells us about the ingredients used in snack manufacturing, for example, the creaminess of an ice cream".

English speakers (US) used more vocabulary to define their understanding of snacks without naming food products. The non-English speakers used food product names to explain their concepts of snacks. The understating of snacks for non-English speakers were mainly context-based. For example, “potato chips, nuts, namkeen, crackers, candies” etc. Therefore, sensory studies of non-English speaking cultures conducted on direct English translation without any contextual backing might be misleading. Some authors (Blancher et al., 2008; Hunter & McEwan, 1998; O’Mahony & Alba, 1980; Son et al., 2012; Tu et al., 2007; Zannoni, 1997) emphasized (a) the importance of context in identifying consumers’ sensory descriptors, and (b) that translation of sensory descriptors among different languages are always not useful. Vlontzos et al. (2018), used a technique where a questionnaire was developed, translated into two languages, pre-tested in each language representing Eastern and Western European countries, and finally translated into the seven languages used in the test. In contrast, other researchers (Castro & Chambers IV, 2019; Chambers et al., 2016; Koppel, Suwonsichon, Chambers, & Chambers IV, 2018; Koppel et al., 2016) have used translation and back translation to the original language to confirm that the meaning was maintained.

Spanish, Hindi, and Mandarin do not have a specific term or terms for “snack” or “snack foods”. These languages do not have a direct translation similar to snack or snack foods, although there are context-specific words driven by time of day or eating occasions. The specific sensory terms provided by consumers were different, and the majority of consumers do not use these terms in daily life. However, Chinese and Indian consumers had one commonality in explaining texture that is something perceived by “hand-feel”. This assertion confirms the basic definition of sensory perception by one of the five senses.

We found that only English speakers explicitly mentioned texture as a factor they consider while making a snack food purchase. Speakers from other languages used terms that represented particular textures of specific foods, such as “a crispy apple, crunchy chips” etc. Languages such as Hindi and Mandarin do not have consumer-relevant terms for the overall concept of “texture”. No term, not even translation, for words like “texture” exist in Spanish, Hindi, or Mandarin. The use of the English term “texture” for Indian, Chinese, and Spanish consumers is meaningless. Conceptual differences across cultures resulted in consumers responding somewhat differently. The non-English language groups’ understanding of texture was based on their previous experiences and memories of certain foods, which they often used to support their comments (Muñoz & Civille, 1998). The consumer experiences and memories of certain food textures can be termed as “contextual experience”, which is one tool to overcome language and understanding barriers in non-English speaking cultures. One paper reported on a technique similar to what we used with the determination of attributes by trained panelists, translation, and back translation by experts, and then using representative products and the lexicon to produce a multi-lingual questionnaire for use in various countries (Monteiro et al., 2017).

These findings may apply to online surveys where sensory questions are presented without contextual references. Eertmans et al. (2006), reported the lack of completeness of food choice questionnaire models (FCQ) and their generalizability to a wide range of countries. The authors suggested that the meaning and connotation of the items may be strongly affected by culture. Steptoe, Pollard, and Wardle (1995), emphasized the need to relook and revise questionnaires investigating the perception of consumers from different cultures to include items related to the main factors of their food choices.

All groups had experienced multi-textured snacks before, and everyone in these groups indicated that they enjoyed such snacks. Consumers across cultures preferred to mix foods for balancing texture, flavor, and taste.

A clear association was observed for snacking occasions with specific textures. Mostly, consumers prefer to eat snacks "at home while watching movies, lying down, resting, convenience, relaxing, passing time, studying, when they see snacks at home that they like, do not want to share with others, and do not want to look bad in office". Phan and Chambers IV (2016b), also reported snacking as to be a more personal event. All of the activities mentioned above are convenient and energy-charging snacking. A US woman consumer mentioned a special category, "fuel texture", which helps "to gain energy from foods like pretzels or jellybeans, but not heavy or thick-textured foods". Other authors also defined snacks as energy-dense food (Johnson & Anderson, 2010), and consumers reported to eat snacks to fulfill energy needs (Phan & Chambers IV, 2016a).

The majority of consumers start their day with soft-textured and sweet-tasting snacks. Indian consumers indicated "culture" as the primary reason to eat soft-textured, less savory, and natural foods early in the day. US consumers eat soft, less crunchy, and less savory snacks for soothing experiences. As the day progresses, consumers tend to move towards crunchy textures and savory flavors or indulgent snacks (ice cream for the end of the day when stressed). This is similar to other findings (Phan & Chambers IV, 2016a; 2016b). Some emotions were related to snack food textures, although this would need to be confirmed by larger studies. When sad, for example, women prefer to eat soft-textured and sweet-tasting snacks, whereas men tend to eat savory and crunchy snacks when they are angry. Some men commented that taking a snack break when stressed would help to release stress and gain focus.

Results showed wide-ranging perceptions, understandings, preferences, and liking of several textures across cultures. The non-English speakers frequently used taste and aroma descriptors to describe snacks, and texture was seldom mentioned, although their descriptions of food they eat as snacks clearly showed variation in texture. Also, its relevance was demonstrated by presenting consumers with food samples. Texture is a strong driver of food liking and aversion, along with flavor (Scott & Downey, 2007). Our texture theme discussion results suggest that consumers (individuals) bring to each food a certain texture expectation. If that expectation is met, then there is less focus on texture. If the expectation is not met, then food is rejected. Our findings on consumer texture expectations of foods are in agreement with Engelen and de Wijk (2012). This expectation of certain texture varies by individual. The variation could be due to a function of consumer prior expectations and experiences for specific foods.

We conclude from these focus groups that the consumers we tested with native languages other than English seem to be less aware of terms similar to those used in English for food texture than English-speaking consumers. Besides, the direct translation of texture terms from English into other languages could lead to misleading identifications, if not backed by specific foods for textural contexts. The vocabulary used by non-English consumers to describe sensory perceptions was different among cultures and was product-specific. Yoshikawa, Nishimaru, Tashiro, and Yoshida, (1970), reported that Japanese consumers were more sensitive to subtle variations in texture and had a much richer texture vocabulary than American consumers. Similar, differences in how consumers in different cultures describe sensory attributes have been reported by numerous authors (Blancher et al., 2007; Cherdchu, Chambers IV, & Suwonsichon, 2013; O'Mahony & Alba, 1980; Zannoni, 1997).

Although some similarities exist with consumers, no specific consistency was observed in understanding and usage of texture terms among cultures. Hindi speakers used the term kurkure to describe both crispy and crunchy experiences, but the term has no direct English translation. Consumers used multiple terms to describe a single sensory perception and vice versa. Spanish and Mandarin speakers used grainy and granular to describe roughness of the surface, particle amount, and powdery. Similarly, the French term *doux*, which means smoothness and sweetness, has no direct translation into English or Spanish (Tournier et al., 2007). Consumers found English terms as too technical and confusing, and the direct translations were not always commonly used in a food context. The use of definitions helped consumers in understanding the attributes, but this creates a problem when marketing specific texture concepts to consumers. When marketing to consumers, it is important that the consumer can understand the term. For words where the meaning is not completely obvious, the use of context or other marketing tactics must clearly demonstrate the meaning of the term. Consumers demonstrated similarities in some texture terms, but their conceptual meanings were completely different. For example, the speakers of Hindi and English described "oily" as a surface property of snacks, whereas Spanish speakers used both oily and greasy interchangeably. Spanish speakers related greasy to animal-based products like meat and measured it as a whole (overall).

The results show the necessity to focus primarily on stimuli rather than words when dealing with consumers. For example, English speakers used juiciness to describe the moistness of jackfruit but stated that the term might be different if the product was different. A similar trend was noticed for smoothness, roughness of surface, and cohesiveness among English speakers. The different conceptual understating for texture terms was present in all four cultures. The direct translation of texture terms isolated from any context could be problematic with

consumers (Zannoni, 1997). The selection of the context product should be carefully considered for the development of sensory vocabularies with consumers (Son et al., 2012).

We conclude that researchers must avoid direct translation of English words, as they are presented out of context and could potentially lead to misunderstanding, inconsistencies, and confusion. It may not be feasible to develop a comprehensive and complete polyglot list of texture terms across cultures. However, after careful investigation, a limited and common contextual texture vocabulary is possible across languages.

Limitations

The study results are based on the inputs of a small number of specifically recruited participants, and caution must be considered in generalizing the findings to a larger population. However, it may be completely logical to infer from the theme of this study that consumer vocabulary differs greatly from sensory scientist vocabulary. A simple translation of sensory terms in consumer studies does not reflect true responses. The consumer vocabulary generated in this study can only be used for textural context, not for flavor, aroma, or appearance.

Conclusion

The accelerated pace of globalization has increased the application of cross-cultural sensory and consumer research (Meiselman, 2013). The rapid growth of the internet will continue to foster new opportunities from multiple countries at a much faster, easier, and cheaper rate (Slater & Yani-de-Soriano, 2010). Cross-cultural study models based on the assumption of conceptual and linguistic equivalence are problematic. The validity of such models should be

tested thoroughly before application. Researchers should avoid imposing constructs and models developed in one culture to other cultures.

Consumers used numerous terms to describe the textural properties of various snack food products. Sometimes, the terms were quite consistent across cultures, suggesting an underlying understanding of the concept. Sometimes, the use of terms was mainly contextual-based, i.e., food or snacks versus other products (e.g., the term for "hardness/firmness" in Chinese depends on whether the person is talking about the hardness of steel or hardness of foods), and certain terms were product-specific, as noted. Texture terms developed by trained descriptive panels are easy to translate at a scientific level to produce consistent information across panels but much too technical for use to describe the products to consumers. We found divergent understanding and usage of English terms in each culture. When conducting consumer studies or communicating the benefits of products to consumers, it is essential to pre-test the terminology to ensure that the meaning is conveyed appropriately.

Our results conclude that a simple translation of sensory terms without context may be problematic in consumer studies. We provide a method where linguistic differences could be minimized if backed by the contextual perception of sensory terms. The direct translation of descriptors from one language to another does not mean that they are intercepted as conveying the same meaning in both languages. The vocabulary used by consumers to describe sensory characteristics depends on context, culture, and previous exposure to different products. Some of the terminologies are specific to products and may change when the product characteristics or product itself change. Hence, it is important to investigate the cultural mindset and its implications on food testing.

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Chapter 5 - Generating New Snack Food Texture Ideas Using Sensory and Consumer Research Tools: A Case Study of the Japanese and South Korean Snack Food Market

Abstract

Food companies spend a large amount of money and time to explore markets and consumer trends for ideation. Finding new opportunities in food product development is a challenging assignment. A majority of new products launched in the market are either copy of existing concepts or line extensions. This study demonstrates how the global marketplace can be used for generating new texture concepts for snack foods. One hundred twenty-three prepacked snack foods from South Korea (SK) and ninety-five from Japan (JP) were purchased for this study. Projective mapping (PM) was used to sort snacks on a 2-dimensional map (texture and flavor). Snacks were grouped on similarities and dissimilarities by sensory scientists. PM results showed, 64.7% (JP) and 75.8% (SK) snacks were considered as hard textures, ranging from moderate to extremely hard. Sixty-five percent of JP snacks were savory, whereas 59% of SK snacks had a sweet flavor. The PM 2-dimensional map was used to find white spaces in the marketplace. Thirty-two diversified snacks from each country were screened and profiled using descriptive sensory analysis by trained panelists. Attributes such as sustained fracturability, sustained crispness, initial crispness, and fracturability were the main sensory texture characteristics of snacks. Results showed, how descriptive analysis results can be used as initial sensory specifications to develop prototypes. Prototype refinement can be performed by doing multiple developmental iterations and consumer testing. The study showed how white spaces are

potential opportunities where new products can be positioned to capture market space. Practical Application: The methodology produced in this study can be used by food product developers to explore new opportunities from the global marketplace.

Keywords: new product development, texture, snacks, ideation, white space, market

Introduction

Food companies need to continue to innovate products to sustain market leadership. Current markets are overloaded with product offerings; thus, the challenge is to innovate new products and update existing products to gain new consumers (Fuller, 2016). The innovation of new products has a positive effect on the economic growth of companies (Guiné, Ramalhosa, & Valente, 2016). Innovation helps to develop new market segments, expand current market segments and product portfolio, positive image building, and bring new consumers to food companies (Santoro, Vrontis, & Pastore, 2017a). The rapid changes in technology, market trends, and consumer expectations (for example, specific dietary, health, environmental sustainability, and packaging) is keeping the food industry under tremendous pressure to spend large funds in new food product development (NFPD) to either increase profits or survive (Bresciani, 2017; Della Corte, Del Gaudio, & Sepe, 2018; Merieux NutriSciences & Lascom, 2018; Santoro et al., 2017a).

Broadly new product development (NPD) consists of four stages such as opportunity identification, development, optimization, and launch (Fuller, 2016; Stewart-Knox, Parr, Bunting, & Mitchell, 2003). The success of NFPD is directly related to several factors: 1) a unique product idea or opportunity, 2) large-scale predevelopment research, 3) superior knowledge of the market, and 4) a cross-functional team (management, scientist, marketing and

launch) collaboration (Guiné et al., 2016; Stewart-Knox et al., 2003). The combination of the first three factors truly determines the quality of opportunity identification. The developers at this stage unearth new areas of opportunities to fulfill the unmet needs of consumers (Banović, Krystallis, Guerrero, & Reinders, 2016; De Pelsmaeker, Gellynck, Delbaere, Declercq, & Dewettinck, 2015). Food companies use three primary sources for new product idea generation i.e. marketplace, within the company, and environment outside the marketplace (Fuller, 2016). Global markets can be excellent places to explore new product ideas (Murley et al., 2020).

Globalization has integrated regions, companies, markets, and societies from different countries and continents. It has removed barriers for food companies to explore foreign markets for product innovation and ideas generation (Murley et al., 2020). Food companies have successfully developed global food products by generating ideas from foreign countries. For example, beverages (e.g. Coca-Cola and Pepsi), tea (e.g. Lipton), coffee (e.g. Nescafe), cigarettes (e.g. Marlboro), or chewing gums (e.g. Wrigley). The inclusion of international markets in NPD for generating new product opportunities offers a great diversity of products, customers, and consumers. Food companies use data (consumer involvement, food trends, and environmental factors) most frequently in the opportunity identification and product design stage of NPD (Horvat, Granato, Fogliano, & Luning, 2019). Thus, the researchers and food companies need to find both novel and quality opportunities from the market (Johnson, 2018). These gaps (white spaces) could be potential unmet consumer needs that can be filled by developing products for identified consumer needs (Johnson, 2018).

The main task of NPD is to develop products that deliver desired benefits to consumers. Developing consumer-centric products involves great risks and failures (Jagtap & Duong, 2019; Guiné et al., 2016; Santoro et al., 2017a). Fuller (2016), identified two main early-stage risk

components in NPD: a) wrong investments in new products that would later fail in the market, and b) overlooking of a potentially successful new product, termed an opportunity loss. Dijksterhuis (2016), explained five factors for a high number of new product failures: 1) uncoordinated efforts of many different functions working on different aspects of consumer and product development, 2) lack of understanding of consumer behavior, 3) usage of outdated research models, 4) lack in seriousness towards behavioral sciences s, and 5) high reliability on the notion that good quality products automatically lead to high sales. Even after producing a large amount of literature on NPD, the failure rate is still very high. Between 2011 and 2013, 76% of the newly launched consumer goods did not survive one year on the market (Nielson, 2014), 45% of products remained on the market for less than half a year (Dijksterhuis, 2016), 75% to 95% of newly developed food and beverage products failed within one year of launch (Kemp & Hort, 2015).

To increase the odds of NPD success many researchers recognized the need to consider consumer behavior and choice-based ideas from external global markets (Asioli et al., 2017; Cooper, 2019; Costa & Jongen, 2006; De Pelsmaeker et al., 2015; Grujić, Odžaković, & Ciganović, 2014; Ryynänen & Hakatie, 2014; Simeone & Marotta, 2010). Sensory science and consumer research provide techniques to identify white spaces in NPD, support research and development, and contribute to minimizing the decision uncertainty (Talavera & Chambers, 2017).

So far researchers have identified early stages in NPD as the most important activities that describe both product success and failure (Fuller, 2016; MacFie, 2007). The early stages also were termed as the “fuzzy front-end of NPD” for reasons such as ill-defined processes, ambiguities, confusion, and ad-hoc decisions (Cooper, 2019; MacFie, 2007). Early involvement

of sensory and consumer research in NPD is recommended as an important success factor (Crofton & Scannell, 2020; Cuny, Petit, & Allain, 2020; Guiné et al., 2016; Talavera & Chambers, 2017). Thus, there is a need for a structured sensory science-based framework in the early stages of NPD for idea generation (Santoro et al., 2017a).

Projective Mapping (PM) or Napping, a sensory method, is used as a tool to categorize products and discover white spaces among product groups. In PM, assessors are asked to position the products (samples) on a two-dimensional space according to similarities and differences of product characteristics (Aguiar, Melo, & de Lacerda de Oliveira, 2019; Cartier et al., 2006; Pagès, Cadoret, & Lê, 2010; Risvik, McEwan, & Rødbotten, 1997; Valentin, Cholet, Nestrud, & Abdi, 2018). PM has been described as a natural, holistic, and spontaneous way for people to describe products. It has been successfully applied to various food products. For example, oranges juices (Zhang, Lusk, Mirosa, & Oey, 2016), red sufu (He & Chung, 2019), wine (Brand et al., 2018), pork (González-Mohíno, Antequera, Pérez-Palacios, & Ventanas, 2019), and pea and sweetcorn (Cliceri et al., 2017). Moreover, PM also was used to study the influence of extrinsic factors on consumer's perception of foods. For example, packaging (Thomas & Chambault, 2016), smoked bacon (Saldaña et al., 2020), fermented dairy products (Soares et al., 2017), and chicken meat (Katiyo, Coorey, Buys, & Kock, 2020). Over the years, PM or Napping is proven to be efficient, timely, and cost-effective, and is considered as a rapid descriptive method. The application of PM as a sensory tool for rapid product categorization and characterization for a large number of products is common (Mayhew, Schmidt, & Lee, 2016).

The early stage of NPD includes brainstorming and ideation by looking at consumer and market trends. To develop new concepts, researchers and food companies obtain information from competitive food products in the market. The descriptive sensory analysis gives an edge to

the researcher in a better understanding of competitive products, and of the marketplace where the potential new product will be placed (Valentin, Cholet, Nestrud, & Abdi, 2018). Descriptive sensory analysis is another classic sensory method used in NPD to profile products on all of its perceived sensory properties (Lawless & Heymann, 2013; Valentin, Cholet, Nestrud, & Abdi, 2018). It involves discrimination and description of both quantitative and qualitative sensory attributes by trained sensory panelists (Chambers, 2018; Valentin, Cholet, Nestrud, & Abdi, 2018). The descriptive analysis offers various applications such as help in understanding the relationship between sensory and instrumental measurements, the relationship between descriptive sensory and consumer preference measurements, product optimization and validation, product profiling, quality control (product comparison), sensory mapping and product matching, shelf life and packaging effect, etc. (Chambers, 2019; Chambers, 2018; Luchsinger et al., 1996; Muñoz & Chambers, 1993; Valentin, Cholet, Nestrud, & Abdi, 2018).

Descriptive profiling methods have been used to profile several products such as bread (Tran, James, Chambers, Koppel, & Chambers, 2019), fresh and dried mushrooms (Chun, Chambers, & Han, 2020), snack and snacks like foods (Kumar & Chambers, 2019), coffee (Chambers et al., 2016), soy sauce (Cherdchu, Chambers, & Suwonsichon, 2013), potato varieties (Sharma et al., 2020), mate tea (Godoy, Chambers, & Yang, 2020), ground beef (Laird, Miller, Kerth, & Chambers, 2017), smoked food products (Jaffe, Wang, & Chambers, 2017), and many others. Many sensory studies combined descriptive analysis results with consumer hedonics to determine why food products are liked by consumers (Crofton & Scannell, 2020; Culbert, Ristic, Ovington, Saliba, & Wilkinson, 2017; Lee et al., 2010). The combination also helps to identify consumer segments and their specific sensory preferences for certain product

characteristics, and also give insight into possible gaps in the marketplace (Bowen, Blake, Tureček, & Amyotte, 2019; Sharma, Jayanty, Chambers, & Talavera, 2020).

Descriptive profiling of foods help to identify the main sensory attributes of food products which can be manipulated: a) to create a profile of desirable sensory characteristics to help in the development, and b) to define early-stage specifications for a new product (Valentin, Cholet, Nestrud, & Abdi, 2018). The key sensory attributes that are identified help to distinguish the importance of "tangible" product characteristics that form the basis of technical product specifications (Cooper, 2019; Crofton & Scannell, 2020). Sensory characteristics are measurable and manipulatable, and therefore, characteristics obtained from a wide range of products can encourage the researcher to create a product with different and multiple sensory profiles (Valentin, Cholet, Nestrud, & Abdi, 2018; van Kleef, van Trijp, & Luning, 2005).

The perceived sensory characteristics either intrinsic or extrinsic are what consumer use to determine a product's benefits (e.g. crispiness of potato chips (Salvador, Varela, Sanz, & Fiszman, 2009), creaminess in dairy products (Antmann, Ares, Salvador, Varela, & Fiszman, 2011; Frøst & Janhøj, 2007), "health, good taste and convenience" (Asioli et al., 2017). Principal components analysis (PCA) plots generated on descriptive profiling data provide an opportunity to access the positioning and comparison of products in the market space (Valentin, Cholet, Nestrud, & Abdi, 2018). Using PCA plots, several white spaces (the open space between products) and product clusters can be identified with their identifying main sensory attributes (Valentin, Cholet, Nestrud, & Abdi, 2018). Those sensory attributes are reported to be directly experienced by consumers to assess products' evaluation and significantly influence consumer product appraisal (De Pelsmaeker, Dewettinck, & Gellynck, 2013). The "white spaces" suggest areas where new products could be developed to meet unmet needs (Adriana et al., 2019; Corley,

2017; Murley et al., 2020; Thompson, 2019). Of course, the presence of white space does not necessarily mean that a) products do not exist in that space but only that they were not part of the study, b) just because a product that is made to fill that space the product will succeed, either because of marketing or product flaws or that the reason space exists maybe that no "good" products can exist in that space, or 3) it is impossible to develop a product that fits that white space, meaning that products may not exist because the technology is not available to make such products.

A goal of this project was to highlight one strategic framework to find white spaces in the marketplace and then develop new snack texture concepts to fit the sensory concepts identified as white spaces. The specific objectives were to a) find the new texture and flavor gaps in several large-scale markets, b) identify key sensory texture characteristics of the Japanese (JP) and South Korean (SK) snacks foods, and c) to demonstrate how unfamiliar marketplaces can be used in NPD for ideation. This study is a continuation and expansion of earlier work (Murley et al., 2020).

Materials & methods

Materials

One hundred twenty-three packaged snacks from Seoul and Busan, SK, and ninety-five packaged snacks from Kyoto, JP were purchased in-country and shipped to the Center for Sensory Analysis and Consumer Behavior, Kansas State University (KSU), United States (US). Confectionery and confectionery snack products were excluded from this study. Trained sensory scientists and product developers from the US, China, India, and SK purchased snacks for this

study, following a product procurement strategy recommended by Murley (Murley et al., 2020). Package guidelines were followed for storage and handling.

Table 5.1.

List of the JP snacks screened for descriptive profiling.

