Sensory and consumer profiling of potatoes grown in the USA

by

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B.S., Khalsa College Amritsar, Punjab, India, 2009
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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
College of Health and Human Sciences

KANSAS STATE UNIVERSITY
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Abstract

Many studies related to potato sensory qualities are being published in journals focused on agriculture, plant breeding, biochemistry, biotechnology, marketing, food quality and sensory science. The growing number of these publications imply the importance of sensory based findings in achieving desired phenotype markers, consumer product acceptance, advertising claims, etc. It has been established that sensory tests are required and are of prime importance for future direction of research programs. Keeping this view in mind, a study was planned to investigate a number of potato cultivars for sensory language development, sensory profile, consumer liking and attitudinal responses.

Potatoes have been a commodity of interest for some time due to nutritional and sensory reasons. Tuber quality traits from aroma, flavor and texture point of view are gaining importance in breeding and processing programs, thus, making it a need to develop a standard lexicon to provide common terminology for use in communicating between breeders, producers, marketers, and researchers. A highly trained panel developed, defined, and referenced a lexicon with 66 attributes using a consensus based descriptive analysis method with 55 cultivars of tubers. Samples were served mashed and air fried. Full lexicon includes five appearance attributes, eighteen aroma attributes, nineteen flavor attributes, twelve texture attributes, four mouthfeel and three aftertaste attributes. The 55 cultivars used for lexicon development were also successfully profiled for the developed attributes. Cooked, cardboard, umami, starchy, salty, metallic, bitter and astringent attributes were mostly common among all samples. Attributes such as vegetable complex, beany, nutty, toasted, sweet potato, eggy and cauliflower were unique to certain cultivars.

The underlying construct behind food acceptability was investigated for mashed potatoes. Twelve cultivars of potatoes were tested for sensory profile development by open-ended and

check-all-that-apply (CATA) question methodologies. Consumer terminology associated with liking included cooked potato aroma, cooked potato flavor and sweet taste, whereas chemical, unnatural, odorless, flavorless and metallic taste were associated with disliking. Open-ended question was found difficult by 67% of participants for top 3 box responses on 9-point difficulty scale. Grainy, mealy, lumpy, chunky and pasty texture was found disliked by consumers. Compared to open-ended questions, the amount of information composed by CATA method was less and inefficient to describe the samples fully.

Hedonic potato liking by consumers was linked to sensory outcomes for the purpose to dissect flavor and texture preferences in the potatoes. The consumers were asked to evaluate liking on hedonic scale for 12 cultivars of potato. Sensory findings were collected by using Consensus-based Descriptive analysis approach for the same cultivars. The cluster analysis identified three subgroups with different overall liking patterns, indicating existing possibilities in the acceptance of wild, flavorful potato cultivars. Drivers of liking were identified for respective groups by using internal preference mapping technique. Dissimilar features were found important in determining hedonic potato likings. Purple Majesty, Masquerade and Rio Colorado cultivars were found most liked by respondents while Russian Banana least. Tuber color, price, cultivar name on package, color of peel and locally produced were found as important factors in purchase-decisions.

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Dedication

I would like to dedicate my work to my Mom, Geeta Sharma and to myself. I kept my faith strong and worked continuously to achieve this milestone. Failures are part of success and I take them positively.

"Thanks to all those failures, they gave me another chance to read more books, and this is the most beautiful thing about the failures"

Chapter 1 - Literature review

Introduction

Sensory analysis plays a huge role in modern potato breeding programs. Many cases have been reported in the past where sensory evaluations were not made on a formal basis prior to the release of cultivars, and subsequently many objectionable statements were reported. One such case was of the Ontario potato cultivar, released in 1946, where it was later stated that this cultivar had objectionable flavor, low total solids content, subject to after-cook darkening and that production of this cultivar should be discontinued (True & Work, 1981). In present day potato breeding programs, much focus has been reported on the reduction of glycoalkaloids, eliminating after-cooking darkening and improving color of potato product with high volume and nutritional quality. In addition, there is a key role for sensory science in ensuring that the solutions to maintain the world's food supply are sensorialy acceptable. For example, domestication of wild species and gradual transformation into commercial crops has led to a reduction in bitter compounds and/or flavor compounds, such as in tomatoes (Goff & Klee, 2006) and strawberries (Aharoni et al., 2004). Lower glycoalkaloid content leads the varietal selection in breeding programs, as an example, the selection of AO02183-2 cultivar from the Oregon state potato breeding program was discouraged and discarded, because it had the tendency to accumulate high glycoalkaloids, even though it possessed good agronomic and processing traits. Presumably, selection by breeders for yield, appearance, sweet-taste and disease resistance has resulted in an unintended loss of flavor compounds (Jansky, 2010a). Specific and isolated breeding programs, where culinary quality of tubers is only assessed in the later stages, have been modified to be more holistic in approach and emphasis is growing around sensory properties of produce. Conventional breeding programs were more focused on appearance, processing quality (browning of cut potatoes), yield and disease resistance, whereas comparatively newer breeding programs put more emphasis on nutritional and

nutraceutical quality, shelf-life and hypo-allergenicity of produce, along with sensory properties and potential for their genetic improvement. To nurture North Carolina State's agricultural industry and strengthen the strawberry sector, plant breeders, culinary professionals and Sensory Spectrum (A globally recognized consulting firm) collaborated on a strawberry sensory study (G. V. Civille & Oftedal, 2012). Descriptive analysis technique was used in the 1st phase to document the sensory properties of strawberries and subsequently a consumer study in the 2nd phase to understand the attitudes, expectations and perceptions of consumers and professional chefs. Together, descriptive analysis and consumer preferences will result in the development of consumer-driven improvements in agricultural commodities, which were not possible previously by using traditional sensory tools such as the USDA grading system. These traditional methods were drawn by either trade associations or governmental agencies to aid in standardization of produce, marketing, sorting (based on size, color, physical condition (invisible water core in apples or woo fiber diameter in wool) for local and international markets, provide language for grade basis commerce, reducing the risk of fraudulent marketing, facilitating price negotiations and comparisons, selection of appropriate packaging material, transportation requirements etc. But these above-mentioned grading standards were mainly focused on or around fair marketing strategies (to sort a population with heterogeneous characteristic into lots of more uniform characteristics) and are based on specific attributes such as size (blueberries, dates, potato, mango), juice content (limes) or color (tomato) making them entirely unsuitable for use in present day's product and market research. Indeed, these grade attributes were held responsible for encouraging the use of chemicals during the production process (U.S. Congress, Office of Technology Assessment, 1992). Consumer acceptability or preference do not associate with these grades, as consumer desires were never involved in this process. Nowadays, consumer's perception of skin color (Jemison Jr, Sexton, & Camire, 2008), flesh color (Jemison Jr et al., 2008), flesh quality

(Murray & Delahunty, 2000), origin (Loureiro & Hine, 2002; Storey, 2007), healthiness of potatoes (Jemison Jr et al., 2008), high sensory characteristic scores (Montouto-Graña, Cabanas-Arias, Porto-Fojo, Vázquez-Odériz, & Romero-Rodríguez, 2012), such as skin quality (Jemison Jr et al., 2008), flesh (Jemison Jr et al., 2008), high quality, locally grown, blemish-free (Jemison Jr et al., 2008), flavor (Ducreux et al., 2008), and cultivar (Morris et al., 2007) were reported as key factors, which will likely influence future growth and consumption trends. Even though grades can be found printed on the front labels of many products, some consumer terms such as smooth, rich flavor, creamer and moist texture along with preferred applications in boil, mash, roast, fried, grill, roast, salad would be of importance because the abovementioned information for preparation tips, recipes was appreciated previously by consumers (Fernqvist, Spendrup, & Ekelund, 2015), giving an indication of additional needs for comprehensive sensory evaluation (McGregor, 2007). Lack of information regarding properties of cultivars (McGregor, 2007) available in shops, cultivar and origin were rated as negative factor in consumer choice (Fernqvist et al., 2015). Importance of trained sensory panel for objective assessment (Morris et al., 2007), tuber quality traits in breeding programs as consumers demand greater cultivar and retailers wish to market cultivars that have distinctive commercial advantages have been clearly highlighted in the introduction section by Taylor and co-workers in book chapter “Potato flavor and Texture” (Taylor, McDougall, & Stewart, 2007). Another one of the difficult conundrums for the sensory experts is the flavor of potatoes, if potato has any flavor or they are bland/neutral (Solms & Wyler, 1979; Spear, Holden, Ross, Weddell, & Pavek, 2018), an assertion similar to taste of water, needs greater scrutiny. (Solms, and Wyler, 1979; Spear, Holden, Ross, Weddell, and Pavek, 2018).

Fresh Potato appearance, flavor and texture

Potato source (locally produced) and skin quality have been reported as the highest scored (on 5-point scale) factors influencing fresh potato purchase from consumer point of view.

Understanding which characteristics are most important to the purchase of fresh potatoes is also useful for marketing (Jemison Jr et al., 2008). Clean, blemish-free skin, flesh color and flesh quality influence more than size and shape in halved potatoes (Jemison Jr et al., 2008). Picture of a halved potato, showing flesh on package was predicted by author to affect cultivar selection and sales (Jemison Jr et al., 2008). Contrarily, preference results for red potatoes were found different from those of the white and yellow cultivars. Dark red Norland was the most preferred whole red cultivar and when flesh was exposed, it was selected more than all other reds. The biggest factor(s) reported for preference of whole red potatoes was skin quality and for halved red potatoes were flesh color and flesh quality, respectively. Presence of silver scurf, a disease of potatoes that causes visible small grey spots (surface blemish), causing them to look "dirty" could be a reason for lower response to the purple potato cultivar, as it reduced the attractiveness of the skin quality (Jemison Jr et al., 2008). In most of Europe, the preference for fresh market potatoes is for cultivars with yellow/light yellow-colored flesh (Storey, 2007). Skin finish is also important, and russet cultivars with a netted reddish-brown skin are popular for most uses in the USA and whites and small reds are used for boiling. In most of Europe, a cream to light-yellow skin color is preferred, whereas in many Arabic countries, cultivars with a red skin color are popular (Storey, 2007). Unlike fruits, which emit high concentrations of aromatic compounds during ripening to attract seed dispersal agents, potatoes do not emit such high concentrations of perceptible compounds for attracting dispersal agents, as they can have vegetative reproduction. In this regard, the research by Jansky (2010) made a statement that, since flavor compounds *per se* are not necessary for the function of reproduction, it would be interesting to know whether tubers of wild and cultivated potato relatives differ in types and concentrations of flavor compounds (Jansky, 2010a). Flavor makes an important contribution to the success of potato as a food, and the ongoing development of potato cultivars with preferred or unusual flavor profiles offers the chance to increase consumption even further

(McKenzie & Corrigan, 2016). Most of the volatile compounds in potatoes develop around tissue degradation, such as bruising of skin, rotting or cutting and cooking. A correlation was found between glycoalkaloid content and undesirable potato flavor, but no significant correlation between phenolic content and either bitterness or burning sensation was observed (Sinden, Deahl, & Aulenbach, 1976). In contrast, a positive correlation was reported between phenolic content and bitterness and astringency of potatoes (Mondy, Metcalf, & Plaisted, 1971). Since potatoes contain both glycoalkaloids and polyphenols in various amounts depending on cultivar, the net effect on taste and flavor could be the result of combined, possibly additive, synergistic, or antagonistic effects of both components (Johns & Keen, 1986; Kaaber, 1993; Zitnak & Filadelfi, 1985). Potatoes with closely packed cell arrangement and higher starch content were observed to be much harder and cohesive. A significant positive correlation was observed between the starch content and fracturability of raw potato tubers (r = 0.92). In contrast, potato with loosely packed cell arrangement and large cell size were found to be less hard and cohesive (Bordoloi, Kaur, & Singh, 2012). Some authors clearly mentioned the objective of correlating volatile and non-volatile components with Descriptive panels in their studies (Morris et al., 2010; Thybo et al., 2006) as fewer attempts have been made previously, but still their attempts were found unsatisfactory due to various reasons.