Serial Numbers	Snacks	Manufacturer
1	3D corn bugle	--
2	Bourbon lubera rolls	Bourbon
3	Nagewa potato rings	family mart collection
4	Sesame wafer rolls	--
5	Seaweed coated crackers	--
6	Freeze-dried strawberries	Fukumi
7	Cheese-filled crackers	family mart collection
8	Plum meat snack	Seven eleven
9	Baby star ramen	Oyatsu Company
10	Strawberry filled balls	Seven eleven
11	Freeze-dried ice-cream cone	Glico
12	Cheese-filled rolls	Kirara
13	Squid chips	--
14	Unbranded rice crisps	--
15	Pasta shaped snack	Seven eleven
16	CALBEE Potato Sticks	Calbee
17	Pocky chocolate sticks	Glico
18	Pea crisps	Calbee
19	Sweet potato sticks	family mart collection
20	Unbranded seaweed crackers	--
21	Riska corn potage puffs	Riska
22	Bourbon rice crackers with cheese	Bourbon
23	Zaku curry filled snacks	--
24	Kameda nut clusters	Kameda
25	Renkon lotus root chips	Sokan group
26	Morianga bites	Morianga
27	Steamed plum seaweed	Family mart
28	Edamame crisps	seven eleven
29	Denroku crispy coated nuts	Denroku
30	Mayonnaise potato wedges	seven eleven
31	Soybean FL coated peanuts	Nuts.dom
32	Peanut coated cotton candy balls	--
33	Lay’s classic PC	Frito-Lay's
34	Tostitos original	Frito-Lay's
35	Stacy’s Pita original	Frito-Lay's

Table 5.2.

List of the SK snacks screened for descriptive profiling.

Serial Numbers	Snacks	Manufacturer
1	Orion turtle chips (Himalayan salt)	Orion
2	Orion Peanut Balls	Orion
3	Orion original potato chip	Orion
4	Taco chips	Lotte
5	Peanut crunchy bar	Koon brother SDN BHD
6	Pulmuone Crispy seaweed chips	Pulmuone
7	Deasang sweet potato sticks	Deasang
8	Soy sauce seaweed chips	Tempura Chips
9	Momali crown snack	www.crown.co.kr
10	HAITAI Rice Sticks	Haitai Calbee
11	Daiso orion potato chips	Orion
12	French dessert chip	SSG.COM
13	HEYROO Injeolmi snack	Heyroo
14	HEYROO Noodle snack	Heyroo
15	HEYROO sweet popcorn	Heyroo
16	HEYROO oranda clusters	Heyroo
17	Prawn snack	--
18	Laver Almond	Tom's farm
19	Mushroom snack	No information
20	KIMS crispy roasted laver chips	Dongwon Yangban
21	Seed filled cookie	Lotte
22	Seaweed rolls	Only price 2000
23	Squid rice balls	--
24	Roasted lotus seeds	Daily super nuts
25	Baby crab crunch	Farm & Dale
26	Soft somjulmi snack	Peacock
27	Seaweed crisps	Cheiljedang
28	Honey butter cashew-nut	Tom's Farm 1982
29	Yogurt cashew-nut	Murgerbon
30	Tofu snack	Hav'eat
31	NongHyup grain crisps	NongHyup
32	Chicken shaped snack	Lotte
33	Lay’s classic pc	Frito-Lay's
34	Stacy’s Pita	Frito-Lay's
35	Tostitos original	Frito-Lay's

Methods

Snacks data bank

Information related to each snack-type such as product name, product description, manufacturer, package size, number of packages, ingredient list, and pictures (front and back) were collected to develop a snack data bank for each country (See the supplementary files JapaneseSnacksDataBank.xlsx and SouthKoreanSnacksDataBank.xlsx). The collected data helped in product identification, product cataloging, and, most important, in knowledge generation about various snack foods such as packaging data and ingredient and nutritional data, when those could be determined from the pack. Several authors concluded that knowledge generation and its proper integration with organizational learning are important aspects of NPD (Jagtap & Duong, 2019; Santoro, Vrontis, & Pastore, 2017b).

Projective mapping

PM or Napping was used in its original concept as described by its authors with few modifications (Jérŏme Pagès, 2005; Risvik et al., 1997). The modalities used for PM were texture and flavor. Snack foods were sorted for similarities and dissimilarities on the above-mentioned modalities with the panel determining what aspects were key to placement. The snacks were tasted blind with only a two-digit code and sorted into groups by six sensory scientists with experience in snack food evaluation.

Snacks sensory description

After sorting the entire set of products, 32 snacks from each country were screened for descriptive sensory profiling. The parameters used to screen snacks were diversified and novel

textures, new ingredients, and novel concepts. The screened snack foods are listed in Table 5.1 (for JP) and Table 5.2 (for SK). Besides, three Frito-Lay's snacks (Stacy's Pita original, Lay's classic potato chips (PC) and Tostitos original corn chips) widely available around the world also were included in the test to provide a "reference" set of products that could help anchor the maps and be used by researchers to help better understand similarities and differences shown on the map, particularly since many would never have seen or tasted the products tested.

Descriptive profiling

Consensus methodology was used to develop sensory attributes, definitions, and references (Chambers IV, 2018). Panelists and the sensory analysts determined attributes by consensus for further rating. The final list of attributes was kept consistent for both JP and SK snacks. The snacks were profiled for flavor, amplitude, appearance, and texture attributes. However, because flavors of many snack foods can be changed easily based on consumer preferences and many of the snacks tested come in many different flavors, only appearance and texture attribute data were considered in this analysis and shown in this paper. The JP and SK snacks flavor principal component maps are presented in the Appendix-A (Figure A.6 and Figure A.7). Similar methodology has been used in other recent studies for sensory profiling of several foods (Belisle, Adhikari, Chavez, & Phan, 2017; Chun et al., 2020; Godoy et al., 2020; Griffin, Dean, & Drake, 2017; Kumar & Chambers, 2019; Sharma et al., 2020; Tran et al., 2019).

Sample preparation

The snacks used were all ready to eat and needed no preparation; they were served as is. The samples were blind coded with three-digit codes, served in 8 oz (Styrofoam) and 3.25 oz

(plastic) cups (based on the size and shape of the snacks) covered with a lid. One sample at a time was served to panelists in a randomized order. Panelists cleaned their palates between samples with freshly cut cucumbers, mozzarella cheese (manufactured by Kroger, Cincinnati, OH), hot water, and a washcloth for cleaning of lips and hands.

Panelists

For the descriptive analysis, six highly trained sensory panelists were used for this study. Each panelist had more than 120 hours of training in descriptive panel training and more than 1000hr of descriptive testing experience with various types of foods and beverages, including extensive testing on different snack-type products. Panelist worked on evaluation techniques for appearance, texture, and flavor perception. The panelist received 9hr of additional orientation with both the JP and the SK snacks. The number of highly trained panelist participated in this study has been reported sufficient to differentiate samples in descriptive analysis and have been used in other recent studies.

Data analysis

Correlation type principal component analysis (PCA) and agglomerative hierarchical clustering (AHC) was performed on the sensory descriptive data using data analysis software XLSTAT 2019.3.2.61545. To avoid data redundancy attributes correlations were analyzed by data analytical software R - studio version 4.0.0 (R Foundation for Statistical Computing, Vienna, Austria; https://www.R-project.org/).

Results

The sequential use of sensory tools produced information on the main sensory descriptors, the snacks market categorization based on sensory descriptors, existing snacks market space, and white spaces (potential opportunities). All the above-mentioned information was produced by the PM plots and subsequent PCA mapping along with the original data. The information can be used by a snack manufacturer to see a) an overview of snack markets (based on sensory parameters), b) identify major flavors, textures, and possible trends, c) learn about competitor's product positioning, d) develop new concepts to bring to further sensory (including consumer) research, and e) enhance their product snack portfolio. The results explain how this information can be generated using JP and SK snacks as examples.

Projective mapping

The representative maps of PM results are presented in Figure 5.1 (for JP) and Figure 5.2 (for SK). The snacks are coded with 2-digit numbers for representation purposes.

Japanese snacks

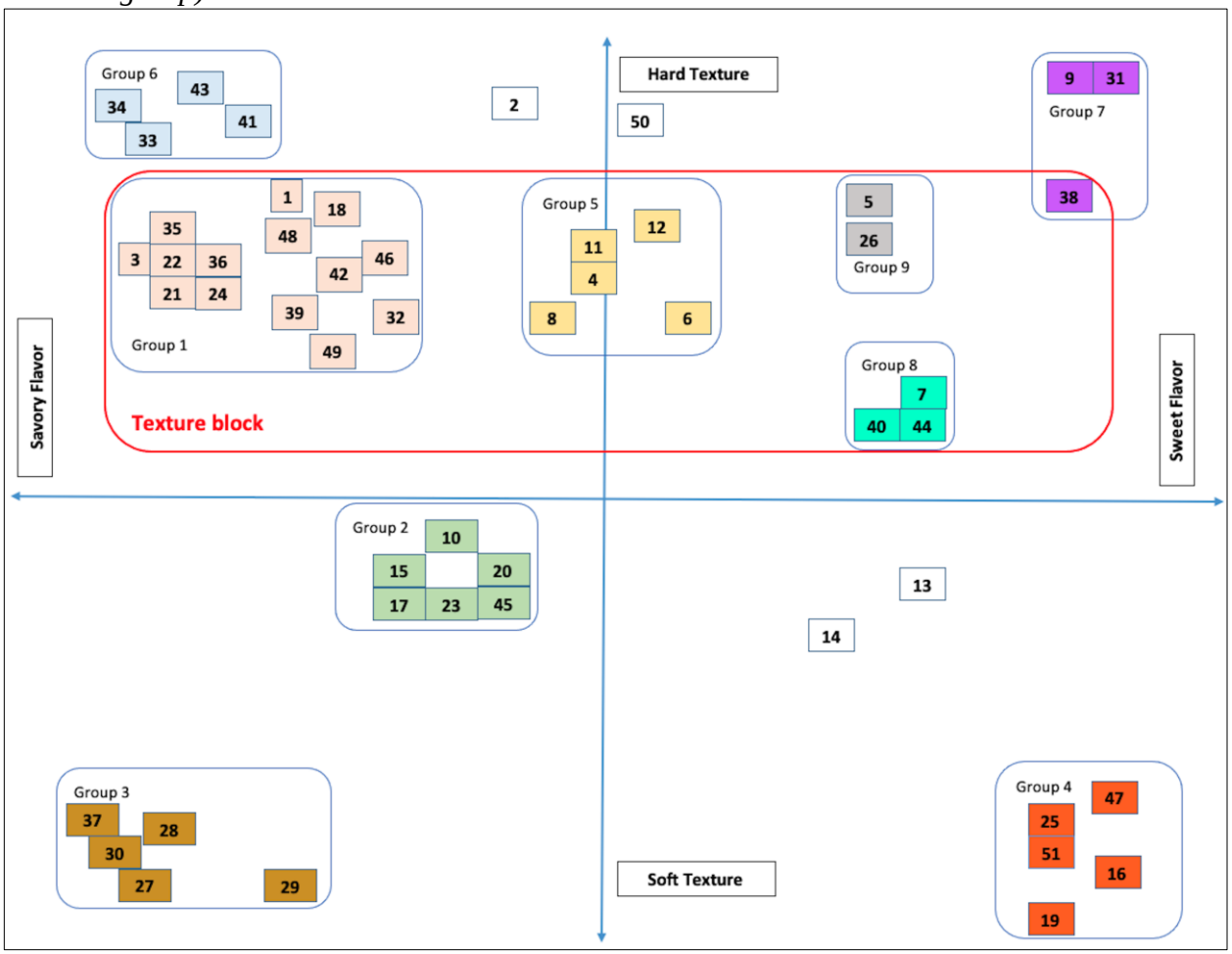
Fifty-one snacks with a variety of texture profiles were sorted into nine groups (Figure 5.1). The PM was primarily focused on the textural dimension from hard to a soft texture. Because the snacks were seasoned with different flavors, sorting them based on flavor was much too difficult for a 2-dimensional space. The only flavor dimension that was considered was savory to sweet. All the products are analyzed visually, in the hand (tactile hand feel), and tested orally (for texture and flavor) by sensory scientists.

Out of 51 snacks, 33 snacks (64.71%) were considered as hard bite textures, ranging from moderately to extremely hard. The main texture descriptors were crispiness, crunchiness, sustained crispiness, sustained crunchiness, and hardness. The largest snacks group (1) had 14 products (for example, crackers, wafers, puffs, and rolls), representing 27.45% of total snacks. Similarly, group-6 had 4 snacks, grouped for extremely hard texture and strong savory flavor. Group-2 had six snacks (for example, corn trumpets, corn puffs, squid crackers, shrimp crackers, cheese-filled sticks, and unbranded grain crackers), representing a soft-bite texture with mild savory flavor category. A complete list of the JP snack food groups is presented in Table 5.3.

Group-1 represents the largest portion of JP snack food from the selected snack pool. The results suggest that most JP snack foods are hard to bite texture snacks seasoned with various flavors such as savory, bland, and plain salt. Group-1 and 5, differed on flavor intensities but were similar on textural dimensions. Collectively, snacks from group 1, 5,7, 8, 9 formed a large hard texture block (highlighted with red border), Figure 5.1. The hard texture block accounted for 49% of the overall JP snacks market space. Hard texture snacks appeared to dominate the JP snacks market, which has a large number of existing products. The possible explanations could be a) JP consumers prefer hard texture (crunchy and crispy) snacks, b) our research team inadvertently collected more hard texture snacks and therefore limited the product pool, or c) it is a true representative of the JP snacks market. Hence, for a new product developer understanding the texture dimensions of JP snacks could be a potential framework or area of interest to explore either as copycat products (harder textures) or to create new textures (e.g. at the softer texture end of the spectrum). Of course, another niche area could be bringing new flavors into the existing texture spectrum where flavors may be lacking.

Figure 5.1.

Projective Mapping plot of fifty-one Japanese snacks showing nine product groupings and outlying products (Snacks are coded with 2-digit numbers and snacks with the same color are in the same group).



Thirty-three snacks (65%) were savory, including snacks seasoned only with plain salt. Other flavors (for example, seafood, seaweed, prawns, squid, crab, and fish) also were present in that grouping. Savory flavored snacks occupy the largest space in the JP snack market. Thus, for a product developer a savory flavor could be an easy carry-over from one snack-type to another, but also positions the product against a larger competitive set.

The broad range of textures and flavor, some of which were not found in tests conducted on snacks from other countries represent a new opportunity for manufacturers to transfer ideas from one country and culture to another. Taking ideas for new products from countries with a plethora of products often is an easy way to create new products for countries where existing products may be in more limited supply or exist in fewer sensory segments.

The gaps between the product grouping are the white spaces where no products were found to exist. Those empty spaces are potentially unexplored opportunities in the JP snack market and perhaps in other markets. The bottom half of the plot in Figure 5.1, represents soft texture snacks space. More white space is available in soft texture snacks over hard texture snacks. This may be because a) a smaller number of products are in the soft texture product pool (a potential opportunity), or b) the JP consumer doesn't prefer soft texture snacks. If soft texture snacks are not as popular in various countries, they may not be a real opportunity. For JP, further investigation of that snack segment is required in terms of consumer studies. For other countries, the opportunity for new snack development in the sweet category needs to be considered and further research with potential new products may be warranted. Besides, spaces that are not filled with many products also may be considered "white" spaces. For example, the space between group-1 and group-7 has only 5 products (i.e., group-5). Considering the number of products that exist in other areas of the map, more products could be developed to fill and position in this space.

The plot can be divided into four quadrants (Figure 5.1). The first quadrant (Q1) represents hard texture snacks with a sweet flavor, the second quadrant (Q2) is hard texture snacks with savory flavor, the third quadrant (Q3) is soft texture snacks with savory flavor, and the fourth quadrant (Q4) is soft texture snacks with sweet flavor (Figure 5.1). Each quadrant

produces different information. For example, Q4 and Q1 have the least number of snacks and more white spaces. A product developer can develop a wide range of new textures (hard to soft) with sweet flavors. The market space offered in these two quadrants is quite large. Similarly, other quadrants either individually or in combination with other quadrants can be used to frame initial product concepts.

From a broader perspective, the plot can be divided into two halves. If a product developer is interested in new snack flavors, they can divide the plot on the vertical axis (Figure 5.1). For example, the left half of this plot, vertically divided, characterizes the savory flavor market space ranging from hard to a soft texture. The right half of the plot represents the sweeter flavors market space with the same texture range from hard to soft. If the plot is divided into two halves on the horizontal axis, the top half contains all hard texture snacks with both sweet and savory flavors. The bottom half of the plot comprises all softer texture snacks spreading across savory and sweet flavor. There is a wide range of options that could be explored in soft texture with savory flavors. For example, there was no "soft texture, non-seafood" savory snack found in this study. Only 18 snacks were of soft texture, mainly group-3 and 4. Group-3 consists of fish or seafood flavored soft chewy snack loaded with strong sour-savory flavors. And, group-4 snacks were soft textured sweet snacks but not chewy. Considerable white space is available across the savory-sweet flavor dimension with a soft texture profile that may help the developer in identifying additional products for the market.

One issue that must be considered is that many softer textured snacks were found when conducting the initial product search. However, many of those were in the form of freshly prepared "street snacks" such as fresh seafood or egg products that could not be sold in a shelf-stable manner given current technologies. Those products may be considered as inspiration for

manufactured shelf-stable products but also represent a competitor that is not directly accounted for in this research.

Table 5.3.

Groups identified in the projective mapping of the JP snacks. Group number, number of snacks in each group, snack-type, flavor, and snack names.

Groups	Number of snacks	Texture and flavor	Snacks type and flavor	Snacks
Group-1	14	Moderate hard bite texture with mild to a strong savory flavor	Type: crackers, wafers, rolls, puffs Flavor: cheese, squid, savory	Ramen noodle shaped snack, shrimp chips, seaweed crackers, squid snack, rice crackers, coated rice crackers, rice crackers, pasta shape fried snack, Ginseng root chips, cheese-filled rolls
Group-2	6	Soft bite texture with a low savory flavor	Type: crackers, wafers, rolls, puffs Flavor: cheese, sweet, sesame	3D corn bugles, corn puffs, squid crackers, shrimp crackers, cheese-filled sticks, unbranded rice crackers
Group-3	5	Extremely soft-chewy with strong savory flavor	Type: seafood and meat Flavor: seafood, fish	Dried squid, plum meat, dried fish, cheese with cod, spicy grilled kamaboko fish
Group-4	5	Extremely soft with a strong sweet flavor	Type: cake, freeze dried, puffed balls Flavor: strawberry, chocolate, sweet	Baumkuchen cake, freeze-dried strawberries, strawberry-filled puffed balls, freeze-dried strawberry ice-cream cone, chocolate sweet treats
Group-5	5	Moderate hard bite with a bland taste	Type: sticks, chips, crisps Flavor: bland, plain, salt	Fried rice crackers, potato rings, pea sticks, rice crackers, fried rice crackers with peanuts
Group-6	4	Extremely hard bite with a very strong savory flavor	Type: hard grain crackers Flavor: seaweed	Seaweed crackers, baby star ramen noodle snack, unbranded fried snack, unbranded crackers
Group-7	3	Extremely hard bite with a strong sweet flavor	Type: sticks, crackers Flavor: sweet	Unbranded baked crackers, soybean coated walnuts, sweet potato sticks

Groups	Number of snacks	Texture and flavor	Snacks type and flavor	Snacks
Group-8	3	Moderate hard bite with a mild sweet flavor	Type: puffs, crackers, Flavor: sweet, chocolate	Chocolate coated baked rice puffs, sesame wafer rolls, sugar granules coated crackers
Group-9	2	Moderate soft bite with a mild sweet flavor	Type: sticks Flavor: sweet, chocolate, sesame	Rice crackers with sesame seeds, Pocky chocolate sticks,

South Korean snacks

A total of sixty-six pre-packed snacks were sorted on the texture (hard to soft) and flavor dimensions (savory to sweet). Nine main groups were formed (Figure 5.2). Group-6 had eleven moderately hard texture snacks with a mild sweet flavor, group-3 had ten moderate hard texture snacks with a bland flavor, group-4 had seven sweet snacks with slightly harder texture than group-6, and 3. Group-1 had four extremely hard texture snacks with extremely strong savory flavor, and group-5 snacks had similar texture but strong sweet flavor. Group-2, snack texture hardness was similar to group-3. Group-7, snacks had bland flavors with a slightly softer texture compared to group-3. The other two groups representing soft texture snacks are group-8 and 9. Both groups were similar in the texture dimensions, with group-8 snacks being savory and group-9 being sweet. A complete description of groups, texture, flavor, and snack names are provided in Table 5.4.

Group-3 snacks were bland or seasoned with plain salt. Group-7 snacks were seaweed flavored with a slightly soft texture. Overall 12 snacks, mainly from group-1 and 2 were seaweed flavored. Group-8 snacks were savory chewy meat/seafood snacks. Group-9 snacks were savory with a soft texture. Thirty-nine (59%) snacks were sweet-flavored or lingered with a sweet taste. Among sweet-flavored snacks, thirty-one (47%) had slight to moderate hard texture and only 8

snacks were soft textured. PM results obtained from the pooled products showed that the SK market had more sweet snacks over savory.

PM results showed fifty (75.8%) snacks were in the hard-textured space, varying from slightly hard to moderately hard. Only nine snacks were of extremely hard texture. PM results indicate that the SK snack market space is mainly constituted of slight to moderate hard texture snacks. The texture dimensions of the SK snacks market were similar to the JP snacks market but with slightly less hard textures. The white space in soft texture products either with savory or sweet flavor is due to the small number of snacks available in that segment. Overall, slight to moderate hard texture with low-intensity sweet flavor can be said as the best description of the SK snack market. The texture dimension of SK snacks mainly varied from moderately hard to slightly hard with most being sweet flavored. Whereas, the texture dimension of JP snacks varied from moderately hard to extremely hard seasoned with savory flavors.

The PM results helped to identify existing snack food positioning in the market space. It enabled researchers to do a product segmentation and explore white spaces for new opportunities. The developers can look at PM plots as a whole or as individual quadrants or half plots to find new product opportunities.

Table 5.4.

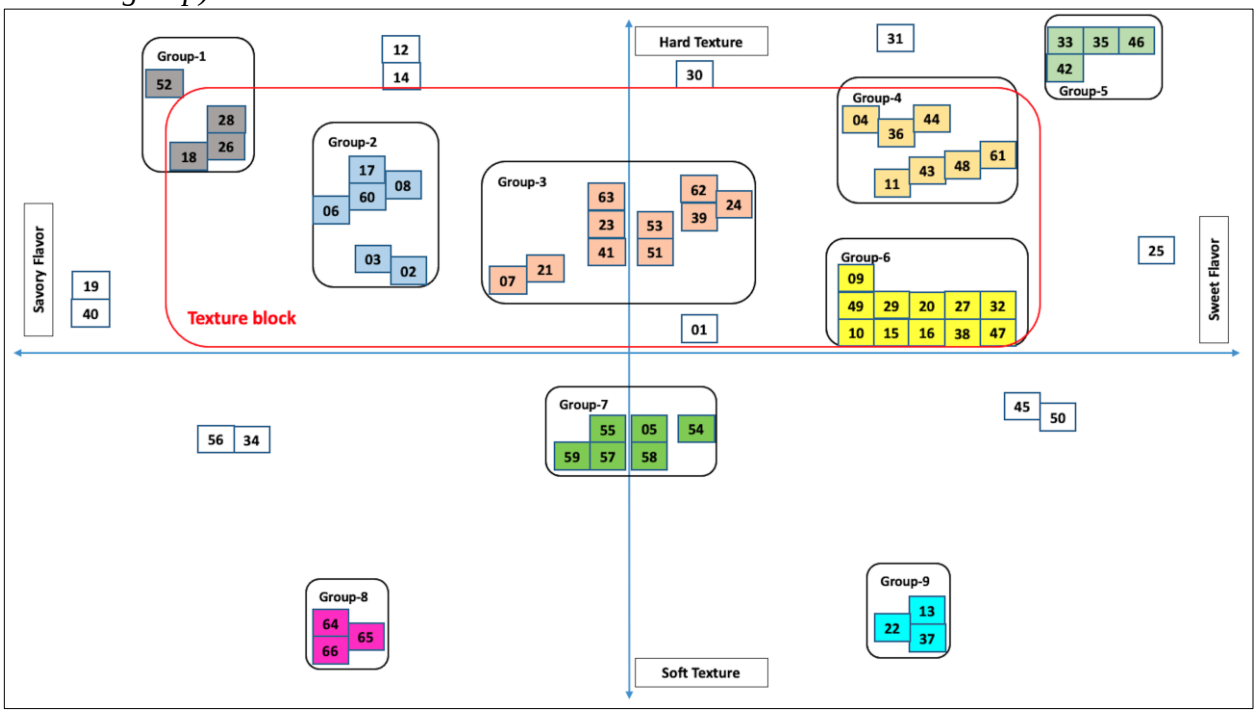
Group identified in the projective mapping of the SK snacks. Group number, number of snacks in each group, snack-type, flavor, and snack names.