Potato processing

Baked, mashed and roasted potatoes were reported as preferred method of preparation than fried, boiled and salad, irrespective of consumer gender differences (Jemison Jr et al., 2008). There are also very definite preferences for the processing industry, depending on the type of product being produced. For the chip (crisp) sector, cultivars with light-yellow and yellow flesh predominate, e.g. in the UK this includes cultivars Hermes, Saturna and Lady Rosetta, whereas for French fries, cultivars Maris Piper, Russet Burbank and Shepody with white or cream flesh color

are preferred (Storey, 2007). Potato with high solid content (20-22%) are preferred for frying due to higher yield, better finished product texture and lower oil absorption (Lisinska & Leszczynski, 1989).

Processed Potato appearance

From the processing standpoint, microwave baking method resulted in significantly inferior products for appearance (skin shrinkage), aroma and flavor properties compared to the corresponding conventional baking method (Maga & Twomey, 1977). From an external appearance standpoint, both conventional and microwave methods resulted in cultivar WC 230-14 being found significantly superior to the other 3 cultivars (WC 285-146, Russett Burbank, WC 285-18) and cultivar WC 285-146 being significantly inferior. Oruna-Concha et al. 2002 found no statistically significant differences between the external and internal color of the organic and conventional potato samples for any of the color parameters. Gilsenan and co-workers described potato (cv. Orla) as having a creamy white external color and a yellow internal color (Gilsenan, Burke, & Barry-Ryan, 2010). True and co-workers reported order of whiteness for 5 tubers, i.e., Russet Burbank (whitest) followed by Katahdin, Kennebec, Superior, and Ontario (grayest) (True & Work, 1981).

Processed Potato aroma and flavor

Baking is a very popular method of cooking for potatoes. In fact, it has been reported that the flavor of baked potatoes is considerably stronger than that of boiled potatoes (Table 1.1) (Oruna-Concha, Bakker, & Ames, 2002). Russet clone cultivars grown in San Luis Valley-Colorado State University experiment station such as WC 230-14 and WC 285-18 were found highly superior than Russett Burbank and WC 285-146 from aroma standpoint, irrespective of processing method (Maga & Twomey, 1977). From flavor standpoint, cultivar russet clone, WC 230-14 was found to be significantly superior to the other cultivars by both baking methods

whereas the Russett Burbank and russet clone cultivar WC 285-146 were found to be significantly inferior. In disparity, the flavor of tubers of the Russet Burbank, Katahdin and Superior cultivars was significantly preferred to that of the Ontario cultivar by a sensory panel of 18 members (True & Work, 1981). Ulrich and co-workers evaluated 3 German potato genotypes, i.e., Adretta, Likaria and St 1365 for sensory profile by descriptive analysis, where they found that Adretta cultivar was higher in sweet-like, earthy, fruity and typical attributes, whereas Likaria and St 1365 were characterized by typical, earthy, fodder, musty and typical, sweet-like, burnt, untypical, musty, respectively (Ulrich, Hoberg, Neugebauer, Tiemann, & Darsow, 2000). No information about training of panelists, language generation (descriptors and definitions) and reference selection was provided in this study, instead some vague terms such as typical and untypical were used, which cannot be replicated in other labs. Glutamic acid, aspartic acid and adenosine 5-monophosphate have been reported as major umami compounds available in potatoes (Jansky, 2010a; Raigond, Singh, Gupta, & Singh, 2014). Though potatoes have been reported previously to contain higher levels of 5'-ribonucleotides (AMP and GMP) than any other plant food, umami attribute was reported only in 2 studies (Chabanet, 2000; Morris, Shepherd, Verrall, McNicol, & Taylor, 2010). Taylor and co-workers (2007) also highlighted this problem and mentioned that only limited taste panel data are available to support the importance of umami compounds in defining potato flavor (Morris et al., 2007; Taylor et al., 2007). In general, correlation of sensory evaluation scores for cooked potato flavor from different cultivars with umami compound measurements was found lacking. It was suggested that the flavor of boiled potato was largely due to the natural mixture of glutamic acid and other amino acids in combination with GMP and other 5'-ribonucleotides produced on cooking, thus it can be predicted that boiled potato should have higher umami intensity score on scale compared to baked potatoes. Maillard reaction products could possibly integrate with umami taste and may affect perception in baked potatoes. Aroma was found

negatively correlated to hexanal, AMP, GMP, 2-pentenal, 1-Penten-3-ol while +vely correlated to 2-propanone, dimethyl sulfide, furfural, benzaldehyde, dimethyl disulfide, furan, 3- and 2-methylbutanal and solanine, implying that aroma will decrease with the increase of abovementioned compounds. Flavor intensity was found positively correlated with methylsalicylate, hexanal, pentanal, AMP, GMP, 1-pentanol, 2-heptenal, 2-methylfuran, 2-pentenal, 1-penten-3-ol, 2-propylfuran and octanal while negatively correlated to benzaldehyde, heptanal, 2-pentylfuran, dimethyl disulfide, methional, benzeneacetaldehyde, furan, 2,4-heptadienal, 2-nonenal, 3-methylbutanal, 2-methylbutanal, 2-methylpropanal, chaconine and solanine. Savory and creaminess were found positively correlated to methylsalicylate, hexanal, pentanal, AMP and GMP. Off-flavor notes were found correlated to propanal, dimethyl sulfide, 2-hexenal and chaconine (Morris et al., 2010). Collectively, compounds such as dimethyl disulfide contain sulfur and has an onion and cabbage-like odors, 2-hexenal has green, green grassy notes (Christensen, Edelenbos, & Kreutzmann, 2007), banana, aldehydic, fatty and cheesy odor, propanal has solvent-like and spoiled odor (Ólafsdóttir & Kristbergsson, 2006), and chaconine has a bitter taste. *Phureja* cultivars which are diploid cultivated species of Andes, scored considerably higher on an acceptability scale compared to Tuberosum cultivars which are tetraploid cultivated species of Chile. Creaminess and flavor intensity were highly correlated attributes to acceptability measures (Ducreux et al., 2008; Winfield et al., 2005). Kaspar et al., (2013) studied the pigmented potatoes for sensory qualities, in comparison to white and yellow potatoes by a consumer ranking method (Kaspar et al., 2013) and found higher acceptability for white and yellow cultivars based on aroma and appearance. Sixty consumers and three types of cultivars (white, yellow and purple) were evaluated for appearance, aroma, flavor and overall quality. Statistically, appearance and aroma were found significant modalities, responsible for lower acceptability of purple potatoes. Masking of color for future tests could be a method of evaluation for assessing true effect of aroma,

flavor and quality. No statistically significant effects were observed for flavor and overall quality between the three cultivars. No detailed information regarding the method of sample preparation, serving protocols or data collection was found. A list of key compounds found in baked potatoes shown in Table 1.2.

Table 1.1 Key compounds found in boiled potato

Compound	Sensory perception	Reference
Diacetyl	Buttery, sweet, caramel, green	(Ulrich et al., 2000)
Hexanal	Green	Ulrich, Hoberg, Neugebauer, Tiemann, and Darsow, 2000)
E-2-pentenal	Roasty, rubber, unpleasant	Ulrich, Hoberg, Neugebauer, Tiemann, and Darsow, 2000)
2-methylbutanol	Unpleasant, sweat	Ulrich, Hoberg, Neugebauer, Tiemann, and Darsow, 2000)
2-pentylfuran	Unpleasant, green beans, cooked	Ulrich, Hoberg, Neugebauer, Tiemann, and Darsow, 2000)
Methylpyrazine	Nutty, strong	Ulrich, Hoberg, Neugebauer, Tiemann, and Darsow, 2000)
Octan-2-one	Mushroom, earthy	Ulrich, Hoberg, Neugebauer, Tiemann, and Darsow, 2000)
2,6-dimethylpyrazine	Nutty, warm	Ulrich, Hoberg, Neugebauer, Tiemann, and Darsow, 2000)
2-methyl-5-isopropylpyrazine or 2-ethyl-6-methylpyrazine	Nutty, warm, chemical	Ulrich, Hoberg, Neugebauer, Tiemann, and Darsow, 2000)
3-ethyl-2,5-dimethylpyrazine	Nutty, earthy, herbaceous	Ulrich, Hoberg, Neugebauer, Tiemann, and Darsow, 2000)
2-ethyl-3,5-dimethylpyrazine	Roasty, coffee-like	Ulrich, Hoberg, Neugebauer, Tiemann, and Darsow, 2000)
Methional	Cooked potato	Ulrich, Hoberg, Neugebauer, Tiemann, and Darsow, 2000)
Pyrrole	Nutty, roasty	Ulrich, Hoberg, Neugebauer, Tiemann, and Darsow, 2000)
(E,E)-3,5-octadienone	Nutty	Ulrich, Hoberg, Neugebauer, Tiemann, and Darsow, 2000)

(E,E)-2,6-nonadienal	Fatty, cucumber	Ulrich, Hoberg, Neugebauer, Tiemann, and Darsow, 2000)
Phenylacetaldehyde	Flowery	Ulrich, Hoberg, Neugebauer, Tiemann, and Darsow, 2000)
2,4-decadienal	Fatty, unpleasant	Ulrich, Hoberg, Neugebauer, Tiemann, and Darsow, 2000)
Dimethyl disulfide	Onion-like, cooked cabbage	(Oruna-Concha et al., 2002)
Methional	Cooked potato	(Oruna-Concha et al., 2002)
1-octen-3-ol	Mushroom like	(Oruna-Concha et al., 2002)
(E)-2-nonenal	Cucumber, cardboard	(Oruna-Concha et al., 2002)
(E,E)-2,4-decadienal	Oily, deep fried-like	(Oruna-Concha et al., 2002)
Phenylacetaldehyde	Floral, roses	(Oruna-Concha et al., 2002)
2-ethyl-3,5-dimethylpyrazine	Nutty, roasted	(Oruna-Concha et al., 2002)
2-ethyl-3,6-dimethylpyrazine	Nutty, roasted, earthy, baked potato-like	(Oruna-Concha et al., 2002)
2-isopropyl-3-methoxypyrazine	Earthy, raw potato, potato-like	(Oruna-Concha et al., 2002)
Hexanal	--	(Oruna-Concha, Duckham, & Ames, 2001)
Heptanal	--	(Oruna-Concha et al., 2001)
(E)-2-heptenal	--	(Oruna-Concha et al., 2001)
Benzaldehyde	--	(Oruna-Concha et al., 2001)
1-octen-3-ol	mushroom-like	(Oruna-Concha et al., 2001)
2-pentylfuran	--	(Oruna-Concha et al., 2001)
(E,Z)-2,4-heptadienal	--	(Oruna-Concha et al., 2001)
(E,E)-2,4-heptadienal	--	(Oruna-Concha et al., 2001)
Nonanal	--	(Oruna-Concha et al., 2001)
(E)-2-nonenal	cucumber, cardboard	(Oruna-Concha et al., 2001)
Decanal	--	(Oruna-Concha et al., 2001)
(E,E)-2,4-nonadienal	--	(Oruna-Concha et al., 2001)
(E,Z)-2,4-decadienal	--	(Oruna-Concha et al., 2001)