Groups	Number of snacks	Texture and flavor	Snacks type and flavor	Snacks
Group-1	4	Extremely hard bite with an extremely strong savory flavor	Type: chips, sticks Flavor: savory, corn, garlic, seaweed	Binggare smoky bacon chip with spicy beef flavor, Britos snacks-Mexican taco chip, Mister free'd chia seed tortilla chips, HAITAI spicy Rice cake sticks
Group-2	6	Moderate hard bite with a mild savory flavor	Type: potato chips, fish chips Flavor: seaweed, chicken, crab, savory	Nong shim cuttlefish roasted butter chips, crab shaped baked snack, Nongshim chicken leg snack, Nongshim potato chips, Pulmuone seaweed chips
Group-3	10	Moderate hard bite with a bland or little sweet flavor	Type: chips, trail mix, crackers Flavor: soy, seaweed, bland, salt	Orion turtle shaped chips, Peacock Seoul crispy rice chips, Pulmuone crispy seaweed snack, Soy Sauce Tempura Seaweed Snacks, HEYROO noodle snack, Prawn snack, HEYROO seaweed tofu snack, Dried fish snack, Mum Mum rice rusks, ChungWoo Fermented Hardtack crackers, The KIMS crispy laver chips
Group-4	7	Moderate hard bite with a mild sweet flavor	Type: nuts, chips, crackers, Flavor: squid, coffee, sweet	Orion squid flavored peanut balls, crunchy and tasty deep anchovy fried, Momali shinchon (crown) snack, Peacock brand chips french dessert, HEYROO sweet popcorn Corn kernel covered with sweet butter scent, Coffee coated peanut, Nobrand coconut sticks,
Group-5	4	Extremely hard bite with an extremely sweet flavor	Type: puffs, chips Flavor: sweet, peanut	Nobrand seashell shaped snack, Haitai matdongsan peanut crunch, HEYROO oranda snacks, Amigo chips,

Groups	Number of snacks	Texture and flavor	Snacks type and flavor	Snacks
Group-6	11	Slight hard bite with a mildly sweet flavor	Type: chips, sticks, crisps, crackers, rolls Flavor: sweet, rice, seaweed, fish	Fried butter potato chips, Orion potato sticks, Orion Gosomi Sweet Cookie Cracker, heyroo injeolmi traditional Rice Cake Snack Crispy Coated by Bean powder, HEYROO egg snacks, Shinhwa seasoned dried fish meat, Haitai calbee sweet potato chips, Crown rice crackers, Market O nature mushroom snack, Big roll grilled seaweed roll: classic flavor, Pulmuone snack chip
Group-7	6	Slight soft bite with a bland or little sweet flavor	Type: sticks, chips, crisps Flavor: seaweed, sweet, sesame	Roasted sweet potato chew snack with pineapple flavor, ILDONG coconut seaweed baby snack, ILDONG seaweed snack with white sesame, THE KIMS crispy roasted laver chips, Team Korea crispy laver snack, K-fish seaweed chips
Group-8	3	Very soft chewy texture with a mild savory flavor	Type: Jerky, dried meat Flavor: seafood and meat	Roast horse mackerel, Baked cheese dried squid, Hot pork jerky
Group-9	3	Very soft texture with a mild to very sweet flavor	Type: grain bars, crisps Flavor: sweet, banana	Mybizcuit peanut crunchy bar, Premium Grain bars, Kiddylicious banana crispy

Figure 5.2.

Projective Mapping plot of sixty-six South Korean snacks showing nine product groupings and outlying products (Snacks are coded with 2-digit numbers and snacks with the same color are in the same group).



Descriptive profiling

Japanese snacks

Thirty-three texture descriptors were used to profile thirty-five snacks. The PCA plot obtained from descriptive data is presented in Figure 5.3. The product variability explained by the first two principal components (PCs) was 44.07% of the total variability. The main differentiating texture attributes were PC1 (roughness of mass, sustained fracturability, sustained crispness, initial crispness, fracturability, particle size, roughness of surface, particles/residuals, and tooth packing) (Figure 5.4) and PC2 (fibrous, moistness, moisty appearance, firmness,

dissolvability, chew count and surface shine) (Figure 5.5). One set of snacks featured high-intensity scores of PC1 attributes, the other set of products highlighted strong intensities of dissolvability, powdery, porous, and chalky mouthfeel. Another large set of snacks close to the center of the PCA plot represented low intensities of attributes such as adhesive, cohesive of mass, oily mouthfeel, gritty, mealy, uniformity of bite, and uniformity of surface.

The PCA plot provided a space where new products of certain textures can be developed. For example, there is a scarcity of snacks that are fibrous, cohesive, mealy, moist, having waxy mouthfeel, etc. Similarly, large white space can be seen around descriptors such as firmness, chew count, gritty, etc. The developer can utilize descriptive data to incubate new textures profiles to fulfill empty texture spaces by introducing new prototypes. The analytical descriptive profiling data can be used as a reference guide to shaping new prototypes for further development (MacFie, 2007; Valentin, Cholet, Nestrud, & Abdi, 2018). Of course, white spaces such as one mentioned in the firm, chewy, gritty area may be undeveloped because that product "concept" may not be appetizing for consumers. However, some products, such as meat jerky, may fit with some aspects of that concept. We also imagine that some high protein products made from plants might fall into that category and whether they are successful or not may depend on accentuating characteristics that might be desirable (firm, chewy) in certain contexts, which reducing characteristics that usually are less desirable (e.g., gritty). Overall, the descriptive sensory profiling can help to design the prototype, determine prototype requirements, and define key sensory specifications (Cooper, 2019).

Figure 5.3.

PCA plot representing descriptive texture profiling results of JP snacks. The text (include dots) highlighted with blue color represents snack-type, and text (include dots) in red color denotes texture attributes. Three US snacks Stacy's Pita original, Lay's classic potato chips (PC), and Tostitos original corn chips (highlighted in yellow color) were used to compare texture dimensions with JP snacks.

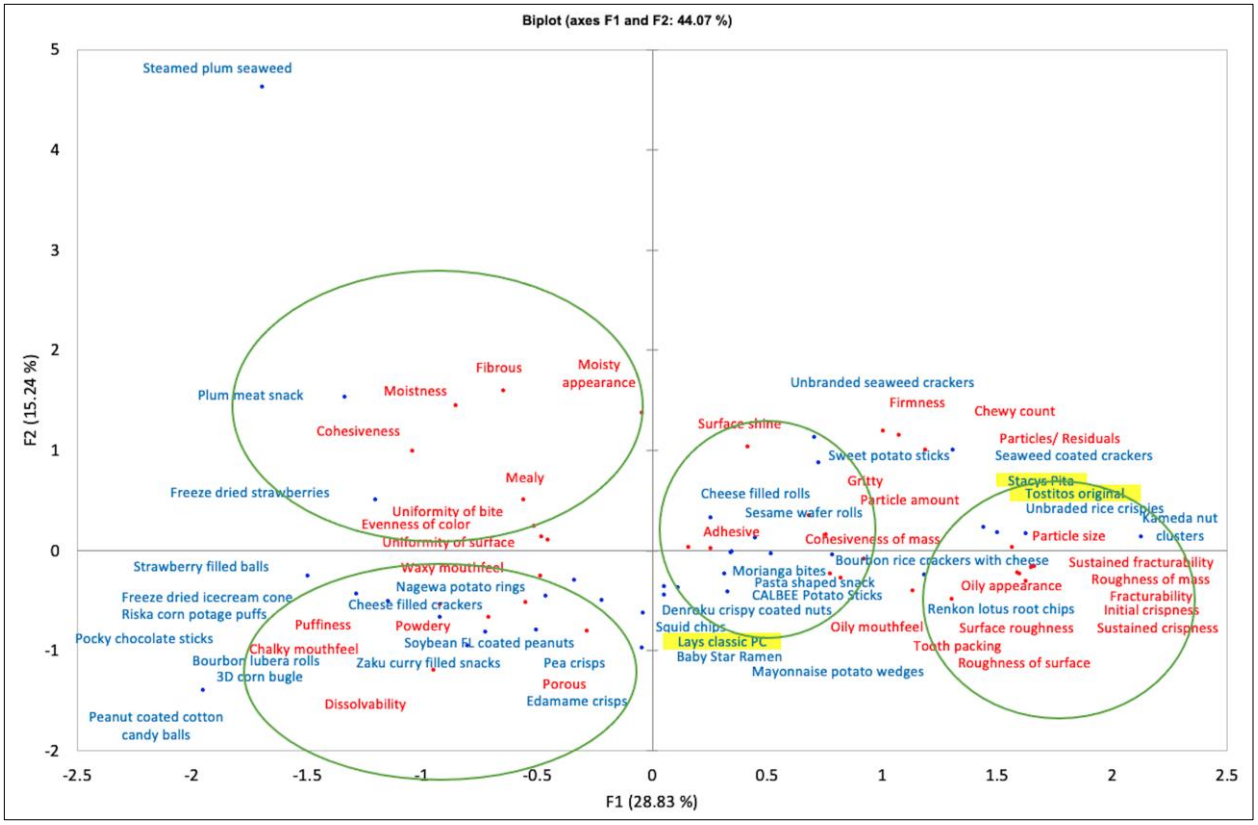


Figure 5.4.

PCA loadings for PC1 for the JP snacks.

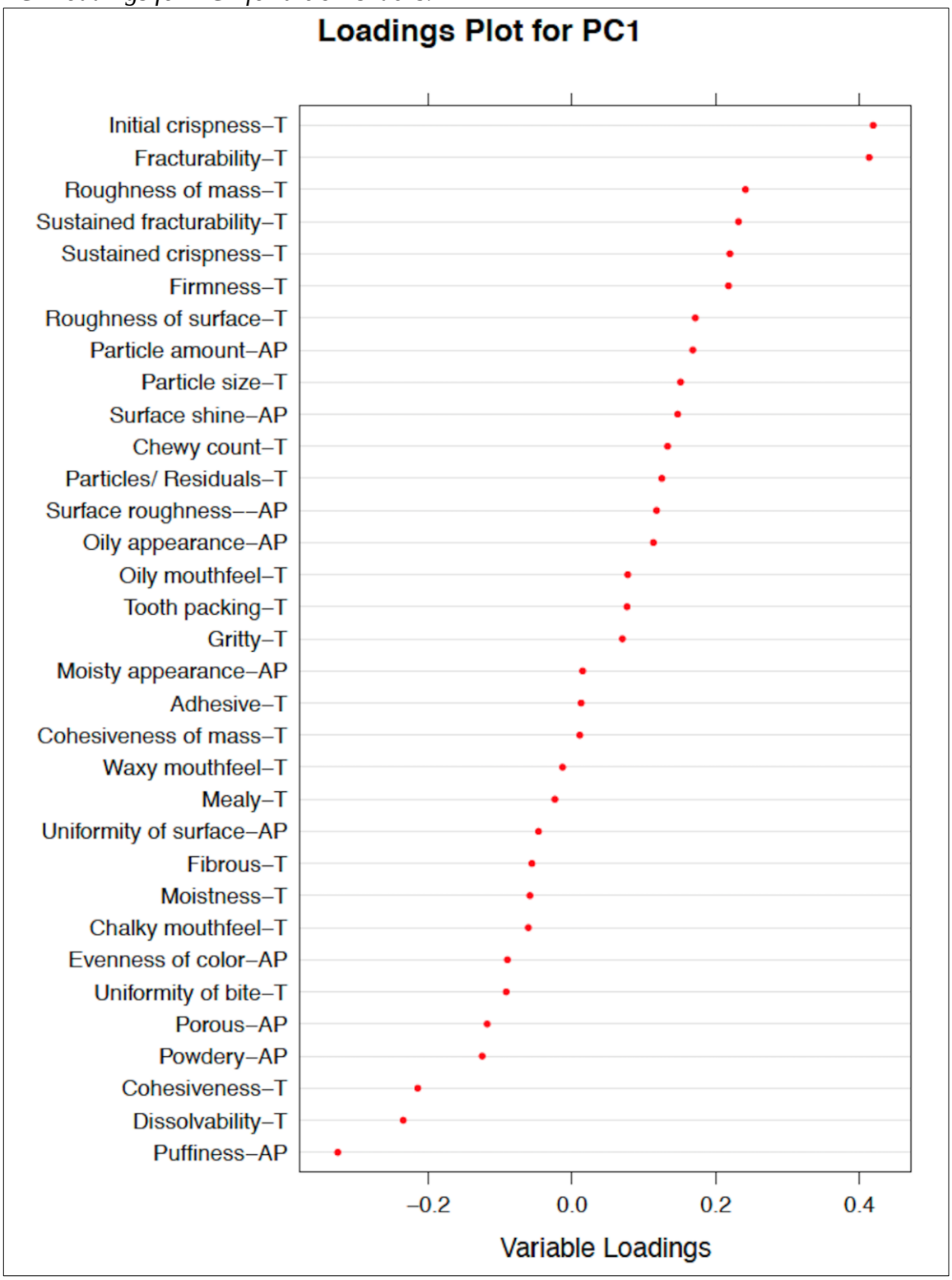
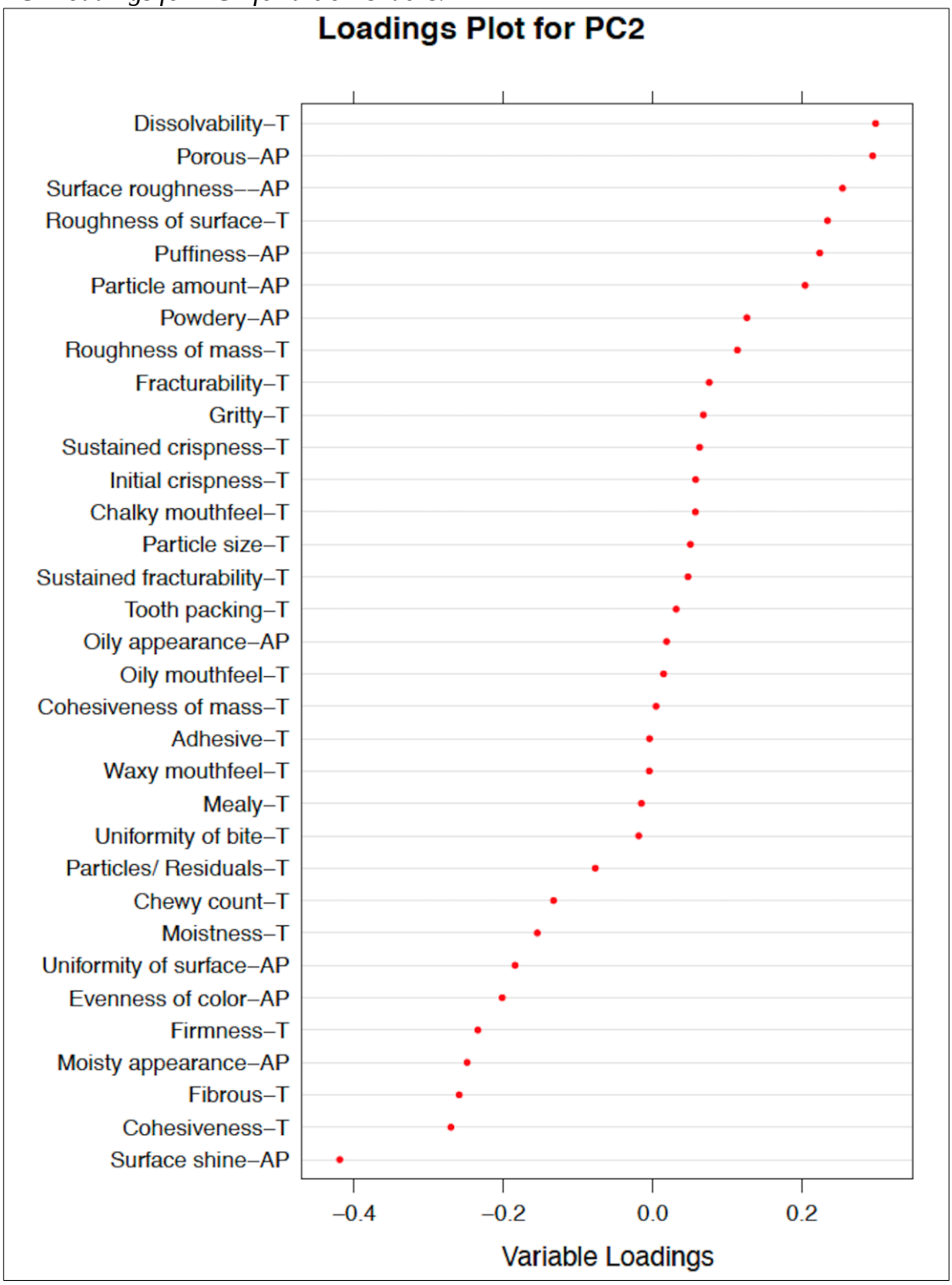


Figure 5.5.

PCA loadings for PC2 for the JP snacks.



South Korean snacks

The PCA plot representing texture descriptive results is shown in Figure 5.6, with three main snack clusters being noted. The largest groups of snacks had moderate intensities mainly described by the cohesiveness of mass, uniformity of surface, mealy, chalky mouthfeel, moistness, and adhesive. The second group of snacks profiled by cohesiveness, doughy, evenness of color, puffiness, and dissolvability. The third group of snacks with strong intensities of texture attributes was marked by PC1. The snacks with strong intensities are represented on the edges of the PCA plot, whereas the snacks with low intensities of textures attributes are located near the center of the PCA plot (Figure 5.6). The first (PC1) and second principal (PC2) components explained 40.42% of the total variability. The texture attributes contributing to PC1 were roughness of mass, sustained crispness, sustained fracturability, fracturability, initial crispness, particles, particle size, and roughness of surface (Figure 5.7). The texture attributes for PC2 were adhesive, porous, tooth packing, firmness, chewy count, dissolvability, and cohesiveness of mass (Figure 5.8).

Large white spaces between and within snack groups are present. For example, the white space around Stacy's Pita chips shows the unavailability of a similar product in the SK snack market. Similarly, white space around French dessert chip, prawn snack, and heyroo noodle snack show where new texture concepts could be developed to fill these spaces. The developers can use the tested products as references to quantify texture descriptors.

Discussion

This research work has adopted a market assessment and product category appraisal approach (Muñoz, Chambers, & Hummer, 1996) for new product ideation. This research work

applied sensory tools to deliver a pool of new texture concepts. The developer can narrow down the list of new concepts after evaluating consumer response and technical feasibility. The discussion below explains how a step by step process can be used to funnel new ideas.

Figure 5.6.

PCA plot representing descriptive texture profiling results of SK snacks. The text (include dots) highlighted with blue color represents snack-type, and text (include dots) in red color denotes texture attributes. Three US snacks Stacy's Pita original, Lay's classic potato chips (PC), and Tostitos original corn chips (highlighted in yellow color) were used to compare texture dimensions with SK snacks.

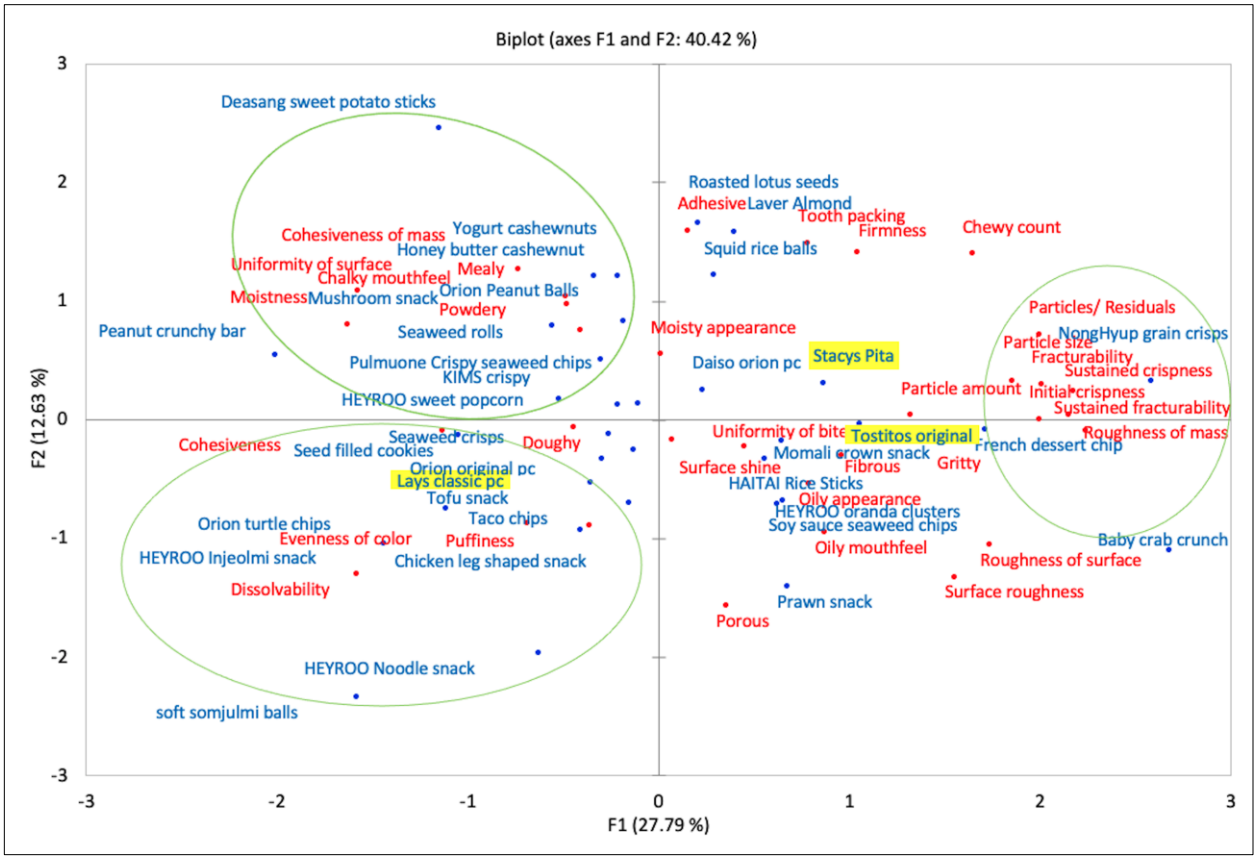


Figure 5.7.

PCA loadings for PC1 for the SK snacks.

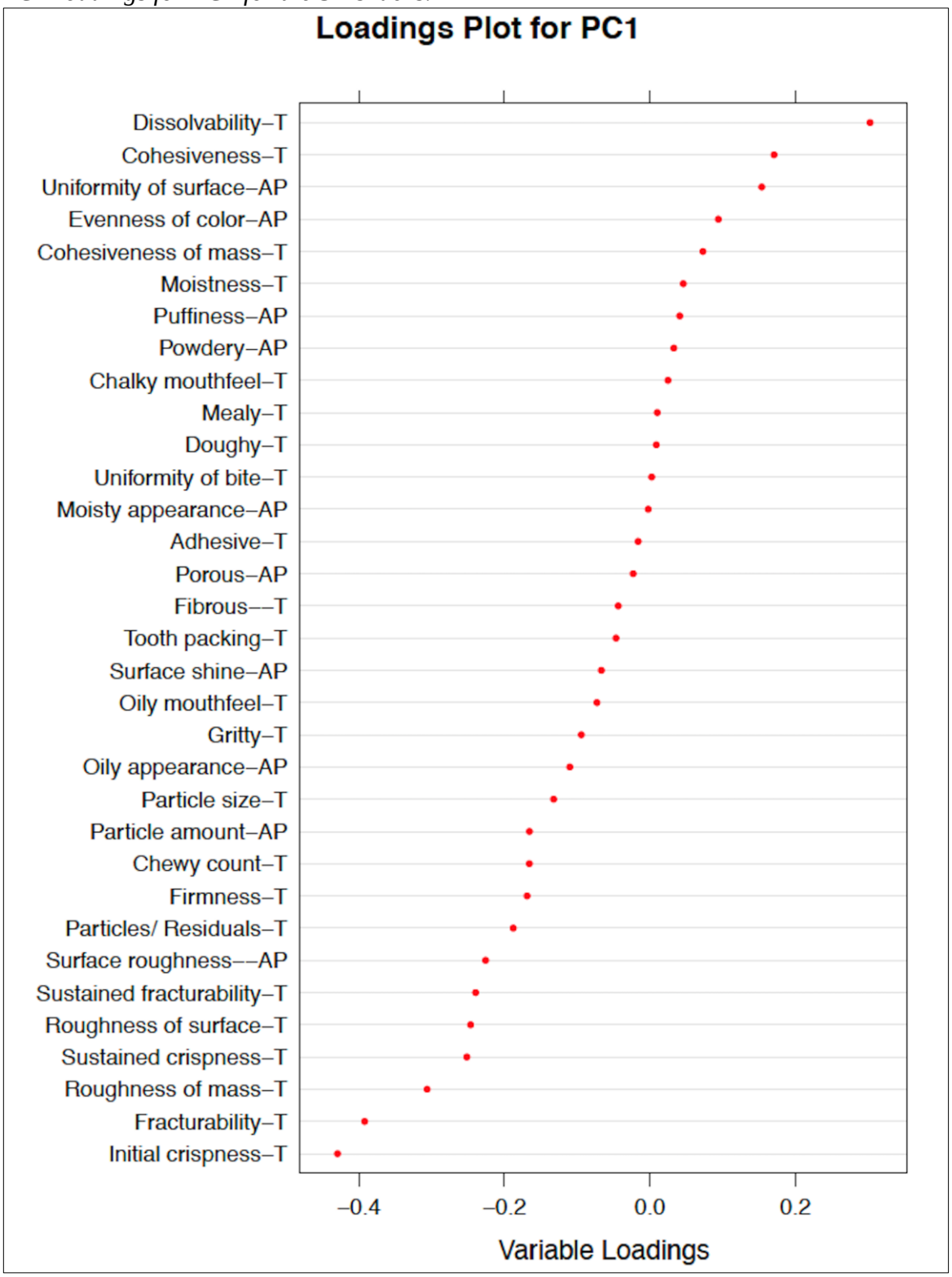
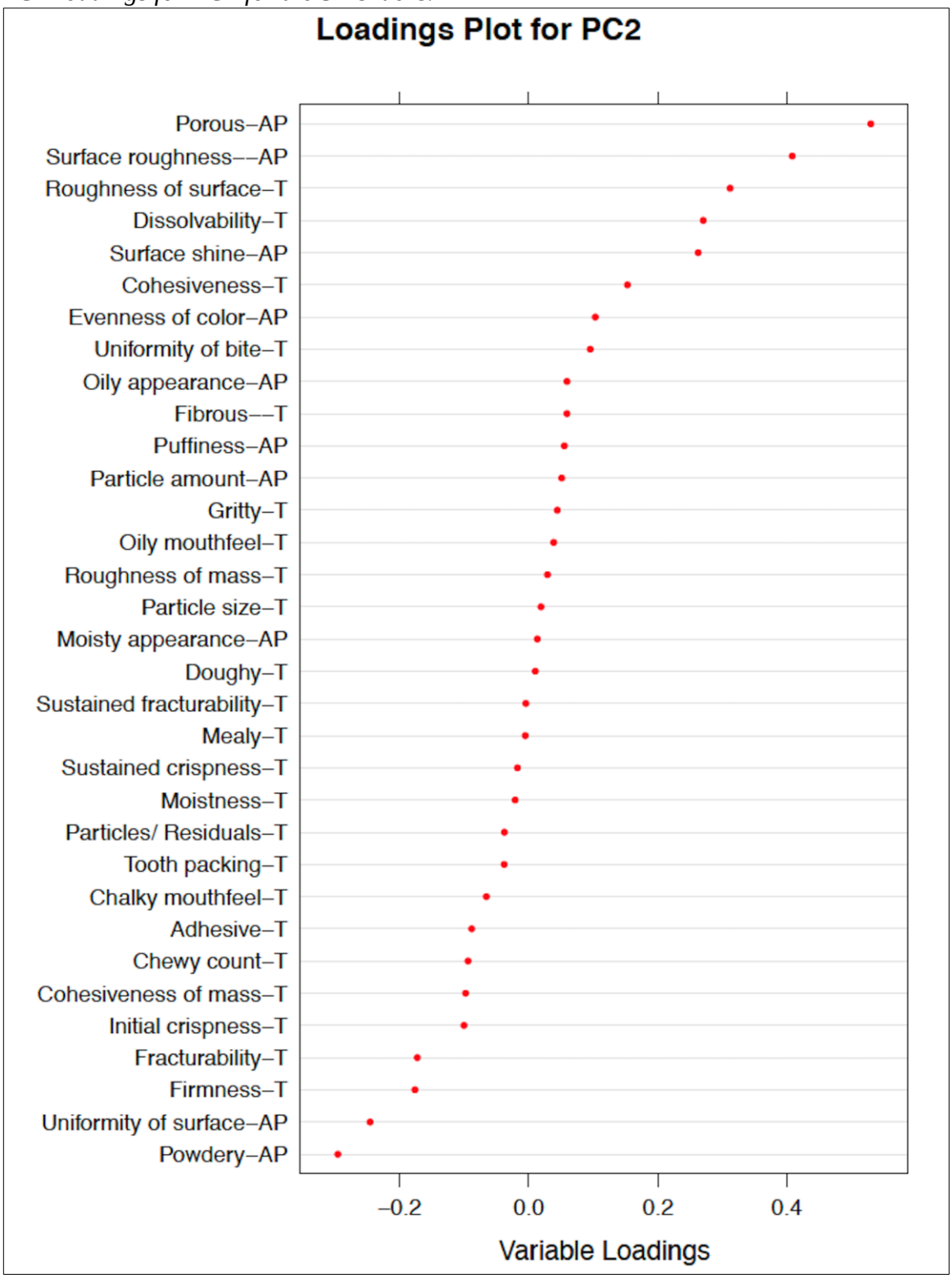


Figure 5.8.

PCA loadings for PC2 for the SK snacks.



Step-1 Pre-development homework (preliminary market assessment, which markets and why?)

A detailed preliminary homework was done to explore the JP snack market (Murley et al., 2020) and similar work was done for the SK except that an in-country sensory professional was used to help the process move more quickly. The critical sections covered in pre-development homework includes an assessment of the JP snack market potential, desired snacks market portfolio, size, feasibility, and area of interest. The other pertinent segments were market selection, location, information acquisition, innovation trends, funds, skilled teams (manpower), product procurement strategy, product shipment, timelines, climate, travel, lodging, boarding, storage, and shipment, etc. Pre-development work was considered very important in new product development work (Cooper, 2019; Jagtap & Duong, 2019; Murley et al., 2020; Santoro et al., 2017b). During the early stages of NPD, researchers aim to search for novel ideas (For example, texture, ingredient, shape, size, packaging, convenience, and flavor) (Fuller, 2016; Grunert, 2017; Simms & Trott, 2017). Many researchers reasoned that earlier stage work such as market exploration is most beneficial for the NPD process (Fuller, 2016; Horvat et al., 2019; Wind & Mahajan, 1997).

Step-2 Market-driven product assessment

A deep understating of the nature of the market, competitive index, and consumer trends are essential for new product ideation and success (Cooper, 2018). Failure to understand market orientation, assessment, and leaving consumers out of the development process could lead to disasters for innovators. The notion of deep market research to discover white space is supported in several studies such as (Cooper, 2019; Corley, 2017; Johnson, 2018).

The researchers undertook a detailed market assessment which included the participation of local consumers from both countries (Murley et al., 2020). A multi-stage market assessment process includes different teams exploring different zones of the market, product procurement strategy, consumer interviews, daily sensory evaluation by sensory scientists, information collection, and shipping enough quantities from the market for further investigation.

Once snacks were procured, sensory tools such as a 2-dimensional PM was applied to sort products into groups. The snacks were segmented for texture and flavor modalities. Sixty-five percent of Japanese snacks had hard textures (ranged from extremely hard to moderate hard). Results indicate a big block of snacks across the flavor dimension accounted for 49% of snacks marketspace. PM results are a close representation of the JP snacks market space.

In the SK snacks, PM results showed 75% of snacks are hard textured, varying from slightly hard to moderately hard. Fifty-nine percent of SK snacks are sweet-flavored or had a sweet aftertaste. Among sweet-flavored snacks, 47% were hard textured and only 8 snacks were soft textured. PM results obtained from pooled products shows that SK consumers eat more sweet-flavored snacks than savory.

The overwhelming presence of hard bite texture snacks in the JP and SK market also reflects what the product characteristic should be that derives consumer's interest. This also advances the need to explore detailed texture attributes that forms a product profile. Therefore, once foundational characteristics are framed then the developer should go into measuring these texture attributes via descriptive analysis. By identifying what texture attributes form product characteristics (for example crispness, fracturability, firmness in case of snacks) the developers can concrete inputs for the subsequent technical prototype developmental stage (Banović et al.,

2016; Cuny et al., 2020; De Pelsmaeker et al., 2015; Moussaoui & Varela, 2010; Guiné et al., 2016)

Large white spaces were discovered on the soft texture axis for both countries. Plenty of white space is available across the savory-sweet flavor dimension with a soft texture profile in the JP market (Figure 5.1). The other niche area could be bringing new flavors in the existing hard texture spectrum for the JP market. For example, 65% of the JP snacks were savory, occupied a major part of the snack market space. Hence, for a developer savory flavor for the JP and sweet flavor for the SK could be a possible go.

The PM tool helped to portray both country's existing snack market texture and flavor outlooks. PM enables the researcher to do a product segmentation and explore white spaces in the market. New ideas can fill the white spaces by testing with consumers through models, mock-ups, product concepts, and actual prototypes (Cooper, 2019; Costa & Jongen, 2006; Costa et al., 2020). Once the new product concepts are extracted, they should be tested to explore insights on consumer relevance (MacFie, 2007). The initial inputs from the consumers on needs, likings, and preferences can help to screen and envisage these concepts. A thorough market assessment is a key step in new product development (Cooper, 2018; Fuller, 2016). Developers also can use any other sensory dimensions to sort products based on their interests. For example, scientists who work on product renovation or novel ingredients can also use PM as a tool to identify an ingredient's market space.

Step-3 Opportunity definition (distinct, early features, requirements, and product specifications)

Another essential part of new product development is defining project scope, target market, and product features, attributes, and specifications (Cooper, 2017, 2019). The PCA plots generated from sensory profiling of snacks can be used as guidelines to frame the sensory profile of new concepts and the direction of potential new product definitions and specifications. Descriptive profiling provided essential elements of the existing snacks such as appearance (color), shape, flavor, and texture attributes (physical components). These key attributes and components can be manipulated in iterative or "structured ways" to come up with new product configurations (Lawless & Heymann, 2013; Simms & Trott, 2017). For example, attributes of PC1 and PC2 contributed most in explaining total variability from a list of key texture and appearance attributes. The strengths of these texture attributes are measurable and manipulatable to predict and develop new product candidates. Because texture has been identified as an important function of snack foods that derive consumer desired benefits (Kumar & Chambers, 2019) and serves as the base of many snack food development projects, knowing that attributes are key information. The descriptive analysis helped to quantify product attributes and translate them into measurable product characteristics (Valentin, Cholet, Nestrud, & Abdi, 2018).

The white spaces between snack groups identified by their texture attributes represent the gaps where new prototypes can be placed. The existing snacks (near to white space) key sensory specifications could be used as a starting point for prototype development. Developers can tweak the key sensory texture intensities by using consumer's feedback. Sensory profiles of prototype products can be plotted on the same PCA plot to verify texture positioning. For example, there is a scarcity of snacks that are fibrous, cohesive, mealy, moist, and have a waxy mouthfeel for the

JP market (Figure 5.3). Similarly, wide product space is available for snacks with other key sensory attributes such as firmness, chew count, and gritty.

For the SK snacks, large white spaces were found between and within each snack group (Figure 5.2). For example, the white space around Stacy's Pita chips explains the unavailability of a similar product in the SK snack market. The developers can utilize the tested products as reference products to quantify texture specifications. Throughout the NPD process, the prototypes should be compared with the target product for the key attributes and other desirable sensory characteristics identified in descriptive profiling. The inclusion of either target or main competitive products makes it easier for developers to evaluate whether the newly developed prototypes adhere to the desired product concept (O'sullivan, 2017).

Descriptive analysis is valuable for the replacement of essential components. A product developer can either replace essential components (for example, ingredient, flavors, or base material) of the product with something novel or close to the immediate background of the product that can accomplish the same necessary function. For example, the replacement of oil with plant sterols in mayonnaise. The plant sterols not only fulfill the functional requirement of providing structure and flavor carrying ability but also added health benefits by reducing serum cholesterol (Goldenberg & Mazursky, 2002; MacFie, 2007). Once the desired product is fully developed, multiple consumer studies must be carried out to evaluate hedonics towards the newly developed product(s) and comparison must be made with current or competitive products. The foremost benefit of carrying out the descriptive analysis throughout the NPD is a detailed understanding of products, and descriptive is very cost-effective than consumer studies.

A product developer can also make several copies of an existing snack component and alter them in creative ways. For example, the development of purple corn tortilla chips on the

line of regular yellow corn tortilla chips. Another creative way would be increasing the plant protein component of existing products for delivering more protein within existing product texture space. A smart developer can include several ideas (for example, environmentally sustainable ingredients, novel ingredients, plant proteins, less processing, and natural) to create niche product spaces but maintain similar texture profiles.

Step-4 Opportunity for fine-tuning (iterative, prototype development, test, feedback, and revise iterations)

In rapidly changing consumer needs, it is not always possible to identify consumer needs and obtain correct product definitions. Developers should use iterative steps to build prototypes to fulfill identified white spaces. Sometimes consumer requirements change in the time that passes between the commencement and end of development. Thus, the original product definition no longer satisfies consumer requirements.

Often consumers are not clear or fail to articulate what they need in the product until they see the product (Reid & de Brentani, 2004; Savela-Huovinen, Muukkonen, & Toom, 2018). Thus, it is difficult to get an accurate product definition in the early stages of product development if the developer solely depends on explicit consumer inputs for idea generation. Because of limited exposure, consumer inputs are believed to restrict new ideas (Cuny et al., 2020). Instead, the product definition should be driven by presenting successive versions of the prototypes to consumers for feedback and verification. Iterative development is a dynamic process to capture accurate product definition by presenting a series of deliberative iterative prototypes to consumers. Therefore, iterative development of prototypes is fluid, captures

changing information, and floats the final products close to consumer requirements (Cooper, 2019; Cuny et al., 2020).

Information such as what consumers like, don't like, and the value consumer see in prototypes should be gathered. The developer can revise or reset or plan the next (future) iteration about the benefits required, propositions, and product design based on gathered feedback.

Step-5 Opportunity feasibility (marketing, R&D, engineering, production)

Only those prototypes that address the needs of the consumer will be most likely to succeed and should be offered to product and other technology specialists to develop into a tangible product. Similarly, marketing must be involved to determine how products and market needs can be paired and promoted to produce successful launch and sales data.

Limitations

The NPD methodology used in this study to generate new texture concepts could be used for other food product categories. Readers are advised to do rigorous homework before applying the suggested methodology to any other market. This study suggests the utility of sensory methods in market assessment and ideation. However, the adoption of these methods does not guaranty the success of new products. The prototypes developed by using this methodology only confront consumers with products developed within the existing framework of the market, which may not result in "out-of-the-box" innovation. It may be difficult to understand unfulfilled needs by examining prototypes based on the existing marketplace.

Results projecting products from one market onto another also are not always successful depending on the similarity in preferences and consumer segments between countries. For example, one study showed that the same segments of consumers existed in multiple countries for a product (pomegranate juice) (Koppel et al., 2014). However, the proportion of consumers in segments was completely different in the US and Spain, suggesting that a juice developed for the Spanish market may not be successful in the US. On the other hand, that could be the result of products not being available readily in certain countries or the difference in consumption rates among countries. Testing with consumers who regularly eat certain products in a category is quite different from testing with consumers who are new to the product type. Thus, prototypes developed using the JP and SK snack market framework could be a potential opportunity for the US market or maybe too far out of the current repertory of snack products to be successful. Testing is required.

Conclusion

The world is changing rapidly i.e. more global, less predictable, and more abstruse. The product developers' task is full of multi-facet challenges. A plethora of literature had been published to deal with these challenges. For example, "open innovation, agile development, design thinking for ideation, stage-gate development, and lean product development". The developers require more creative techniques than 'just ask consumers what they want' to increase the chances of success in competitive markets.

This paper shows how new product concepts can be developed using sensory science tools such as product categorization, PM, and descriptive profiling. This research approach for novel and distinctive market opportunities displays a more innovative, practical side of NPD

research as a compliment. The study also identified the foremost sensory attributes of the JP and SK snack foods that drive consumer benefits. The proposed methodology can be used by food manufactures to develop new product ideas from unfamiliar markets.

The results of this study can help the developers to find white spaces in the marketplace and fill these spaces by designing prototypes. The developers can use tested products (close to white spaces) for initial specifications and then build several concepts for consumer assessment. This study is unique in its approach because it allows developers to use sensory methods to put several new ideas on the table for refinement and consumer feedback. The significance of product innovation is critical to business prosperity and consumer satisfaction, and yet the keys to success remain indefinable.

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Chapter 6 - Unreliability of Clustering Results in Sensory Studies and a Strategy to Address the Issue

Abstract

Researchers commonly use hierarchical clustering (HC) or k-means (KM) for grouping products, attributes, or consumers. However, the results produced by these approaches can differ widely depending on the specific methods used or the initial "seeds" chosen in clustering. Although recommendations for various clustering techniques have been made, the realities are that objects in groups can, and do, change their clusters. That can impact the interpretation of the data. Researchers usually don't run the clustering algorithms multiple times to determine stability, nor do they often run multiple methods of clustering although that has been recommended previously. This study applied hierarchical agglomerative clustering (HAC), KM, and fuzzy clustering (FC) to a large descriptive sensory data set and compared attribute clusters from the methods, including multiple iterations of some methods. Attributes (objects) shuffled among clusters in varying ways, which could provide different interpretations of the data. That frequency was captured in the KM output and used to form the "best possible" clusters via manual clustering (MC). The HAC and FC results were studied and compared with KM results. Attribute correlation coefficients also were compared with clustering information. Using results from one clustering approach may not be reliable and results should be confirmed using other clustering approaches. A strategy that combines multiple clustering approaches, including an MC process is suggested to determine consistent clusters in sensory data sets.

Introduction

Cluster analysis (CA) is one of the most common statistical techniques used in both sensory and consumer studies to segment, classify, or group "objects" into homogenous subsets (Pierguidi, Spinelli, Dinnella, Prescott, & Monteleone, 2020). The objects can be consumers, products, or product attributes, and completely depends on the objectives of the study. Studies have used CA for various research purposes such as to summarizes differences among consumers for their likes and dislikes of products, group-specific products or attributes for various product categories, and product optimization in new product development (Zielinski et al., 2014). For example, CA was used to segment consumers for liking similarities of large potato varieties (Sharma, Jayanty, Chambers, & Talavera, 2020), mate tea varieties for sensory properties (Godoy, Chambers, & Yang, 2020), and non-food products (Grygorczyk, Jenkins, & Bowen, 2019) and plant proteins snack development (Saint‐Eve, Granda, Legay, Cuvelier, & Delarue, 2019).

For multivariate sensory and consumer data, the two most common types of clustering methods are hierarchical agglomerative clustering (HAC) (Jacobsen & Gunderson, 1986) and the non-hierarchical partitioning method e.g. K-Means (KM) (Myers & Mullet, 2003). In both methods objects are arranged into relatively homogenous groups according to selected criteria, so objects that show more similarities are placed together in a cluster than with those placed in other clusters (Zielinski et al., 2014). One main challenge with the CA application is that the obtained results strongly depend on the choices made by the investigators. Among them, the selection of the clustering method, the true number of clusters, stability, and repeatability of results are particularly important in sensory studies (Qannari, 2017). Different clustering

methods use different assumptions about the structure of the data which yields different results (Yenket & Chambers, 2017).

Mostly, investigators do not have any prior knowledge about the number of clusters and their structure. To overcome this problem some researchers run data with different clustering methods, using different cluster numbers, and present their best interpretable solutions (Næs, Varela, & Berget, 2018). The stability of clustering results is extremely important in both market segmentation of consumers, and sensory attributes or products grouping in new product development. A significant amount of literature has been produced on the utilization of clustering methods in various sensory and consumer studies, but much less attention has been paid to the stability, validity of results, and properties of clusters obtained from these methods (Sauvageot et al., 2017).

The internal stability of cluster results defines the possibility of replicating the results with the same or similar data (Wedel & Kamakura, 2000). Studies have evaluated internal cluster stability by using variations of clustering methodologies on consumer segmentations but rarely on descriptive sensory data. Müller and Hamm (2014), found consumers could change from one cluster to another when they were retested, and cautions must be taken in the application of clustering methods. Their results suggested that the best solution remains subjective and researchers were advised not to take final solutions for granted. Sauvageot et al. (2017), reported the existence of unstable clusters with KM methods, compared KM clusters with principal component analysis (PCA) results to confirm the true nature of clusters and make subjective decisions to influence a final decision in describing dietary patterns in a population.

In a consumer study, a HAC method differentiated six alcoholic beverages for emotions and context but failed to distinguish for sensory properties even though the six samples were

sensorially different (Pierguidi et al., 2020). Those authors employed several other multi-factor analysis tools to explain differences between clusters. Clustering procedures that produce clusters with reasonably high homogeneity can "miscommunicate" information in typical mapping situations (Yenket & Chambers, 2017). Another study by Yenket, Chambers, and Johnson (2011), found that clustering procedures based on liking place consumers in groups with other consumers who did not necessarily like the same products.