(E,E)-2,4-decadienal	oily, deep fried-like	(Oruna-Concha et al., 2001)
Pyridine	--	(Oruna-Concha et al., 2001)
3-methyl-1-butanol	--	(Oruna-Concha et al., 2001)
Methylpyrazine	--	(Oruna-Concha et al., 2001)
2-furfural	--	(Oruna-Concha et al., 2001)
2,5- and/or 2,6-dimethylpyrazine	--	(Oruna-Concha et al., 2001)
2-ethyl-6-methylpyrazine	--	(Oruna-Concha et al., 2001)
2-ethyl-5-methylpyrazine	--	(Oruna-Concha et al., 2001)
Phenylacetaldehyde	floral, roses	(Oruna-Concha et al., 2001)
dimethyl disulfide	onion-like, cooked cabbage	(Oruna-Concha et al., 2001)
3-(methylthio)propanal (methional	--	(Oruna-Concha et al., 2001)
	--	(Oruna-Concha et al., 2001)
3-carene	Citrus, pine	(Bough, 2017)
Alpha-copaene	Woody, spicy, honey	(Bough, 2017)
1-octen-3-ol	Earthy, green, fatty	(Bough, 2017)
(E)-2-heptenal	Green, fatty, fruity	(Bough, 2017)
1-nonanal	Citrus, green, potato	(Bough, 2017)
Pentanal	Fermented, yeasty, wine	(Bough, 2017)
p-methyl-acetophenone	Creamy, fruity, vanilla	(Bough, 2017)
2-ethylfuran	Musty, earthy, yeasty	(Bough, 2017)
2-pentylfuran	Fruity, green, earthy	(Bough, 2017)
Benzoate-3-methyl-2-buten-1-ol	Woody, fruity, chocolate	(Bough, 2017)
2-isopropyl-3-methoxypyrazine	Earthy, chocolate, nutty	(Bough, 2017)

Table 1.2 Key compounds found in baked potatoes

Compound	Sensory perception	Reference
1,2-dimethylnaphthalene	--	(Coleman, Ho, & Chang, 1981)
1,3-dimethylnaphthalele	--	(Coleman et al., 1981)
2-isopropylnaphthalene	--	(Coleman et al., 1981)
1,4,6-trimethyl-l,2,3,4-tetrahydronaphthalene	--	(Coleman et al., 1981)
2-methyltetrahydrofuran-3-one	--	(Coleman et al., 1981)
2,4,5-trimethyloxazole	--	(Coleman et al., 1981; Oruna-Concha et al., 2002)
5-acetyl-2,4-dimethyloxazole	--	(Coleman et al., 1981)
2-ethyl-3-methylpyrazine	--	(Coleman et al., 1981)
2 -ethyl-3,6-dimethylpyrazine	nutty, roasted, earthy, baked potato-like	(Coleman et al., 1981)
2-ethyl-3,5-dimethylpyrazine	nutty, roasted	(Coleman et al., 1981)
2-ethyl-6-vinylpyrazine	--	(Coleman et al., 1981)
2-isobutyl-3-methylpyrazine	--	(Coleman et al., 1981)
2,3-diethyl-5-methylpyrazine	--	(Coleman et al., 1981)
3,5-diethyl-2-methylpyrazine	--	(Coleman et al., 1981)
2-ethyl-3,5,6-trimethylpyrazine	--	(Coleman et al., 1981)
2,3-dimethyl-5-butylpyrazine	--	(Coleman et al., 1981)
2,5-dimethyl-3-butylpyrazine	--	(Coleman et al., 1981)
2,6-dimethyl-3-butylpyrazine	--	(Coleman et al., 1981)
2-methyl-6,7-dihydro-5H-cyclopentapyrazine	--	(Coleman et al., 1981)
5-methyl-6,7-dihydro-5H-cyclopentapyrazine	--	(Coleman et al., 1981)
3,5-dimethyl-6,7-dihydro-5H-cyclopentapyrazine	--	(Coleman et al., 1981)

5,7-dimethyl-2,3,4,7,8-hexahydroquinoxaline	--	(Coleman et al., 1981)
2,5-diethyl-4-methylthiazole	--	(Coleman et al., 1981)
Hexanal	--	(Oruna-Concha et al., 2001)
Heptanal	--	(Oruna-Concha et al., 2001)
(E)-2-heptenal	--	(Oruna-Concha et al., 2001)
Benzaldehyde	--	(Oruna-Concha et al., 2001)
1-octen-3-ol	--	(Oruna-Concha et al., 2001)
2-pentylfuran	--	(Oruna-Concha et al., 2001)
(E,E)-2,4-heptadienal	--	(Oruna-Concha et al., 2001)
nonanal	--	(Oruna-Concha et al., 2001)
(E)-2-nonenal	--	(Oruna-Concha et al., 2001)
(E,E)-2,4-nonadienal	--	(Oruna-Concha et al., 2001)
E,E)-2,4-decadienal	--	(Oruna-Concha et al., 2001)
(E)-2-undecenal	--	(Oruna-Concha et al., 2001)
Pyridine	--	(Oruna-Concha et al., 2001)
2-methyl-3(2H)-furanone	--	(Oruna-Concha et al., 2001)
Methylpyrazine	--	(Oruna-Concha et al., 2001)
2-furfural	--	(Oruna-Concha et al., 2001)
2,5-and/or2,6-dimethylpyrazine	--	(Oruna-Concha et al., 2001)
Ethylpyrazine	--	(Oruna-Concha et al., 2001)
5-methyl-2-furfural	--	(Oruna-Concha et al., 2001)
2-ethyl-6-methylpyrazine	--	(Oruna-Concha et al., 2001)
Trimethylpyrazine	--	(Oruna-Concha et al., 2001)
2-ethyl-5-methylpyrazine	--	(Oruna-Concha et al., 2001)
Phenylacetaldehyde	--	(Oruna-Concha et al., 2001)
2-ethyl-3,5(6)-dimethylpyrazine	--	(Oruna-Concha et al., 2001)
3-(methylthio)propanal (methional)	--	(Oruna-Concha et al., 2001)
	--	(Oruna-Concha et al., 2001)