Endrizzi, Gasperi, Rødbotten, and Næs (2014), compared HAC and KM results of consumer likings for fruit juices to determine the agreement between clustering methods. The results were not completely comparable, many consumers moved from one group to another in the KM output, and visual clustering was done through PCA for the identification of an additional cluster representing consumers with liking score in the opposite direction. The study concluded that algorithm-based automatic clustering methods (HAC and KM) failed to identify and separate consumer groups, and alternative approaches such as visual clustering, a form of MC, must be applied to identify natural clusters. Segmentations based on visual inspection of plots (PCA, HAC, and KM outputs) represents a more flexible approach than automatic procedures (Endrizzi, Menichelli, Johansen, Olsen, & Næs, 2011; Wajrock, Antille, Rytz, Pineau, & Hager, 2008).

Granato, Santos, Escher, Ferreira, and Maggio (2018), cautioned researchers on the indiscriminate use of HAC to establish an association between bioactive compounds and their antioxidant functional properties. They suggested the results could be misleading or may not represents natural groups. Similarly, other researchers also highlighted issues with the validity of clustering results. For example, HAC doesn't always recover true clusters, and also doesn't offer any mechanism to assess if clustering is stable or changing (Wajrock et al., 2008), both HAC and

KM clustering approach yielded different results with the same data set (Horn & Huang, 2016), consumer segmentation by clustering methods lack stability and repeatability (Müller & Hamm, 2014), and the HAC method failed to clearly distinguish one consumer group for its relationship with mandarin flavor attributes and overall drivers of liking (Simons, McNeil, Pham, Slupsky, & Guinard, 2019). Therefore, clusters produced by using one method, without investigating the stability and reproducibility, researchers could easily end-up with misleading conclusions (Yenket et al., 2011).

Over the last decade, researchers have proposed many strategies to help reach stability with clustering results. Vigneau, Qannari, Navez, and Cottet (2016), added a "noise cluster" to remove low-signal consumers using the FC approach. Simons et al. (2019), replicated a consumer study four times over two years to produce steady consumer clusters for 29 mandarin varieties. The study concluded that repeating studies may help to validate cluster solutions. However, the ability to repeat studies often is impossible given time and money constraints. Vigneau, Charles, and Chen (2014) added external variables to validate cluster results. Similarly, other studies have also suggested various tools of applied statistics to ensure stability. For example, if there are many variables, then removing the redundant ones before segmentation may help (Dolnicar & Grün, 2011). A combination of factor analysis, HAC, and KM method was used by Müller and Hamm (2014), and PCA and HAC were used in combination to validate consumer segments (Endrizzi et al., 2011; Juárez-Barrientos et al., 2019). Thus, it remains challenging to determine a single cluster solution with confidence and, as a consequence, it essentially depends on the methodology applied.

Although studies have highlighted issues with clustering results in consumer studies, the repeatability of CA with descriptive sensory data has been less studied. This study was

undertaken to increase the researcher's knowledge of three clustering methods (HAC, KM, and FC). The objectives of this study were (1) to underline the unreliability of clustering outputs with large data set, (2) to provide a methodological approach to identify the stable and moving object's within clusters, and (3) to show how other elements of applied statistics can be used for meaningful interpretation of clustering results.

Material and methods

Data source

Data was obtained from Kumar and Chambers (2019), that evaluated 76 multi-sensory i.e., visual (V), hand-feel (H), lip-feel (L), first-bite (FB), multi bite (MB), and in-throat (TH), descriptive texture attributes of 50 snack foods were used in this study. The previous study used repeated KM clustering and found 28 clusters were optimal, although the clusters were not completely stable. Therefore, this study was designed to investigate the stability of clusters using different clustering approaches.

Methods

Table 6.1, lists clustering methods used in this study along with the number of times algorithms run, iterations, and the number of results saved for analysis.

Table 6.1.

Clustering methods, the number of times algorithm run, the number of iterations per run, and cluster outputs saved for analysis.

Clustering Method	Number of time's algorithm run	Number of iterations per run	Clusters outputs saved for analysis
HAC	1	1	1
k-means	30	1000	30
Fuzzy	100	1000	100

Hierarchical clustering

The HC method operates in one of two directions. In the most common approach (HAC) each object is initially considered to be a cluster of size one and the analysis successively merges the objects until only one cluster exists. This is referred to as agglomerative clustering (Figure 6.1). The starting point is a distance matrix between the objects to be clustered and it begins by identifying (by distance measures) objects that are closest. The closest objects are then put in one cluster. The first step ends up with N-1 clusters (N = total number of objects), with one cluster consisting of the first two closest objects and the others consisting of only one object each. In the next step, the method again identifies the objects or clusters which are the closest using the same distance criterion. The process continues until all objects are collected with one large cluster (Jacobsen & Gunderson, 1986; Næs et al., 2018).

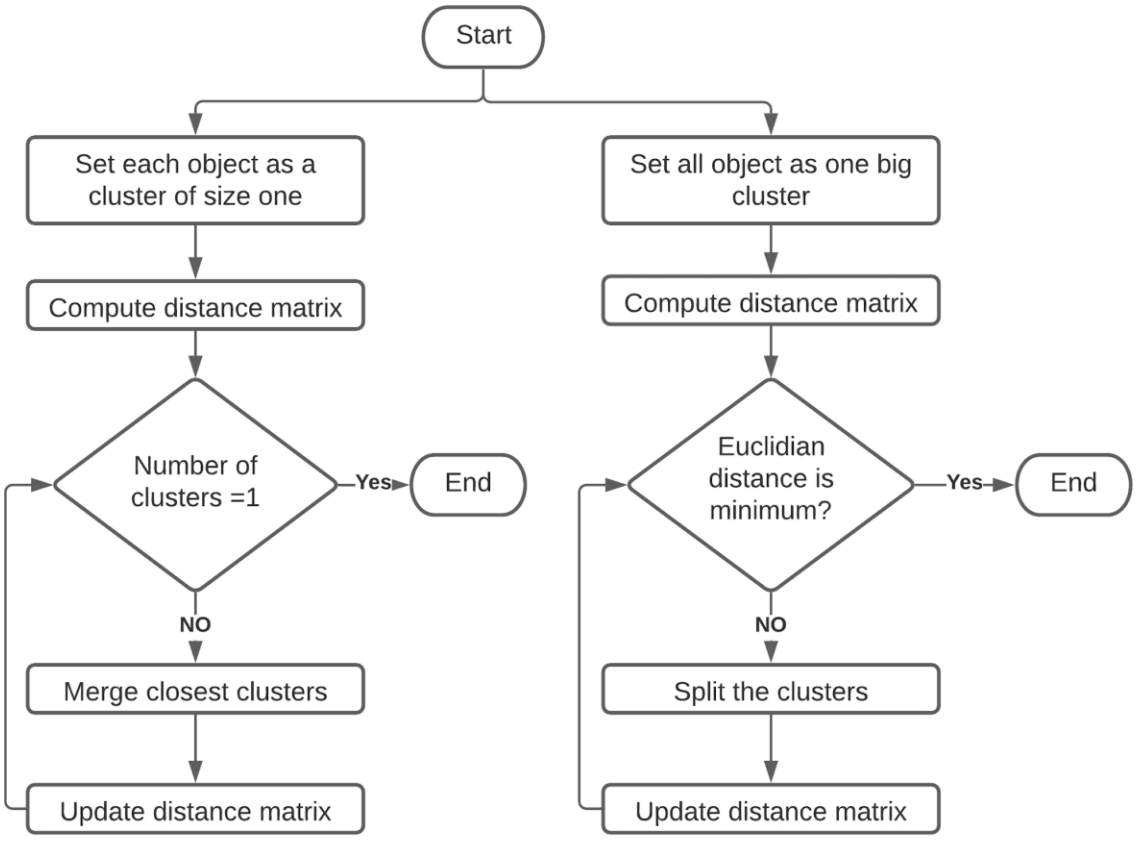
In the second direction, clustering begins by treating all the objects as one big cluster and then breaks groups of objects apart until only a single object remains in each cluster, referred to as divisive clustering (Figure 6.1). The results of HC produce a tree-like diagram termed a dendrogram or "tree". The graphical representation often manifests cluster structures by long vertical line segments, also used to decide the actual number of clusters that exist, and identifying outlier objects (Næs et al., 2018). The outlier object has a large distance to all other objects, and it is put in a cluster at the top level of the dendrogram (largest distance).

In the "tree" style diagram, there are multiple ways to determine which "neighbors" are clustered together in which order and each of those methods can provide differences in the final clusters (Chambers, Chambers IV, & Johnson, 2005; Chambers et al., 2016; Prell & Sawyer, 1988). Common distance measuring approaches used in algorithms are average linkage, centroid

linkage, median linkage, furthest neighbor, nearest-neighbor, and Ward's minimum variance linkage (Denis, 2020).

Figure 6.1.

Flow chart of hierarchal agglomerative clustering.



Ward's method is one of the most frequently used methods in agglomerative clustering, is available in many statistical software packages, and was used in this study. Ward's method uses an analysis of variance (ANOVA) type sum of squares as a distance measure between clusters.

Each distance measuring approach has its merits and limitations. Sensory studies on a wide variety of products have used HAC recently (e.g., di Donfrancesco, Gutierrez Guzman, & Chambers, 2019; Godoy et al., 2020; Granato et al., 2018; Sharma et al., 2020; Tran, James, Chambers, Koppel, & Chambers, 2019).

k-means

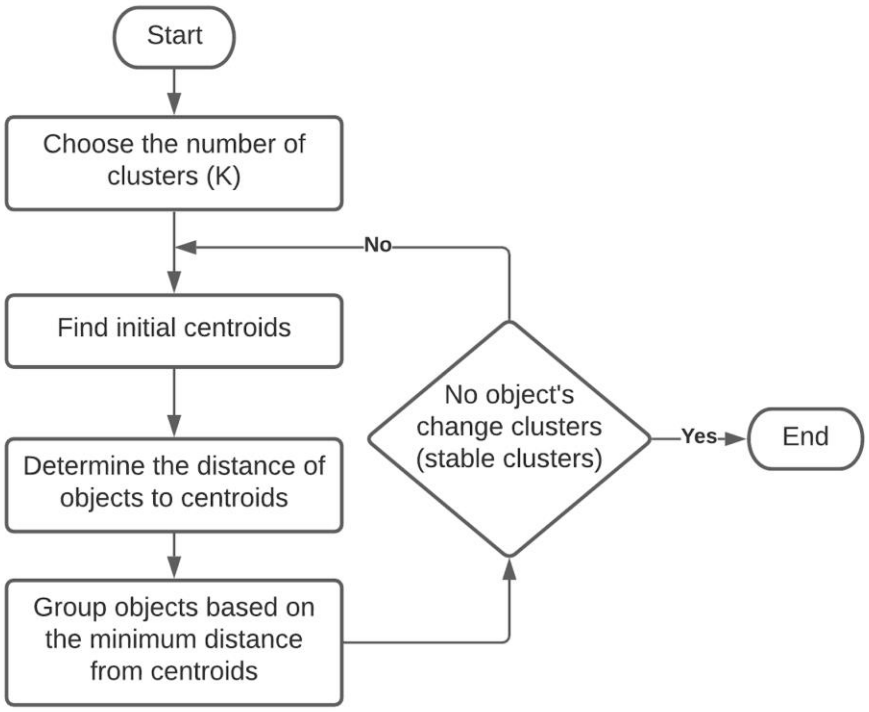
Non-hierarchical methods also known as partitioning methods include the KM method and the FC method (Næs et al., 2018). In both methods, the investigator needs to decide the number of clusters beforehand. The objects can be assigned to clusters based on prior knowledge or considering natural groupings. Another approach is to assign objects to any random number of clusters using an iterative algorithm. The algorithms are run through programs that reassign each object to clusters until homogeneity within-cluster is achieved (Denis, 2020). The KM method assigns each object to a cluster based on its distance (Euclidean) from the center of the cluster, as more objects are added to a cluster, the cluster centroid changes (Figure 6.2). Many sensory studies have used the KM approach in recent years (e.g., Kumar & Chambers, 2019; Sauvageot et al., 2017; Tleis, Callieris, & Roma, 2017).

The KM approach of seeding the cluster center at a new position on every iteration can result in an object changing its association with the final clusters. Thus, researchers are advised to repeat the iteration for object assignments to clusters until no further changes occur. However, the number of iterations that need to be repeated to reach homogeneity within-cluster is not known. It is left to the discretion of the researcher. Many researchers, particularly new or naïve researchers, typically don't run KM algorithms multiple times to obtain the stability of clusters. Also, if the true number of clusters is not known beforehand then the procedure must be repeated

for different numbers of clusters of interest to the researcher. By its nature, the KM method produces many cluster solutions based on the expected number of clusters and different starting seeds. Therefore, the researcher must select the "best" solution that addresses study objectives, a process that can produce a bias toward a particular solution.

Figure 6.2.

Flow chart of k-means clustering.



For this study, the KM approach also was used assuming that the number of clusters was 28 based on the original study. The KM algorithm (R program) was run 30 times (producing 30 cluster solutions) where each run used 1000 iterations to determine the appropriate cluster solution (Table 6.1). A clustering frequency matrix was produced to record the number of times attributes stayed with each other and vice-versa. Each attribute was studied for its frequency of

clustering with each other and compared to the most frequent clustering solution. Using the clustering frequency matrix, clusters were reorganized manually (MC) to produce the best possible representation of clusters (Table 6.2).

Fuzzy clustering

Probabilistic cluster analysis technique a.k.a. FC is where each object is given a degree of membership relative to each cluster (Næs et al., 2018). FC algorithm generates membership values between 0 and 1, to each object for each cluster (Figure 6.3). FC offers the advantages of differentiating objects that are strongly associated with a particular cluster (i.e., degree of membership close to +1.0) from those objects that have some link with more than one cluster (i.e., an equal degree of membership for two or more clusters). In this study, a fuzzy c-means clustering algorithm was applied to cluster attributes but not assign them strictly to one cluster. The objective of FC was to identify attributes that are strongly associated with one cluster and also to understand the floating nature of other attributes. The number of clusters was set to twenty-eight, the number of iterations for each run was set at 1000, the seed was set at random, and the algorithm was run 100 times to produce 100 cluster solutions (Table 6.1). Those 100 outputs were generated and analyzed to observe the clustering patterns, and the output with the highest number of occurrences was selected for final discussion and comparison.

Statistical software

Data analysis was performed using R-studio version R-4.0.0.pkg (R Foundation for Statistical Computing, Vienna, Austria; https://www.r-project.org/). Published packages such as factoMineR, factoextra, fclust (fuzzy clustering), flashClust (Optimal hierarchal clustering),

ggplot2, SensoMineR, and e1071 (e-means FC) were used throughout the analysis. The analysis and results obtained are reproducible within the limits of the methods used.

Figure 6.3.

Flow chart of fuzzy clustering.

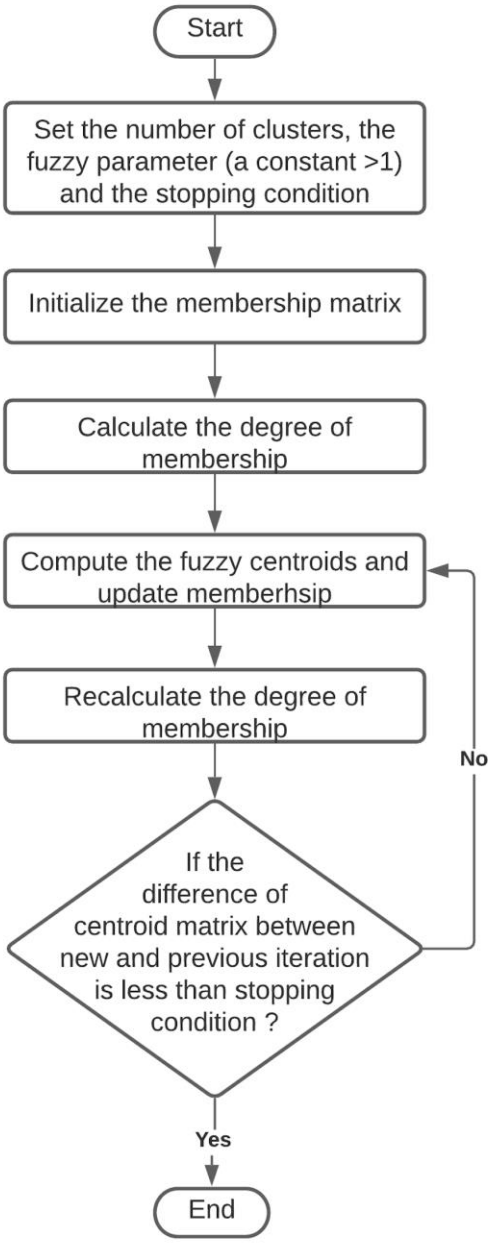


Table 6.2.

Manual clusters reorganized based on the clustering frequency of the k-means method.

		Waxy-H	Waxy-L	Waxy Mouthfeel-MB	Waxy mouthcoat-TH
Cluster-1	Waxy-V	30	30	30	30
	Waxy-H	--	30	30	30
	Waxy-L		--	30	30
	Waxy Mouthfeel-MB			--	30
	Waxy mouthcoat-TH				--
		Pressure on throat-TH	Swallowability-TH		Cohesiveness-TH
Cluster-2	Residuals Throat-TH	15	15		13
	Pressure on throat-TH	--	30		28
	Swallowability-TH		--		28
	Cohesiveness-TH				--
		Roughness of surface-H		Roughness of surface-L	
Cluster-3	Roughness of surface-V	21		21	
	Roughness of surface-H	--		28	
	Roughness of surface-L			--	
Cluster-4	Slickness during swallow-TH				
		Adhesive-L			
Cluster-5	Adhesive-H	30			
		Moistness-H	Moistness-L		
Cluster-6	Moistness -V	28	30		
	Moistness-H	--	28		
	Moistness-L		--		
Cluster-7	Mealy-MB				
		Initial crispness-FB	Sustained crispness-MB		Sustained Fracturability-MB
Cluster-8	Fracturability-FB	29	18		18
	Initial crispness-FB	--	18		18
	Sustained crispness-MB		--		30
	Sustained Fracturability-MB				--
		Fibrous-MB	Fibrous-V		
Cluster-9	Fibrous-FB	30	28		
	Fibrous-MB	--	28		
	Fibrous-V		--		
		Chalky Mouthfeel -MB		Chalky mouthcoat-TH	
Cluster-10	Astringent-MB	30		30	
	Chalky Mouthfeel -MB	--		30	
	Chalky mouthcoat-TH			--	

Cluster-11	Flaky-V					
Cluster-12		Powdery-H	Powdery lip feel-L			
	Powdery-V	26	26			
	Powdery-H	--	30			
	Powdery lip feel-L		--			
Cluster-13		Uniformity of bite-FB				
	Cohesiveness-FB	13				
Cluster 14		Moistness-FB				
	Moistness of mass-MB	16				
Cluster-15	Dissolvability-MB					
Cluster-16		Heat burn-MB	Heat burn-TH	Heat burn-FB	Sting bite-L	
	Heat burn-L	20	20	20	29	
	Heat burn-MB	--	30	30	19	
	Heat burn-TH		--	30	19	
	Heat burn-FB			--	19	
	Sting bite-L				--	
Cluster-17	Springiness-H (13)					
Cluster-18		Greasy-H	Greasy-L	Oily-V	Oily-H	Oily-L
	Greasy-V	21	21	23	14	14
	Greasy-H	--	30	14	22	22
	Greasy-L		--	14	22	22
	Oily-V			--	21	21
	Oily-H				--	29
	Oily-L					--
Cluster-19		Smoothness-H	Smoothness-L	Uniformity of surface-V		
	Smoothness-V	18	30	24		
	Smoothness-H	--	18	18		
	Smoothness-L		--	24		
	Uniformity of surface-V			--		
Cluster-20	Particle amount-V					
Cluster-21		Cooling-MB	Doughy-MB	Sting bite-MB	Tongue Tingle-MB	
	Melt in Hand-H	26	26	26	26	
	Cooling-MB	--	30	30	30	
	Doughy-MB		--	30	30	
	Sting bite-MB			--	30	
	Tongue Tingle-MB				--	
Cluster-22		Chew count-MB	Cohesiveness of mass-MB			
	Firmness-FB	30	22			
	Chew count-MB	--	22			
	Cohesiveness of mass-MB		--			
Cluster-23			Adhesive to teeth-MB			
	Adhesive to teeth-FB		27			
Cluster-24		Gritty-L	Particle amount-L			
	Gritty-H	29	26			
	Gritty-L	--	26			
	Particle amount-L		--			
Cluster-25		Effervescence-MB				
	Effervescence-FB	30				

Cluster-26	Oily Mouthfeel-MB		Oily mouthcoating-TH 30	
Cluster-27		Roughness of mass-MB	Roughness of swallow-TH	Residuals Mouth-TH
	Particles amount-MB	29	29	14
	Roughness of mass-MB	--	30	14
	Roughness of swallow-TH		--	14
	Residuals Mouth-TH			--

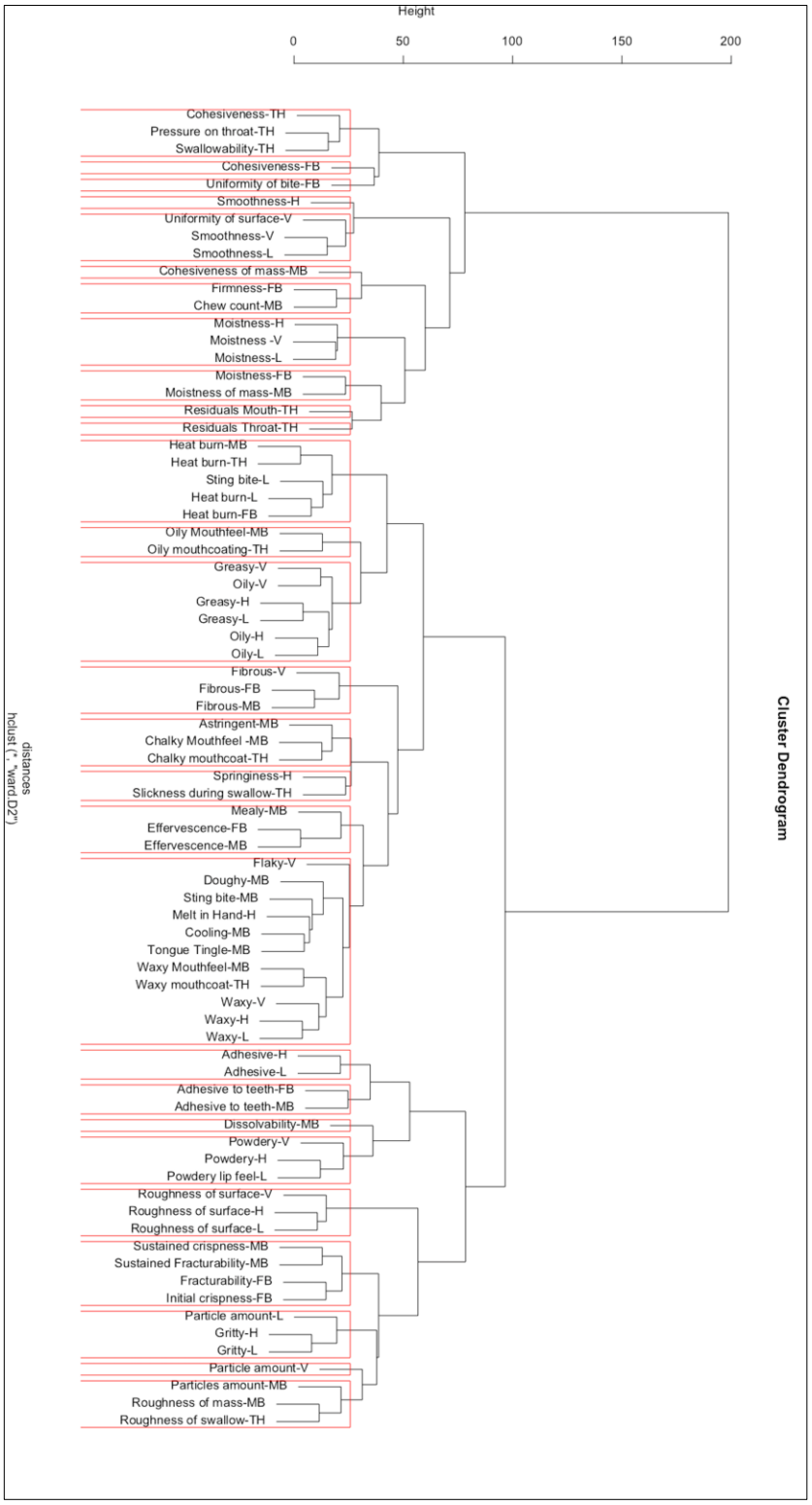
Results

Hierarchical clustering

HAC Ward's method clustered texture attributes measured by non-oral senses (vison, hand-feel, and lips) and oral senses (Kumar & Chambers, 2019). Using Ward's method again in this research, the HAC analysis-maintained groupings of attributes that were the same although measured by different senses into the same cluster (Figure 6.4). For example, 1) smoothness-V, H, L, and uniformity of surface-V, 2) moistness-V, H, and L, 3) moistness-FB and moistness of mass-MB, 4) residual mouth-TH and residual throat-TH, 5) heat burn-MB, TH, L, FB, and sting bite-L, 6) oil mouthfeel-MB and oil mouth coating-TH, 7) greasy-V, H, L, and oil-V, H, L, 8) fibrous-V, FB, and MB, 9) chalky mouthfeel-MB and chalky mouth coat-TH, 10) effervescence-FB and MB, 11) waxy mouthfeel-MB, waxy mouth coat-TH, waxy-V, H, and L, 12) adhesive-H and L, 13) adhesive to teeth-FB and MB, 14) powdery-V, H, and L, 15) roughness of surface-V, H, and L, 16) sustained crispness-MB, sustained fracturability-MB, fracturability-FB, and initial crispness-FB, 17) particle amount-L, gritty-H, and L, 18) particle amount-V, MB, the roughness of mass-MB, and roughness of swallow-TH (Figure 6.4)

Figure 6.4.

Dendrogram for hierarchal agglomerative clustering using Ward's method showing attribute clusters.



The major challenge with Ward's was to find the true number of clusters and a mechanism to deal with attributes that clustered together but had no meaning from a sensory point of view. For example, 1) springiness-H and slickness during swallow-TH or 2) flaky-V, doughy-MB, sting bite-MB, cooling-MB, tongue tingle-MB (Figure 6.4) formed clusters. However, attributes like springiness and slickness neither share obvious structural relationships nor causes that would necessarily result in those attributes grouping together. The same could be said for flaky, dough, sting, cooling, and tongue tingle some of which are purely textural and others that have both a textural and a trigeminal component. The scree plot produced by HAC, a classic way to evaluate the number of clusters, implies that the number of clusters can be any number between twenty and thirty (Figure 6.5). The sharpest elbow or flattening of the sum of squared residuals curve (Wilderjans & Cariou, 2016), suggests that the optimum number of clusters could be just below thirty (Figure 6.5). The HAC approach is not designed to cluster objects for a specified number of clusters, instead, that number must be chosen based on interpretation of aspects such as scree plot, visual inspection, and interpretation of the clusters.

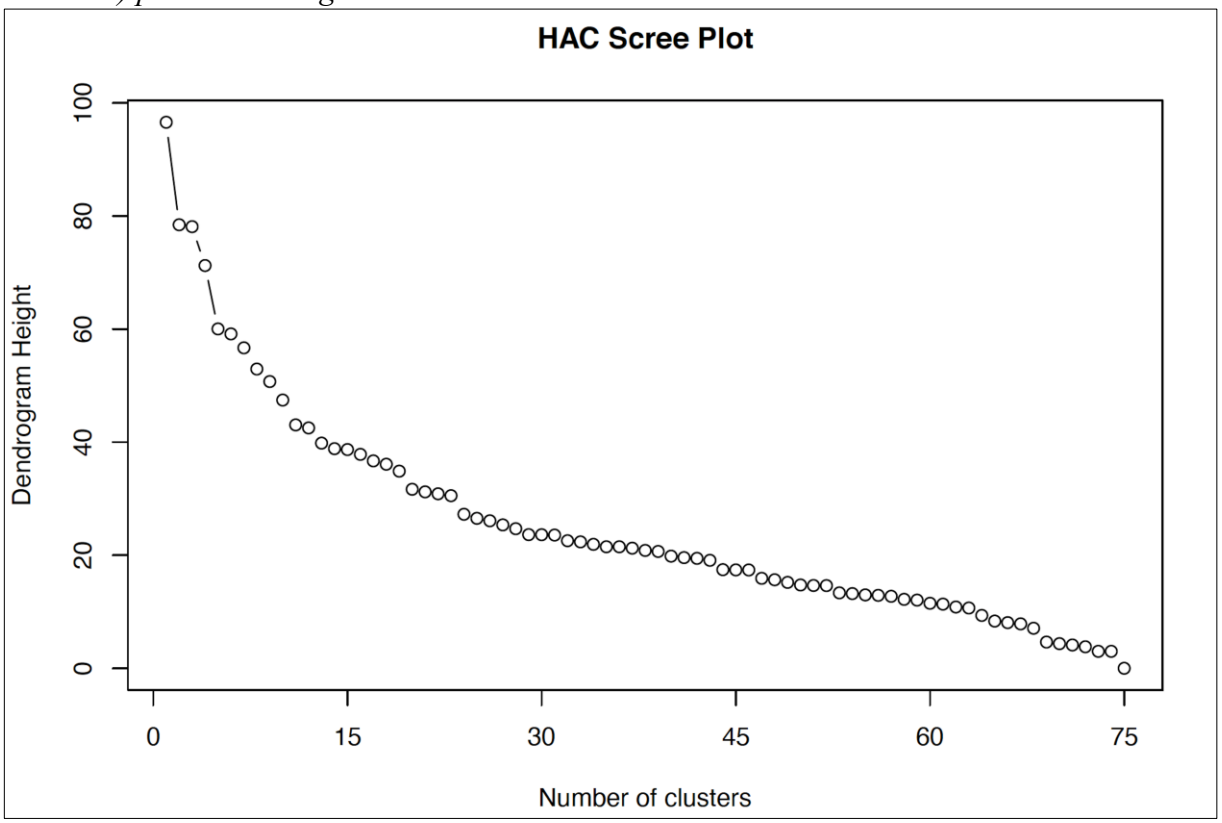
HC methods are used for simplicity and dendrograms are useful for visual inspection, and selection of clusters. Clusters formed using mathematical algorithms by HC methods may look natural, but it may not be a correct representation of true clusters (Denis, 2020). Additionally, because HC uses a variety of linkage options (single, complete, average, and centroid), each linkage could yield different clustering solutions (Denis, 2020; James, Witten, Hastie, & Tibshirani, 2013).

HC methods do not depend on initialization and a chosen number of clusters beforehand (Næs et al., 2018). However, clusters overlap in HC solutions, and HC methods are less sensitive to noise. Therefore, the method may not be suitable for large data sets, including those in

consumer studies (Wajrock et al., 2008). The main problem with HC methods is that the merges are final and there is no option for reassigning an object that was clustered at earlier stages. This could avert global optimization, specifically when there are no true clusters in the data, but HC will always form clusters (Næs et al., 2018).

Figure 6.5.

Scree plot with the number of clusters plotted against the dendrogram height (sum of squared residuals) produced using HAC Ward's method.



k-means

The number of clusters was kept at twenty-eight used by Kumar and Chambers (2019). While examining the KM clustering solutions, we noticed that one clustering solution occurred more frequently than others, and that was the one published by Kumar and Chambers (2019). However, the movement of attributes within clusters never stopped.

The clustering frequency matrix can be used to identify strong, moderate, and weak links of attributes with each other (Table 6.2). Attributes with a frequency greater than 25 could be considered strong associations meaning 84% (0.84 out of 1) chance of clustering consistently. For example, clusters 1, 5, 6, 9, 10, 12, 21, 23, 24, 25, and 26 (Table 6.2). In the FC method, which is a generalization of KM, and uses many of the same principles to achieve clustering, objects with membership values close to 1 are considered as almost certainly in that cluster or group (Bedalli, Mançellari, & Asilkan, 2016; Næs et al., 2018). Thus, we used that standard for KM as well.

Besides, components (attributes) within clusters in which a few attributes have a high frequency of clustering (≥25) while others are lower can also be termed as strong associations. For example, in cluster-2 pressure on throat-TH, swallowability-TH, and cohesiveness-TH) have a high frequency of clustering (≥28) with each other and that relationship is stronger than with residual throat-TH (≤15) (Table 6.2).

Attributes with the frequency between ≥15 to <25 could be termed as moderate associations, and ≤15 could be termed as weak associations. Attributes with frequency ≤15, were changing cluster associations on every other run of the KM algorithm. Attributes that mostly remained independent, are the most distinguishing ones. For example, slickness during swallow-

TH, mealy-MB, flaky-V, dissolvability-MB, springiness-H, and particle amount-V. These attributes never clustered with any other attribute (Table 6.2).

Thus, an MC solution was produced using the clustering frequency matrix and the use of manual clustering reduced the number of clusters to twenty-seven (Table 6.2). The total mean variability explained by KM was 87.3%. Out of 27 manual clusters, 19 (68%) clusters matched exactly as they were published in the earlier work (Kumar & Chambers, 2019). Nine clusters that didn't match, were not completely different but had one or two attributes moved to different clusters. These attributes had a higher frequency of association with other attributes that were not captured in the previous publication. For example, fibrous-V was independent but clustered 28 times with fibrous-FB and MB. Therefore, fibrous-V, FB, and MB were all put into one cluster together (Table 6.2).

Comparison between HAC and KM frequency-based MC

An assessment of KM, HAC, and FC results is presented in Table 6.3. All 76 attributes are included in KM results, and clusters were compared to HAC results. HAC clusters that didn't match the KM clusters were not included in Table 6.3. The dissimilar attributes either remained independent or formed new associations (not shown in the table). Fifteen (56%) of KM clusters (3, 5, 6, 8, 9, 10, 12, 14, 15, 16, 18, 23, 24, and 26) were found to be similar in HAC results. These 15 clusters can be said to have a very strong association with each other and could also be termed as true clusters. These true clusters are confirmed both in the KM and HAC approach.

Six clusters (1, 2, 19, 22, 25, and 27) had either additional attributes joining the cluster or attributes moved out of the cluster (Table 6.3). The changing attributes of these six clusters can be termed as dominant attributes in cases where they mostly remained independent and form

single attribute clusters. Attributes that constantly changed irrespective of the clustering method can be called changing attributes. The clusters formed by these changing attributes are unreliable, lack stability and repeatability. The percentage of dissimilarity between the KM and HAC was 44% percent, which can not be understood until results from both clustering approaches are compared. Researchers can adapt this methodology in their solutions to classify clusters as true clusters and changing clusters (Denis, 2020).

Correlation co-efficient and k-means MC

The attributes clustered by the KM approach also were investigated for their correlation coefficients. A scatterplot was generated to examine the relationship between the frequency of clustering and correlation values (Figure 6.6). It was found that few attributes had a very high frequency of clustering (30) but had correlation values varying from low to high. For example, waxy-V and waxy mouth coat-TH were clustered in all KM solutions (30) but had moderate correlation (0.54), waxy mouthfeel-MB and waxy mouth coat-TH clustered in all KM solutions but had very high correlation (0.97), and cooling-MB and tongue tingle-MB clustered in all KM solutions but were negatively correlated (-0.04). This study presents strong evidence of no relationship between KM cluster solutions and correlation coefficients (Figure 6.6).

Table 6.3.

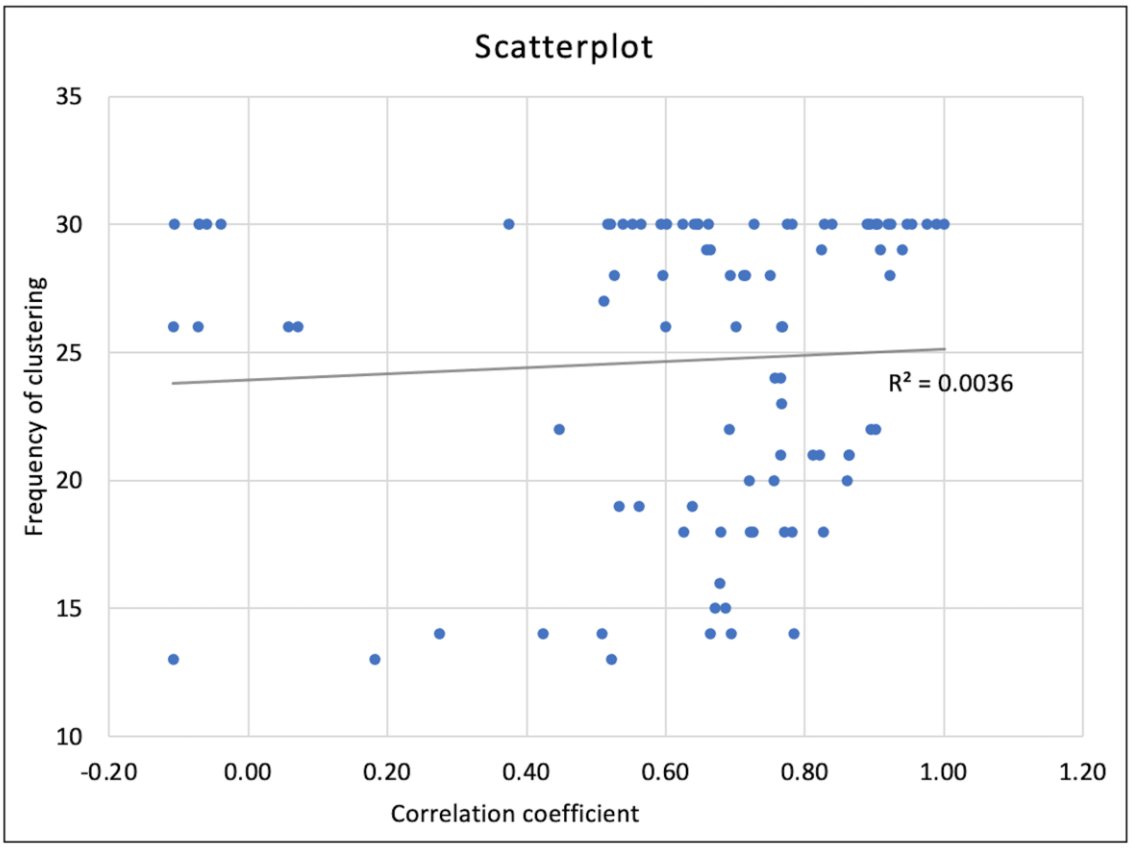
Comparison of the k-means, HAC, and fuzzy approach cluster results.

Clusters	K-means frequency-based MC	HAC	Fuzzy
Cluster-1	Waxy-V Waxy-H Waxy-L Waxy Mouthfeel-MB Waxy mouthcoat-TH	Waxy-V Waxy-H Waxy-L Waxy Mouthfeel-MB Waxy mouthcoat-TH Melt in Hand-H Cooling-MB Doughy-MB Sting bite-MB Tongue Tingle-MB Flaky-V	Waxy-V Waxy-H Waxy-L Waxy Mouthfeel-MB Waxy mouthcoat-TH
Cluster-2	Residuals Throat-TH Pressure on throat-TH Swallowability-TH Cohesiveness-TH	Pressure on throat-TH Swallowability-TH Cohesiveness-TH	Pressure on throat-TH Swallowability-TH Cohesiveness-TH
Cluster-3	Roughness of surface-V Roughness of surface-H Roughness of surface-L	Roughness of surface-V Roughness of surface-H Roughness of surface-L	
Cluster-4	Slickness during swallow-TH	Slickness during swallow-TH Springiness-H	
Cluster-5	Adhesive-L Adhesive-H	Adhesive-L Adhesive-H	Adhesive-L Adhesive-H Adhesive to teeth-FB
Cluster-6	Moistness -V Moistness-H Moistness-L	Moistness -V Moistness-H Moistness-L	Moistness -V Moistness-H Moistness-L
Cluster-7	Mealy-MB		
Cluster-8	Fracturability-FB Initial crispness-FB Sustained crispness-MB Sustained Fracturability-MB	Fracturability-FB Initial crispness-FB Sustained crispness-MB Sustained Fracturability-MB	Fracturability-FB Sustained crispness-MB Sustained Fracturability-MB
Cluster-9	Fibrous-FB Fibrous-MB Fibrous-V	Fibrous-FB Fibrous-MB Fibrous-V	Fibrous-V Fibrous-FB Fibrous-MB
Cluster-10	Astringent-MB Chalky Mouthfeel -MB Chalky mouthcoat-TH	Astringent-MB Chalky Mouthfeel -MB Chalky mouthcoat-TH	
Cluster-11	Flaky-V		

Clusters	K-means frequency-based MC	HAC	Fuzzy
Cluster-12	Powdery-V Powdery-H Powdery-L	Powdery-V Powdery-H Powdery-L	Powdery-H Powdery-L Chalky Mouthfeel-MB Chalky mouthcoat-TH
Cluster-13	Uniformity of bite-FB Cohesiveness-FB		Uniformity of bite-FB Cohesiveness-TH
Cluster 14	Moistness-FB Moistness of mass-MB	Moistness-FB Moistness of mass-MB	Moistness-FB Moistness of mass-MB

Figure 6.6.

Scatter plot representing the clustering frequency of attributes in the k-means method and correlation coefficient.



Fuzzy clustering

The mean degree of membership for each attribute produced by using a fuzzy c-means algorithm is represented in Figure 6.7. The mean degree of membership ranged from 0.963 to 0.453, and the highest degree of membership of all attributes ranged from 0.997 to 0.71 and the minimum ranged from 0.025 to 0.001. Because of the large range of mean values, it was difficult to identify which association to use in a final cluster solution.

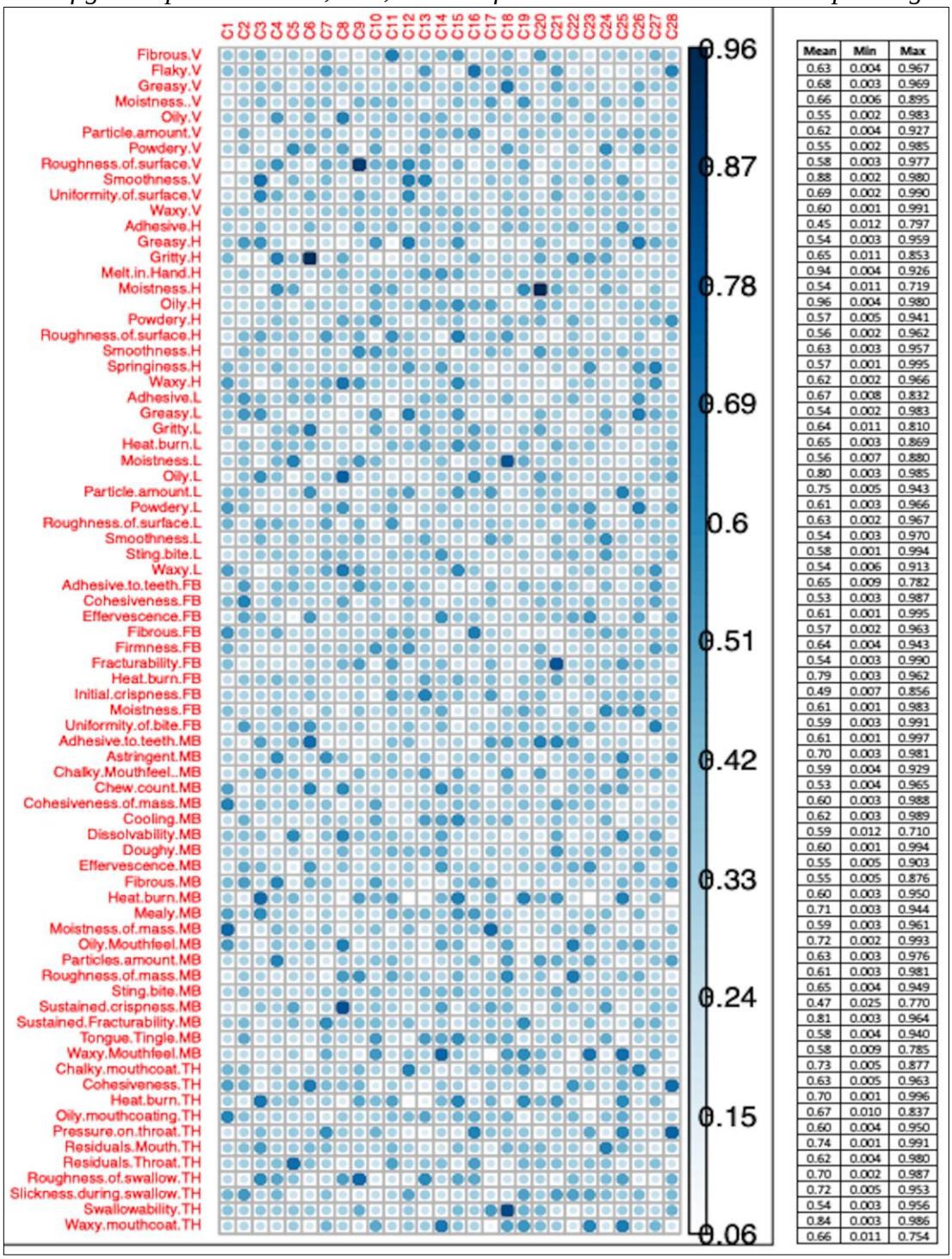
The range of degree of membership for each attribute to clusters also was large. For example, Fibrous-V had a mean (0.63), max (0.967), and min (0.004) degree of membership with cluster-11 (Figure 6.7). A similar pattern was noticed for other attributes. The degree of association for attribute to clusters kept changing on every run, resulting in a large range of mean values. Few clusters solutions were repeated more often than others, five FC solutions are presented as an example in Figure 6.8 (a, b, c, d, and e). The most frequent FC solution was compared with the KM frequency-based manual cluster solution in Table 6.3.

Comparison between fuzzy and k-means frequency-based MC

Only 45% of the cluster were alike between the FC and KM solution. Twelve clusters (1, 5, 6, 9, 13, 14, 18, 19, 21, 22, 24, and 25) were identical (Table 6.3), and four clusters (2, 8, 12, 16) had either one or more than one attribute changing its association with clusters. The clustering result from the KM approach only translates at a meager 45% in the fuzzy approach, which means the dissimilarity between clustering solutions was high (55%).

Figure 6.7.

Mean degree of membership for each attribute obtained by c-means fuzzy. A small table attached to the figure represents mean, max, and min for each attribute to the corresponding cluster.