Processed Potato texture

As with flavor, texture is a complex trait to analyze as it depends on the interaction of many factors (Kumar & Chambers, 2019). Defining texture that is attractive to consumers also depends on sensory panel analysis rather than analytical measurements (Taylor et al., 2007). Changes in the mechanical properties of potato tubers during cooking were mainly attributed to the changes affecting structural components (cell wall and middle lamella) (Bordoloi et al., 2012). Factors that affect cooked potato texture include, starch content and distribution within the tuber, starch swelling pressure, cell size, cell-wall structure and composition, and the breakdown of the cell wall middle lamella during cooking (Taylor et al., 2007). High dry matter and total starch content showed higher fracturability and hardness, whereas potatoes from waxy cultivars showed lower values for these parameters. Hardness and fracturability of cooked potatoes were significantly correlated with the total starch content. Gelatinization and microstructure were found to have major impact on the texture of cooked potatoes. Less dry matter content but similar acidity were reported previously in conventionally grown potatoes compared to organically grown (Gilsenan et al., 2010). Similarly, a significant difference between both types of raw potato was found for maximum puncture force. Conventional potatoes were reported significantly softer than the organic potatoes, which could be attributed to the higher dry matter content in the organic potatoes. Dry matter has been correlated with texture previously (Gopal & Khurana, 2006). In addition, the conventional baked potato was reported softer than the organic baked potato (Gilsenan et al., 2010). Gilsenan and co-workers found that conventional baked potatoes were softer, had more moisture, and were less adhesive than baked organic potatoes. Lower solids content of conventional potatoes could be a reason for softness and moisture, since lower solids results in lower density and lower starch or sugar content available for available water. Adhesiveness could be due to starch granules. Mealy texture was reported in Russet Burbank, Katahdin, and Superior

potatoes, compared to Kennebec and Ontario tubers (True & Work, 1981). Russet Burbank tubers were previously reported significantly higher in total solids content than tubers of the other cultivars tested, i.e., Katahdin, Superior, Ontario and Kennebec (True & Work, 1981). Mealy, soggy, floury and waxy texture has been reported for Indian potato cultivars (Raigond et al., 2014). Mealiness and waxiness seems can be seen as two contrasting anchor points on the texture spectrum graph. Mealy potatoes have been reported to contain higher dry matter than waxy potatoes.

Different consumer groups prefer different kinds of potatoes. Fresh market russet cultivars are predominantly grown in the United States, while Europeans prefer smooth skin potatoes. Consumer liking for texture was also found to be dependent upon geographical and cultural differences. For example, dry boiled potato texture is preferred in Scotland, whereas a waxy texture is preferred in the Netherlands (Taylor et al., 2007). When consumers were shown photographs of two baked potatoes, 80% preferred white/cream colored flesh, whereas 20% preferred the darker yellow/gray translucent appearance. In another study, 83% of panelists indicated preference for a baked potato texture that ranged from creamy/smooth to light/fluffy (Spear et al., 2018). Dijk and coworkers (2002) concluded that dry matter content of steam-cooked potatoes determines the texture rather than the cultivar. Low dry matter content was found associated with moist, sticky whereas high dry matter content was found associated with crumbly and grainy (van Dijk et al., 2002). Dry matter content was also found highly correlated with sensory (firmness (0.53) and adhesiveness (0.62)) and instrumental attributes [(firmness (0.83), chewiness (0.56), gumminess (0.62), springiness (0.78), hardness (0.62) and fracturability (0.63)] (Goldner, Pérez, Pilosof, & Armada, 2012). Texture has been the most influential attribute to consumer preferences (Montouto-Graña et al., 2012; Thygesen, Thybo, & Engelsen, 2001) and needs to be addressed carefully by appropriate sensory analysis.

Language development in Descriptive analysis

Language development is the first pillar of descriptive analysis, and selection of descriptors governs the potential applications or benefits of this evaluation technique (Table 1.3). Different approaches of language development could be used based on intended application. For example, terms may be chosen based on objective underlying physical or chemical properties of the product to aid research and development or could also be consumer-oriented to aid in screener and/or questionnaire development for consumer studies. A well-defined lexicon of terms which adequately describes the sensory properties of products, as described by Civille and Lawless (1986), considers that the terms should be neutral, orthogonal (independent), based on an underlying structure (such as rheology and geometrical principles for texture terms, chemical principles for aroma or flavor terms, color and geometrical principles for appearance terms and somatosensory principles for feelings), based on a broad reference set, precisely defined and should be primary in nature rather than integrated or a combination of stimuli (G. V. Civille & Lawless, 1986). Sensory terminology including appearance, aroma, flavor and texture and mouthfeel modalities should be looked similarly as those for chemical, physical and biological terminology. In any terminology development approach, each stimulus has its own separate identifiable name/term, similar stimuli are placed closer/together or under a defined class, duplication of terms usually avoided, subjective terms are avoided unless required and each term has a clear definition and identifiable available reference standard. However, many published papers where descriptive analysis was used lacked the rigorous and objective development process needed for language generation and sensory profiling. Even though the use of trained panels for hedonic profiling is highly questionable in sensory science due in part to large bias incorporated during training, still many published papers were found with this mistake (Morris et al., 2007). In the same way, it is common knowledge that naïve/untrained consumers should not evaluate the

intensity of complex sensory attributes because their understanding of the attribute will be questionable, and they may bring their personal bias into a more objective evaluation. In some instances, though trained panelists were used for intensity evaluation, the quality of work was found questionable. Montouto-Graña et al. (2002) developed a sensory profile to evaluate potatoes from Galicia, Spain and other places of origin by using descriptive analysis. Though it was one of the main objective to update older original declaration, which showed poor specificity with newer and more detailed sensory profile but using only 8 descriptors (internal color, odor intensity, moistness, pastiness, chewiness, sweet taste, flavor intensity, and aftertaste persistence) for 'detailed' sensory profile are still hard to justify. Similarly, Morris et al. (2010) used six sensory attributes to study the association between sensory and non-sensory metabolites for *Solanum tuberosum* group *Phureja* and *Solanum tuberosum* group *Tuberosum* (Morris et al., 2010). Many such examples could be found in published literature where fewer descriptors were used for bigger product categories. Indeed, there is no universally accepted standardized requirement available for "minimum number of descriptors" but ideally the number of descriptors should be equal to the number of sensory concepts a product holds in itself. For example, sweet, sour, salty, bitter are four basic sensory or taste labels, which are used for communication purpose of these 4 sensory or taste concepts. The next question would be then "how many sensory concepts" should be included for a sensory profile study. The choice of number of sensory concepts should be based on panel's sorting capacity of tastes (aroma, flavor, texture and mouthfeel modalities) into their conceptual categories and then labelling the respective categories (Ishii & O'Mahony, 1987). In turn, a panel's sorting capacity of concepts will be based on previous experiences, vocabulary richness of that language etc. Climatic conditions, geographical position, age of civilization also affects the richness of vocabulary. For example, thanks to geographical position Eskimos have tens of words for defining the concept of "snow", whereas Aztecs had only a word. Similarly, "*Nihang*/ਨਿਹੰਗ"