Mean	Min	Max
0.63	0.004	0.967
0.68	0.003	0.969
0.66	0.006	0.895
0.55	0.002	0.983
0.62	0.004	0.927
0.55	0.002	0.985
0.58	0.003	0.977
0.88	0.002	0.980
0.69	0.002	0.990
0.60	0.001	0.991
0.45	0.012	0.797
0.54	0.003	0.959
0.65	0.011	0.853
0.94	0.004	0.926
0.54	0.011	0.719
0.96	0.004	0.980
0.57	0.005	0.941
0.56	0.002	0.962
0.63	0.003	0.957
0.57	0.001	0.995
0.62	0.002	0.966
0.67	0.008	0.832
0.54	0.002	0.983
0.64	0.011	0.810
0.65	0.003	0.869
0.56	0.007	0.880
0.80	0.003	0.985
0.75	0.005	0.943
0.61	0.003	0.966
0.63	0.002	0.967
0.54	0.003	0.970
0.58	0.001	0.994
0.54	0.006	0.913
0.65	0.009	0.782
0.53	0.003	0.987
0.61	0.001	0.995
0.57	0.002	0.963
0.64	0.004	0.943
0.54	0.003	0.990
0.79	0.003	0.962
0.49	0.007	0.856
0.61	0.001	0.983
0.59	0.003	0.991
0.61	0.001	0.997
0.70	0.003	0.981
0.59	0.004	0.929
0.53	0.004	0.965
0.60	0.003	0.988
0.62	0.003	0.989
0.59	0.012	0.710
0.60	0.001	0.994
0.55	0.005	0.903
0.55	0.005	0.876
0.60	0.003	0.950
0.71	0.003	0.944
0.59	0.003	0.961
0.72	0.002	0.993
0.63	0.003	0.976
0.61	0.003	0.981
0.65	0.004	0.949
0.47	0.025	0.770
0.81	0.003	0.964
0.58	0.004	0.940
0.58	0.009	0.785
0.73	0.005	0.877
0.63	0.005	0.963
0.70	0.001	0.996
0.67	0.010	0.837
0.60	0.004	0.950
0.74	0.001	0.991
0.62	0.004	0.980
0.70	0.002	0.987
0.72	0.005	0.953
0.54	0.003	0.956
0.84	0.003	0.986
0.66	0.011	0.754

The numbers on the top of the figure represent cluster numbers (identifiers) and the vertical axis on the right-hand side of the figure represents the degree of attribute membership with clusters.

Discussion

Fifty-six percent of clusters were alike between the KM and HAC, and 45% between KM and fuzzy. Some clusters were completely different, but some clusters had similarities. No method produced the same clusters. Results showed that having common attributes and different attributes in each cluster is dependent on the approach used. For example, cluster-1 produced by MC was different for HAC but was similar in FC's most repeated solution.

Evidence produced in this study suggests that algorithms (methods) used to determine clusters had a significant impact on clustering solutions as noted by Denis (2020). HAC Ward's method assigns an object to a cluster that minimizes the squared Euclidean distance to the cluster mean. In contrast, KM partitions object into a predefined cluster number and then assigns each object to the cluster whose centroid is closet (Denis, 2020; Næs et al., 2018). The cluster arrangement is always dependent on the method used (Yenket & Chambers, 2017; Yenket et al., 2011). The clusters that are alike in all three methods or at least in KM and HAC likely are true clusters and, therefore, can confidently become a part of the final results perspective. James et al. (2013) also concluded that consistent clusters obtained from multiple methods can become part of a final clustering solution.

Each clustering method has advantages and limitations. The KM clustering is hard partitioning where each object belongs to only one cluster but obtaining stability in results is challenging. The one advantage this study applied by using the KM approach is producing a clustering frequency matrix for 30 KM solutions. The frequency matrix helped to reorganize the clusters manually. Researchers can use a frequency matrix to identify strong, moderate, and weak associations of objects to corresponding clusters. While performing KM clustering, it is advised to run the algorithms until 1) stability is reached, 2) identify true and changing clusters,

3) obtain the frequency of clustering, and 4) return to original data to see if results can be explained logically. For the KM approach, true clusters would be the one with the highest frequency of clustering, but the result must be compared with cluster solutions obtained from other methods to ensure that the frequency is set to a high enough threshold.

Vigneau et al. (2016) and Wajrock et al. (2008), concluded that "partitioning methods outperform hierarchical methods". The conclusion may be true for consumer studies with a specific type of data. However, this study results do not support that conclusion, especially for descriptive data with a large number of variables. The KM method is sensitive to noise, and thus, not efficient with high dimensional data (Næs et al., 2018).

HAC methods are widely used in sensory studies and the graphical representation of clusters by HC dendrograms or trees allows the visualization of clusters which facilitates the interpretation of results (Zielinski et al., 2014). The potential limitations of HAC are, 1) overlapping of clusters, 2) variety of linkage methods yield nonunique cluster solutions, 3) once merged, objects cannot be reallocated, 4) does not always recover true clusters, and 5) does not offer any mechanism to assess if clusters are stable or changing (Denis, 2020; James et al., 2013; Næs et al., 2018; Wajrock et al., 2008).

In practice, it is recommended to start with HAC beforehand, to help select the number of clusters (k) to begin using KM. The scree plot generated by the HAC approach can aid in deciding the initial number of clusters (Wilderjans & Cariou, 2016). The KM algorithm seeds the clusters randomly and repositions the random seeding to a different place for every iteration. The researchers could run the KM algorithm iteratively until stability is reached. However, this study provides evidence that reaching stability may not be possible with descriptive data and additional or alternative methods may be needed. Thus, other applied statistics tools should be used (i.e.,

MC based on the frequency of clustering or some other technique) to determine stability in cluster solutions (Yenket et al., 2011). Studies have suggested several other tools that may help to decide the numbers of clusters and stability in cluster patterns. For example, aggregation criterion evolution plots (Vigneau & Qannari, 2002), variability plots (Kumar & Chambers, 2019), a combination of factor analysis, HAC and KM (Müller & Hamm, 2014), and a combination of PCA and HAC (Juárez-Barrientos et al., 2019).

Correlation coefficients do not have any clear relationship with the object's clusters (Figure 6.6). For example, in MC clusters 9, 10, and 21 (Table 6.2), the frequency of clustering was between 26 to 30, but the correlation values varied from -0.07 to 0.92. This trend of varying correlation values is also true for strong associations in cluster-1 (Table 6.2). Therefore, researchers should not use correlation coefficients as a tool to validate true or natural clusters. Granato et al. (2018), concluded that correlation values and HAC cluster results are not related.

A large range of degrees of membership was produced by FC. Only 45% of fuzzy clusters were comparable to the KM clusters. Even after running the algorithms 100 times with 1000 iteration for each run, the mean degree of membership doesn't help to distinguish true and changing clusters. The various cluster solutions in Figure 6.8 (a, b, c, d, and e), indicate that FC is likely to give spurious cluster solutions. Westad, Hersleth, and Lea (2004) also reported a high risk of finding erroneous consumer clusters in FC.

The comparison of frequency-based MC, HAC, and fuzzy clusters indicates that cluster solution based on frequency matrix yielded more common clusters (15) with HAC (Table 6.3). Six other clusters (1, 2, 19, 22, 25, and 27) were not completely similar but certainly had more commonality than fuzzy clustering (Table 6.3). The evidence suggests that KM and HAC did a better job of obtaining similar clusters than fuzzy.

None of the individual approaches can be termed as the best approach. HAC aids in deciding the initial number of clusters (k) that researchers can use to begin and explore partitioning methods. The KM provided an advantage in developing a frequency matrix for MC, to help identify true and changing clusters. Both KM and HAC helped to identify common clusters. The fuzzy approach showed that an object's degree of membership to a particular cluster may vary greatly and there likely will always be a few objects that are going to have a very high degree of membership. However, the degree of membership changed on every algorithm run. Thus, researchers must try different clustering methods to determine what works best for their data and study objectives.

The findings of this study are limited because they are based on a specific descriptive data set. However, that data set easily shows the fallacy of researchers using only one cluster analysis technique to determine the groups. Thus, researchers are advised not to use one clustering method as a "fits all" approach. The application of this study results may vary from case to case.

Conclusion

The application of clustering methodology is a common phenomenon in sensory studies. Different methods are used to determine clusters but there is no agreed-upon or common set of rules concerning which method to use, the exact number of clusters, or which linkage is best. Clustering is inherently subjective, and this study shows that clustering applications cannot provide definitive and unique solutions; rather they usually offer one of many possible solutions (Denis, 2020). Researchers must be cautious with interpretations of CA. The reality of clusters

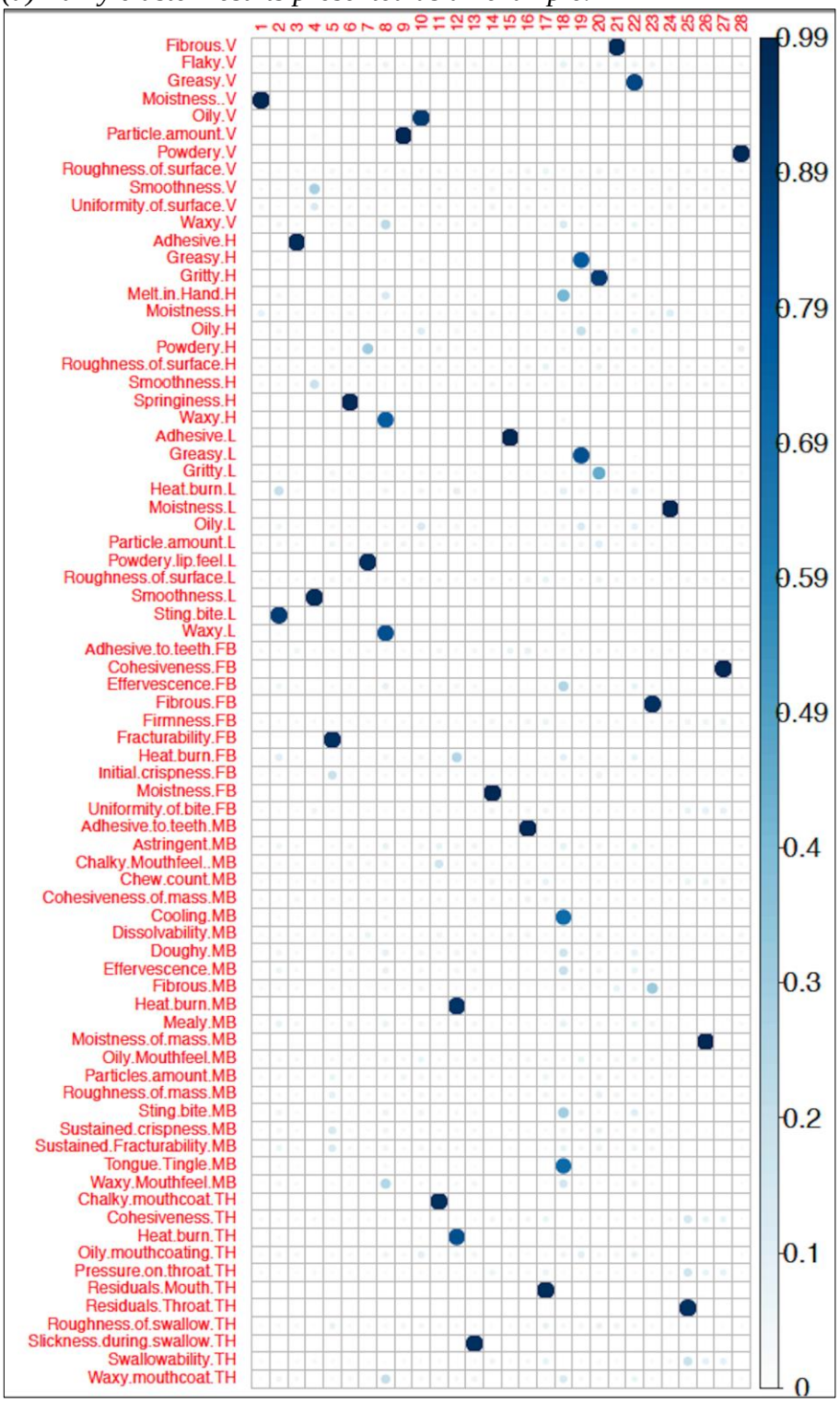
depends on the choices made by the investigator and with many of these choices being subjective, they can significantly change cluster results.

Results, of this study, showed that none of the clustering methods (KM, HAC, and fuzzy) can be said to be the best approach. Each method has its advantages and limitations. For example, HAC doesn't need initialization to begin, helps to visualize clusters, and scree plot assist to find an initial number of clusters. The KM could be used to obtained non-overlapping clusters. The clustering frequency matrix produced from KM solutions helped determine stable and changing objects in the clusters. Also, the frequency matrix helped to identify associations in terms of strong, moderate, and weak. A clustering frequency matrix can be used to perform manual clustering.

In practice, researchers should try several different methods, compare cluster results, must run algorithms for multiple iterations, focus on finding homogenous and repeatable clusters, and look for one with the most useful or interpretable solution. Mere, the use of one clustering method in all sensory studies probably is inappropriate. Thus, researchers must have a fundamental and theoretical knowledge of the chosen methods, their application, and limitations. The investigator must try different clustering methods to determine what works best for their data, always refer to raw data, and results must meet study objectives.

Figure 6.8.

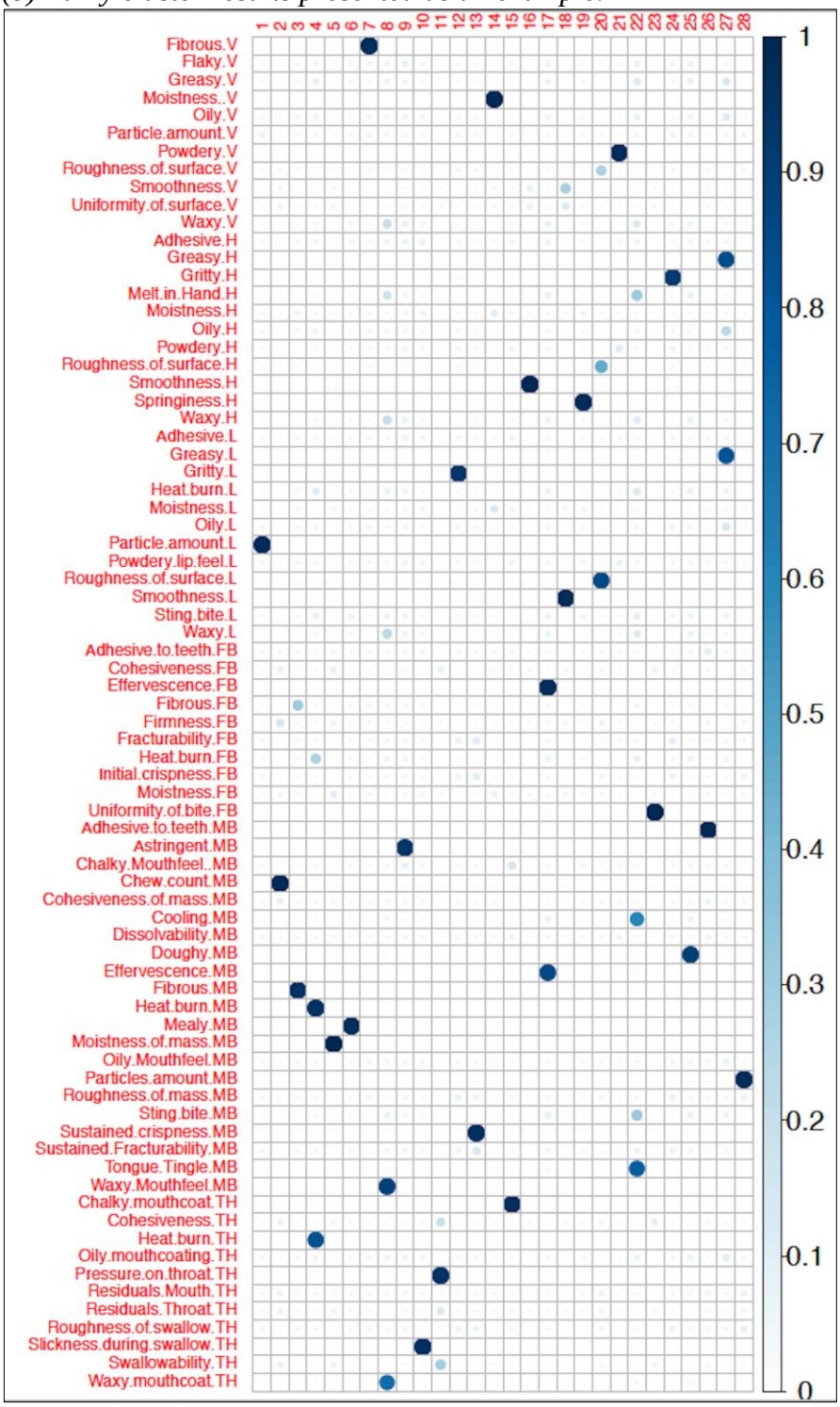
(a) Fuzzy cluster results presented as an example.



The numbers on the top of the figure represent cluster numbers (identifiers) and the vertical axis on the right-hand side of the figure represents the degree of attribute membership with clusters.

Figure 6.8.

(b) Fuzzy cluster results presented as an example.



The numbers on the top of the figure represent cluster numbers (identifiers) and the vertical axis on the right-hand side of the figure represents the degree of attribute membership with clusters.

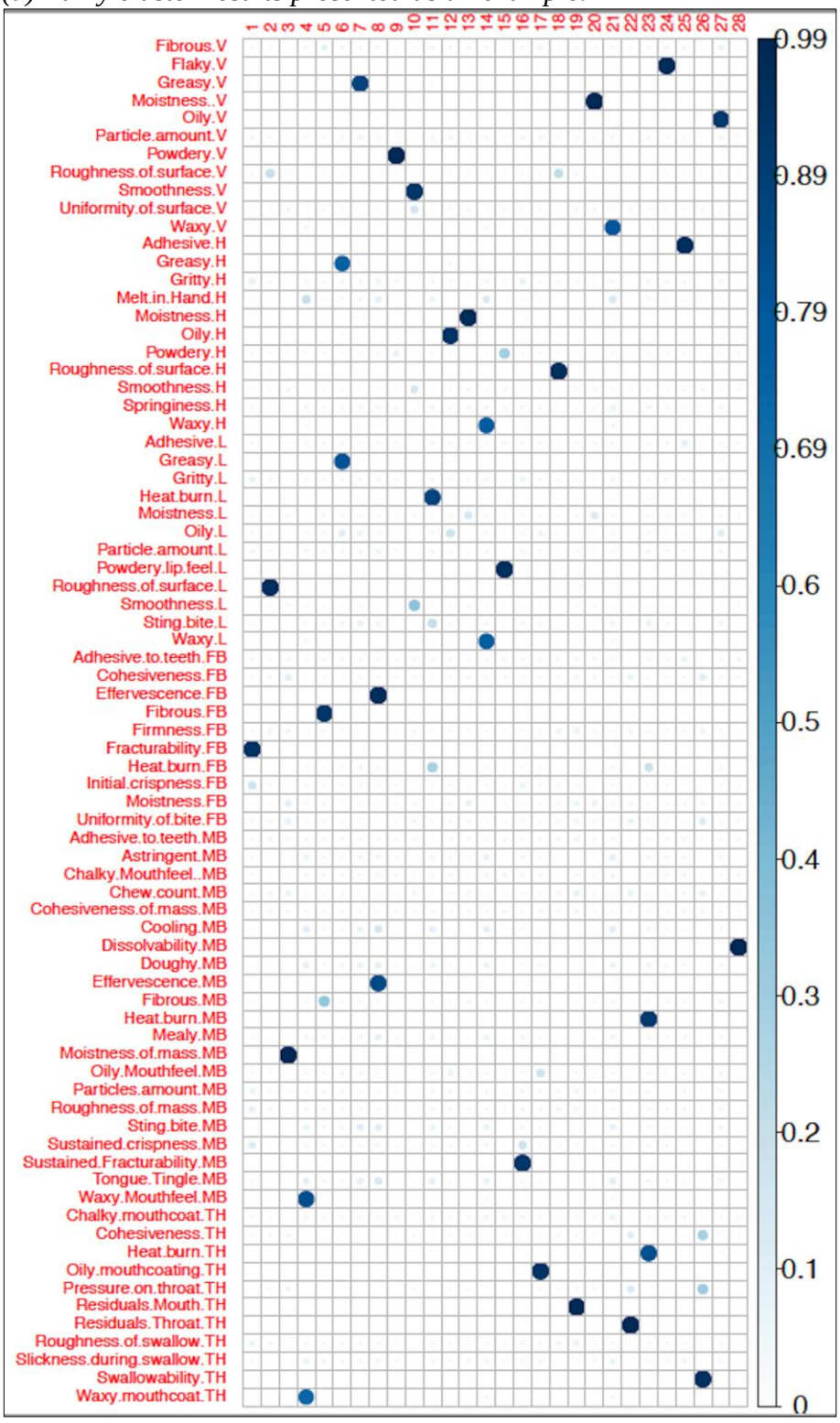
Figure 6.8.

(c) Fuzzy cluster results presented as an example.

The numbers on the top of the figure represent cluster numbers (identifiers) and the vertical axis on the right-hand side of the figure represents the degree of attribute membership with clusters.

Figure 6.8.

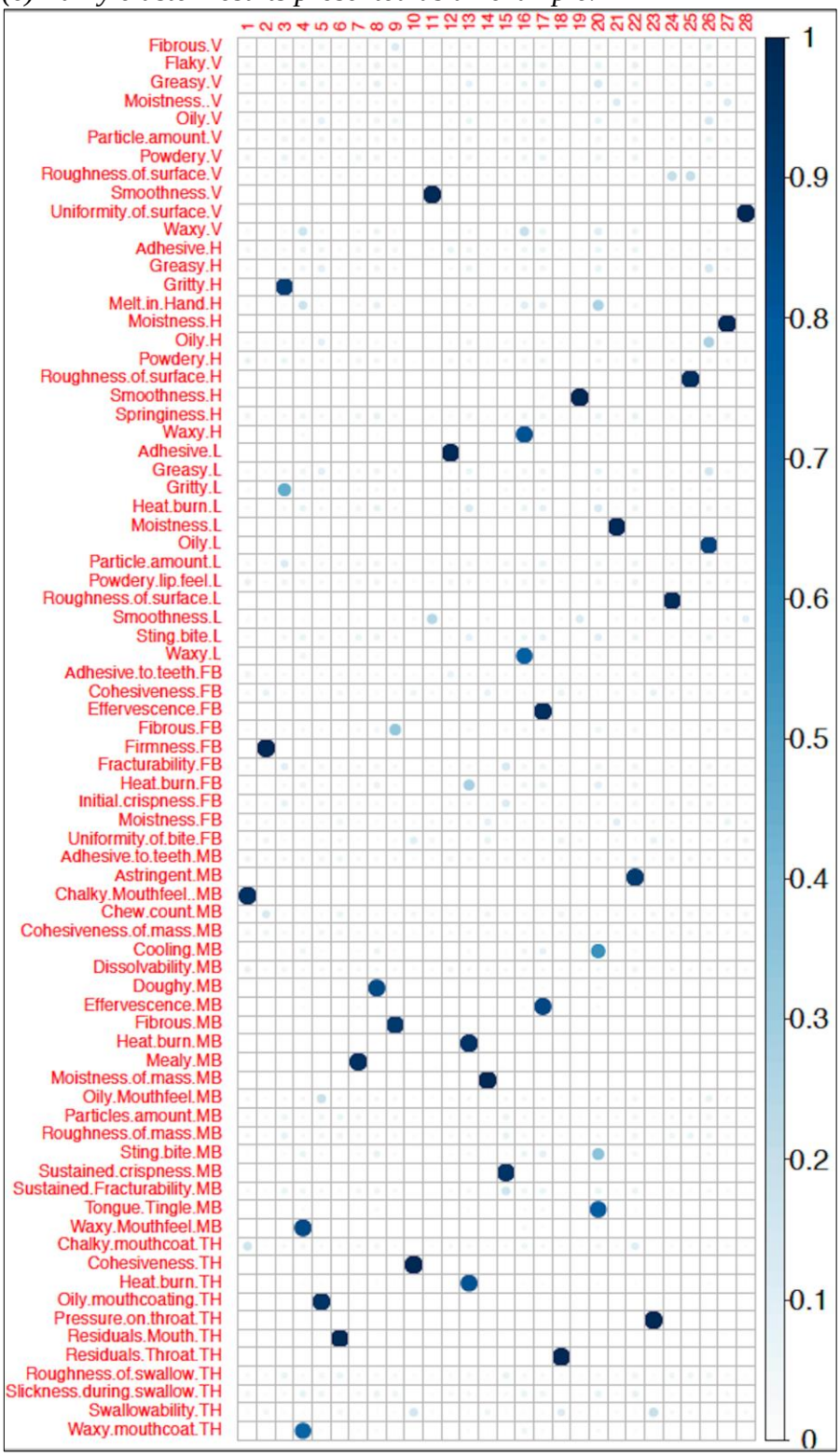
(d) Fuzzy cluster results presented as an example.