a word used to represent a reality in Sikh religion, decorated with five *kakkars*/ਕਕਾਰ and dressed in a particular way. It is different from soldier and the use of word "soldier" or "warrior" cannot replace this concept. Similarly, "*jalebi*/ਜਲੇਬੀ" a word used to represent a sweet in Punjabi cuisine, has particular shape, preparation method and taste, which cannot be replaced by some other word. Every culture has developed a language and a vocabulary which is thus directly connected with the ethnic group. For example, a reality such as, 'snowfall', which doesn't exist in all geographical locations, makes it an unambiguous concept for that location, and eventually needs vocabulary to communicate this reality among local population. For example, in Punjabi language, there is only one word "*barf*/ਬਰਫ਼" for snow and ice, reacting to no snowfall reality. Other geographical regions which doesn't have this abovementioned reality doesn't actually need vocabulary to communicate this. Technically, all languages are rich for its geographical location, landscapes, culture, cuisine and religion. Language works as a channel to communicate reality and because some of the realities don't exist in some other cultures, and ultimately those realities become difficult to translate in other locations. Zannoni (1997) highlighted this growing difficulty of translating descriptors in other languages with the increasing globalization of the food trade (Zannoni, 1997). Textural attribute terms, such as mealy (Chabanet, 2000; Raigond et al., 2014; True & Work, 1981; Van Marle, de Vries, Ria van der Vuurst, Wilkinson, & Yuksel, 1997), floury (Raigond et al., 2014), soggy (Raigond et al., 2014) and waxy (Raigond et al., 2014; Van Marle et al., 1997) have been used extensively in previously published papers, but no definition and references have been reported for these terms. In starch chemistry, term "*waxy*" has been reserved for starches that contain essentially all amylopectin (virtually no amylose) polymer, characterized by a cohesive and gummy texture, whereas term "*non-waxy*" has been reserved for starches that contain amylose polymer, characterized by a gel texture. Some contradictory statements had been also reported in literature, such as waxy potato had a firm and gummy mouthfeel (McKenzie & Corrigan, 2016).

Mealy texture has been defined previously as reverse to waxiness, so in those terms, *non-waxy* and *mealy* attributes come to be similar in meaning. Mealy attribute has been defined as dry and granular (Jansky, 2010a; Jansky, 2010b), and associated with high dry matter content (Jansky, 2008). But at same time, conflicting results were obtained where True and Work (1981) showed that the cultivar "Ontario" was found to be less mealy, irrespective of similar dry matter content to other cultivars (True & Work, 1981). Mealy attribute was found to be important in other produce as well, such as apples, peaches, coconut meat (copra) etc. No detailed studies were found on mealy attribute. Texture attributes such as adhesiveness, dry matter (gravimetric method), and mealy along with flavor attributes such as earthy, bitter, green, grainy and off taste were found less appropriate for mashed potato. No definition was provided for floury and soggy attributes, making it difficult to reproduce these results across labs. Other terms used for texture were mashable, homogeneous, compact, firm, and grainy. Some common attributes such as sweet, chestnut and artichoke were found in all steamed potatoes whereas some other less common attributes such as cereal, earthy, herbaceous, pastry, raw potato, and celery were also found in very few cultivars (Chabanet, 2000). Bitter perception, which could be due to the higher levels of glycoalkaloids, was described in some studies (Baur, 1995; Chabanet, 2000). Tuber glycoalkaloids are toxic to humans if present at levels more than 20 mg/100 g (Friedman, 2006; Omayio, Abong, & Okoth, 2016; Osman, 1983). A positive correlation between glycoalkaloid and undesirable potato flavor was reported (Sinden et al., 1976) previously. Potato glycoalkaloids at elevated levels were reported for flavors described as bitter, burning, scratchy or acrid and are thus generally undesirable components of flavor (Taylor et al., 2007). Cliff and Heymann 1992 stated that irritant stimuli differed significantly in their pungent character, temporal response and spatial location or sensation. Oral pungency was profiled by generating terms via consensus methodology into lag time, burning, tingling, numbing, longitudinal location, lateral location, area, overall intensity and

persistence (Cliff & Heymann, 1992). No such detailed study ever conducted on glycoalkaloid irritant(s). Bitter aftertaste has been also reported in some of the New Zealand potato cultivars having a glycoalkaloid content range from 38.7 to 142.6 mg/kg. Maori potatoes from New Zealand have been reported to have a slightly bitter taste which has been suggested to be related with higher tuber glycoalkaloid content (Savage, Searle, & Hellenäs, 2000). Sweetness and off flavor were found non-discriminating attributes among potatoes by panelists while other attributes such as aroma (overall), creamy, savory and overall flavor intensity were found to be discriminating attributes. Storage was found to affect potatoes, as aroma decreased, and creaminess reduced, but savoriness and flavor intensity remained same (Morris et al., 2010).

When it comes to cooking method, the most appropriate (measured by appropriateness evaluation on 9-point scale, where 1-3 anchored as not appropriate, 4-6 as partly appropriate and 7-9 as very appropriate) cultivars for mashed potatoes were characterized by a higher intensity of the attributes 'moist', 'vanish', 'potato taste', 'butter' and 'sweet'. Likewise, texture attributes such as skin resistance, adhesiveness, mealy, dry matter and chewy along with flavor attributes such as green, reheated taste, earthy/storage, bitter and off taste were found less appropriate for oven fried potatoes. For boiled potatoes, attributes such as lower intensity of – reflection, discoloration (appearance), mealy, adhesive, chewy (texture), dry matter, bitter, earth, green, astringent and salt (flavor) were found less appropriate while high intensity of – yellowness (appearance), butter, creamy, potato taste, sweet (flavor), moist, hardness (texture) and high amylose were found highly appropriate (Seefeldt, Tønning, Wiking, & Thybo, 2011). Dry matter content was found negatively correlated with appropriateness for all culinary preparations. A new descriptor such as "soapiness" was added and used for evaluating organic and conventional potatoes, but no definition or references were found for the same (Tobin, Moane, & Larkin, 2013). Use of descriptors such as "soapy or soapiness" as equivalent to "waxy or waxiness" for texture