The numbers on the top of the figure represent cluster numbers (identifiers) and the vertical axis on the right-hand side of the figure represents the degree of attribute membership with clusters.

Figure 6.8.

(e) Fuzzy cluster results presented as an example.



The numbers on the top of the figure represent cluster numbers (identifiers) and the vertical axis on the right-hand side of the figure represents the degree of attribute membership with clusters.

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Appendix A - Additional Data Figures

Figure A.1.

Texture attributes loadings for principal component 3.

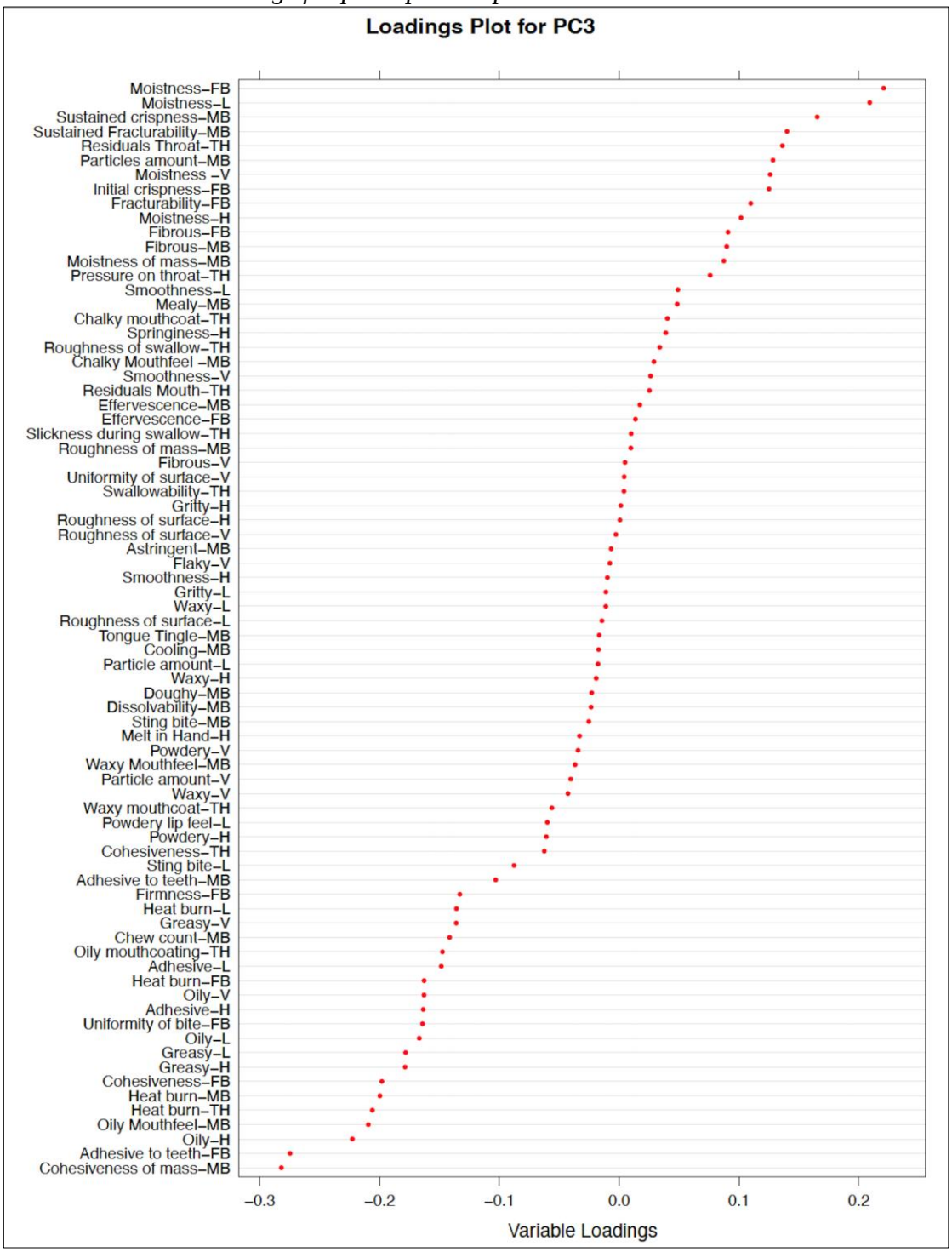

Figure A.2.

Texture attributes loadings for principal components 4.

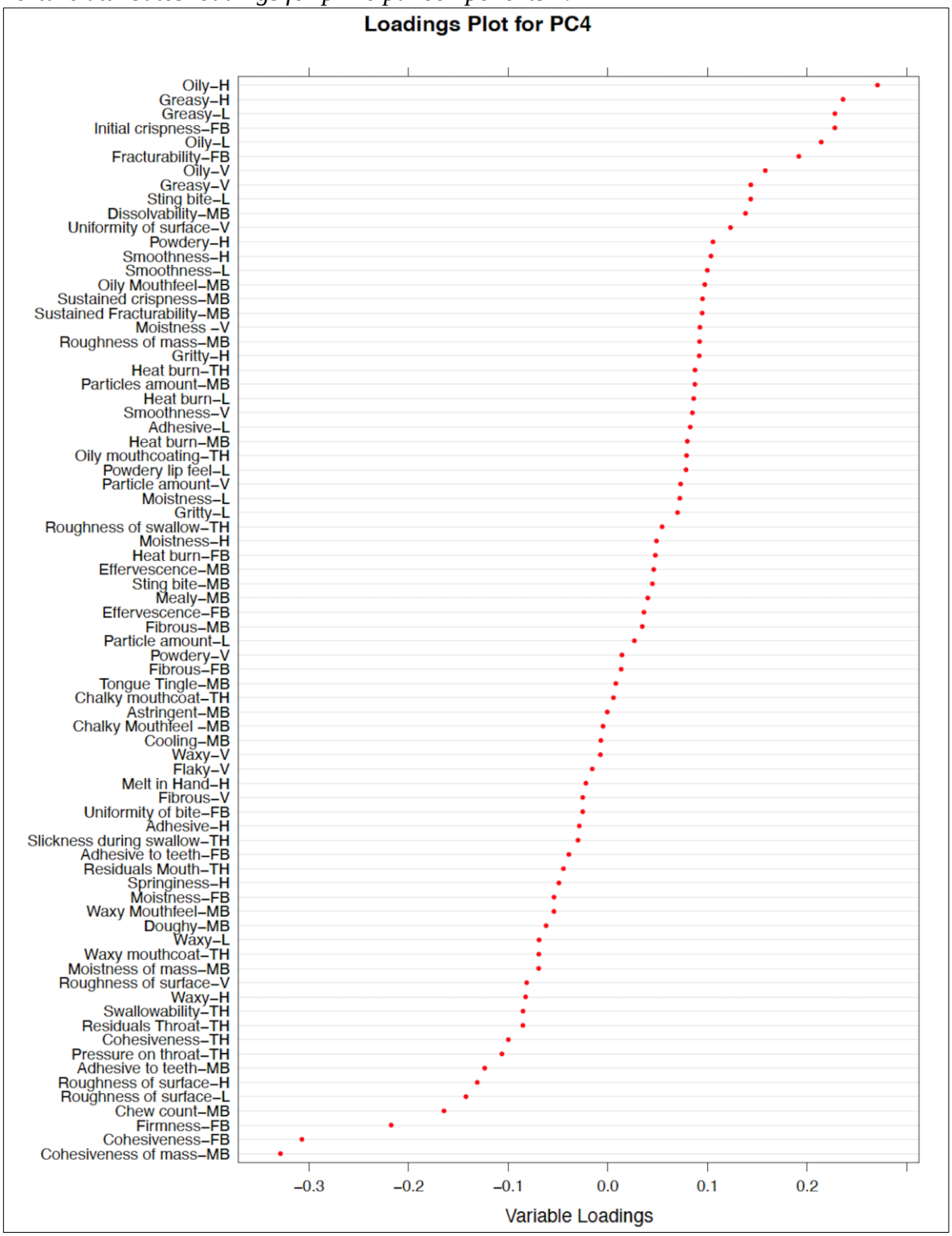

Figure A.3.

Texture attributes loadings for principal components 5.

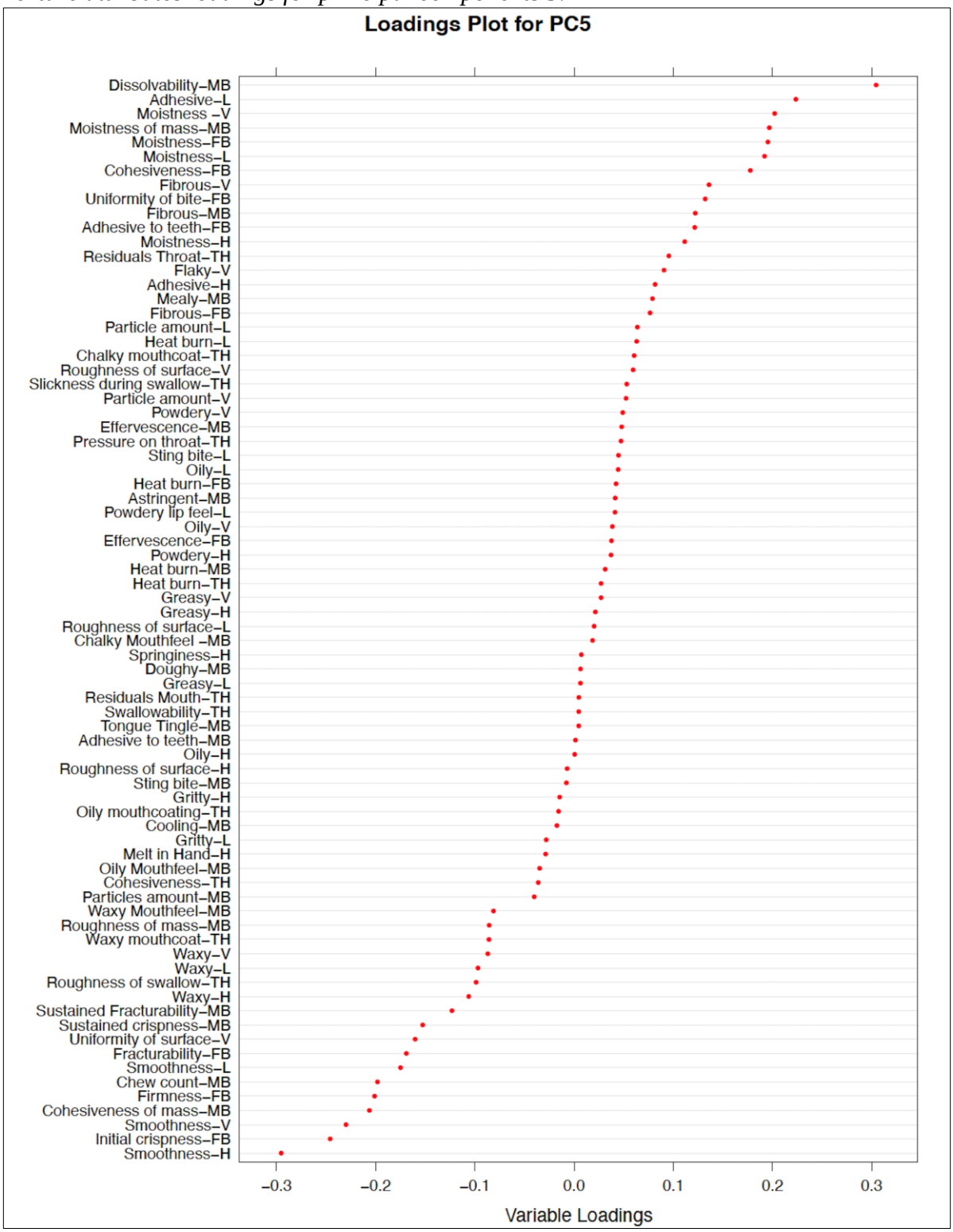

Figure A.4.

Principal component analysis scree plot, where X-axis represents the number of principal components and Y-axis represents variance explained by these principal components.

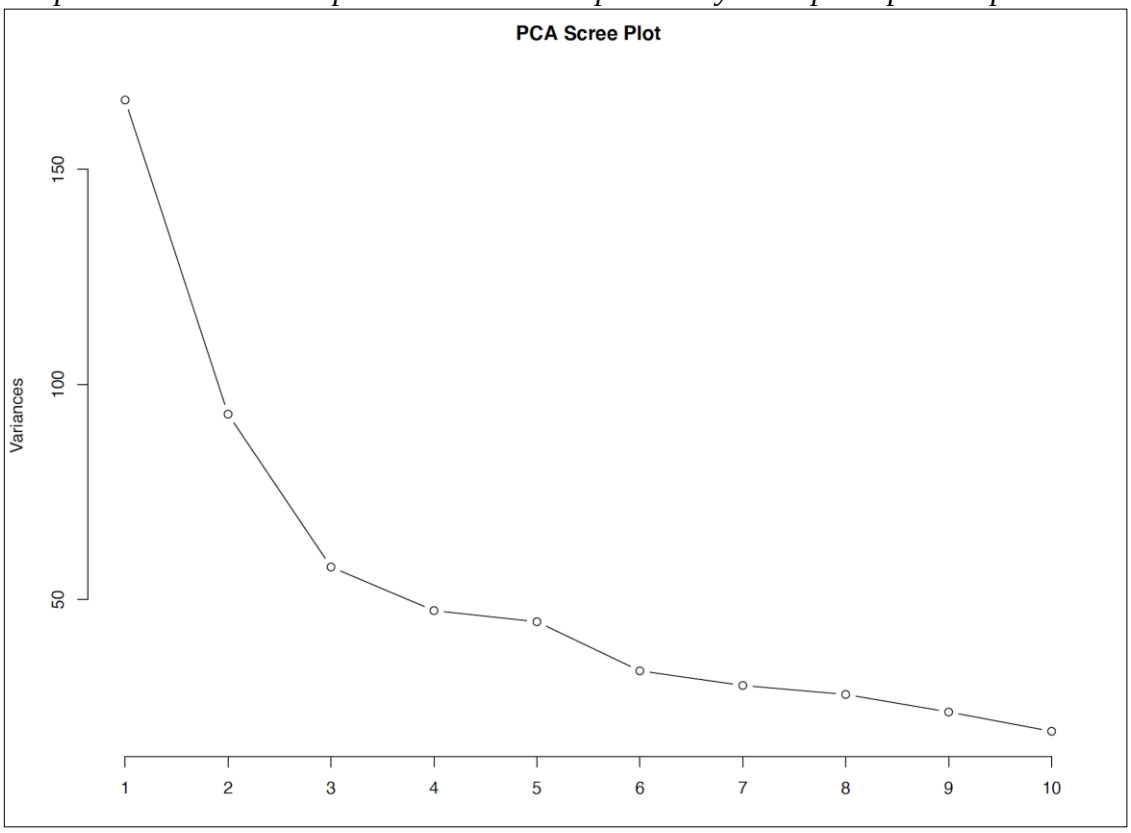

Figure A.5.

Variability plot for snack products for 50 clusters using k-means cluster analysis. The variability never reached a flat cover which is an indicator of snack product diversity.

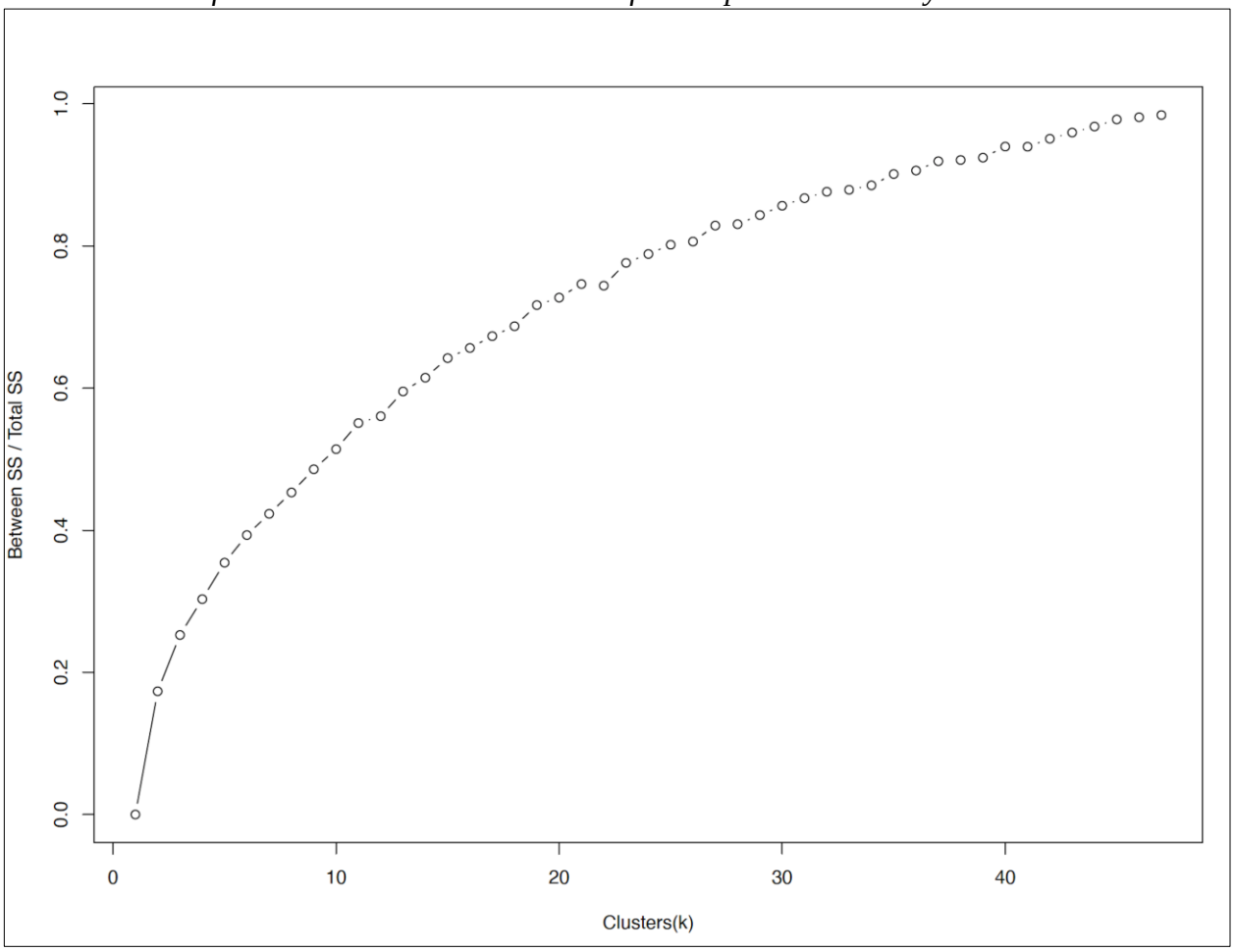

Figure A.6.

PCA plot representing descriptive flavor profiling results of JP snacks. The text (include dots) highlighted with blue color represents snack-type, and text (include dots) in red color denotes texture attributes. Three US snacks Stacy's Pita original, Lay's classic potato chips (PC), and Tostitos original corn chips (highlighted in yellow color) were used to compare flavor dimensions with JP snacks.

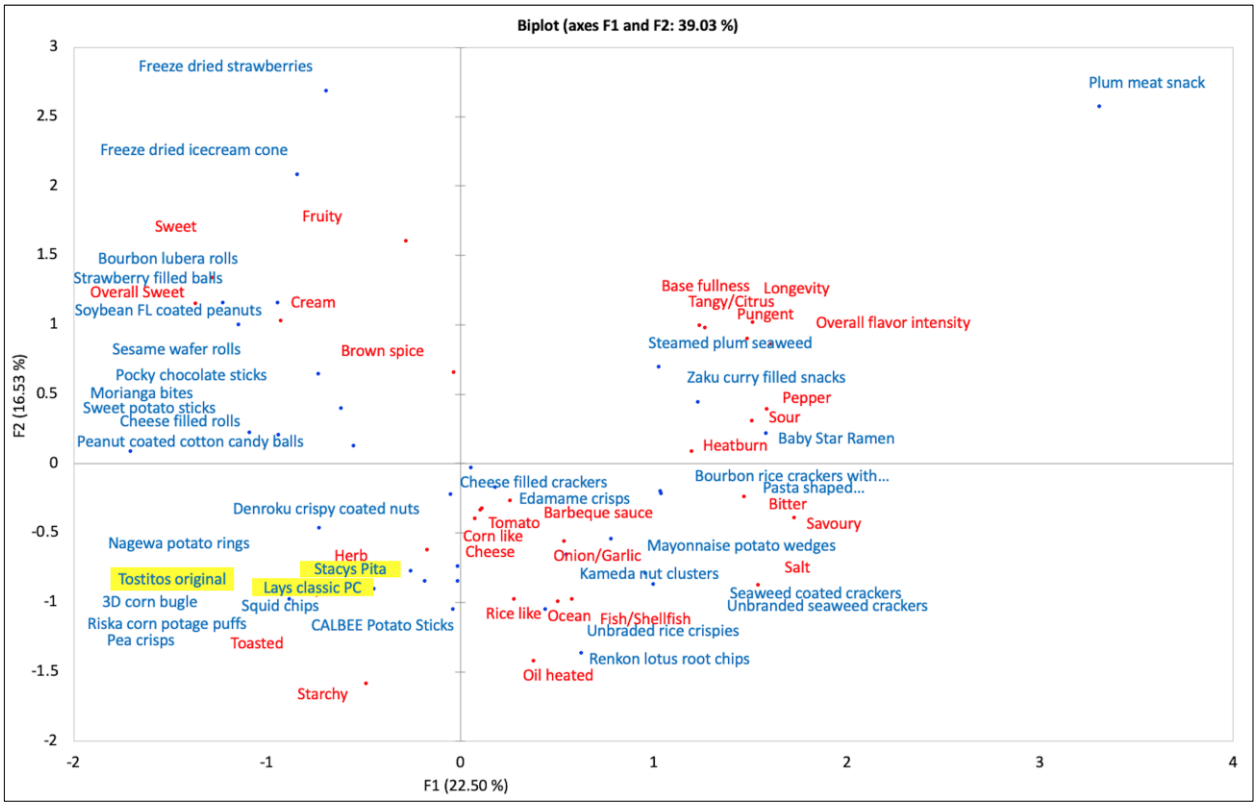

Figure A.7.

PCA plot representing descriptive flavor profiling results of SK snacks. The text (include dots) highlighted with blue color represents snack-type, and text (include dots) in red color denotes texture attributes. Three US snacks Stacy's Pita original, Lay's classic potato chips (PC), and Tostitos original corn chips (highlighted in yellow color) were used to compare flavor dimensions with JP snacks.