modality creates doubts on the reliability of developed language. One of the aforesaid requirements of a well-thought descriptor was that it should be related to the underlying natural structure, which means that "soapiness" attribute should be based on some kind of physical, chemical, geometrical or rheological principle but as per authors knowledge "soapy" attribute has been previously largely related to odor (Eriksson et al., 2012) rather than taste or texture. No previous information regarding the "soapy" term as a texture attribute was found in the literature. However, it has been previously used as an aroma attribute in cheese (Talavera-Bianchi, Chambers, & Chambers, 2010; Talavera & Chambers, 2016), aroma attribute in wine (Noble et al., 1987), flavor attribute in wine (L. J. Lawless & Civille, 2013), both aroma and flavor attribute in spices (L. J. Lawless, Hottenstein, & Ellingsworth, 2012) and feeling factor in almond (G. Civille, Lapsley, Huang, Yada, & Seltsam, 2010). Soapy has been found previously found related to coriander, black pepper, cardamom, cumin, mace, nutmeg, red pepper (L. J. Lawless et al., 2012). Unavailability of a clear definition and references for a soapy texture attribute leads to potential confusion in replicating these results. Organic samples were reported for higher score in color, soapiness and astringency attributes. In contrast, conventional samples were found statistically higher in flouriness/dryness texture.

Recently, one of a kind, "egumi" or "egomi" taste was reported in steamed potatoes of Tokachi, Kamikawa and Abashiri geographic areas of Holkkaido, Japan (Sato et al., 2017). Egumi taste has been defined as an acrid, astringent and bitter-like taste, which irritates the root of the tongue (Sato et al., 2017). Japanese researchers have reported previously to have a more comprehensive texture language due to the diversity of textures in their food (G. V. Civille & Lawless, 1986). Thirteen untrained university students were used for evaluation and a 3-point scale with anchors was used (i.e. 1=no taste, 2=slight taste and 3=strong taste). This unique taste descriptor which was reported previously in bamboo shoots (Hasegawa, Sakamoto, & Ichihara,

1959) is adding more complexity into already complex potato taste discussions, which are frequently dominated by “bland or neutral taste of potatoes”. Free oxalic acid and its salts were reported as the principal component of the egumi taste (Hasegawa et al., 1959). Later, it was reported by Hasegawa et al. (1959) that oxalic acid does not correspond to egumi taste, as their concentration was found not correlating to the strength of the egumi taste attribute. In the same study, homogentisic acid was found responsible for egumi taste (Hasegawa et al., 1959). Similarly, hange (*Pinellia ternate* Brilenbach), a Chinese drug used for morning sickness, and taros (Hasegawa et al., 1959), were reported to have egumi taste. Thirteen μg/ml of homogentisic acid was reported as detection threshold for perception. Though the definition of egumi in literature is referred to acrid, astringent and bitter-like taste/mouthfeel descriptors, they are orthogonal and cannot be combined to give a holistic new impression, i.e., “egumi”. This Japanese perception needs thorough scrutiny and more detailed testing is needed. Descriptive analysis could prove to be an efficient tool to define and investigate reference standards for this attribute in potatoes. Of previous studies of language importance, those of Civille and Lawless (1986) and Zannoni (1997) merit attention for further readings (G. V. Civille & Lawless, 1986; Zannoni, 1997).

Table 1.3 List of descriptors used for sensory language development in potato or potato products

Descriptors used previously	**Modality**	**References**
Mashable[1]	Texture	(Chabanet, 2000)
Moist[1]	--	(Chabanet, 2000)
Homogeneous	Texture	(Chabanet, 2000)
Greasy[1]	--	(Chabanet, 2000)
Artichoke[1]	Flavor/Taste	(Chabanet, 2000)
Butter[1]	--	(Chabanet, 2000)
Celery[1]	Flavor/Taste	(Chabanet, 2000)
Acid[1]	--	(Chabanet, 2000)
Herbaceous[1]	Flavor/Taste	(Chabanet, 2000)
Bitter[1]	--	(Chabanet, 2000)
Metallic[1]	--	(Chabanet, 2000)
Astringent[1]	--	(Chabanet, 2000)
Earthy[1]	Flavor/Taste	(Chabanet, 2000)
Raw potato[1]	Flavor/Taste	(Chabanet, 2000)
Pasty[1]	--	(Chabanet, 2000)
Mealy[1]	--	(Chabanet, 2000)
Compact[1]	Texture	(Chabanet, 2000)
Sweet[1]	Flavor/Taste	(Chabanet, 2000)
Chestnut[1]	Flavor/Taste	(Chabanet, 2000)
Sticky[1]	--	(Chabanet, 2000)

[1] steamed

Pastry[1]	Flavor/Taste	(Chabanet, 2000)
Umami[1]	--	(Chabanet, 2000)
Nuts[1]	--	(Chabanet, 2000)
Mushroom[1]	--	(Chabanet, 2000)
Loastedb[1]	--	(Chabanet, 2000)
Straw[1]	--	(Chabanet, 2000)
Cereal[1]	Flavor/Taste	(Chabanet, 2000)
Firm[1]	Texture	(Chabanet, 2000)
Grainy[1]	Texture	(Chabanet, 2000)
Sweet-like[4]	Flavor	(Ulrich et al., 2000)
Earthy[4]	Flavor	(Ulrich et al., 2000)
Fodder[4]	Flavor	(Ulrich et al., 2000)
Musty[4]	Flavor	(Ulrich et al., 2000)
Burnt[4]	Flavor	(Ulrich et al., 2000)
Typical[4]	Flavor	(Ulrich et al., 2000)
Untypical[4]	Flavor	(Ulrich et al., 2000)
Waxy[1]	Appearance, mouthfeel	(Van Marle et al., 1997)
Crumbly[1]	Appearance, mouthfeel	(Van Marle et al., 1997)
Grainy[1]	Mouthfeel	(Van Marle et al., 1997)
Moist[1]	Mouthfeel	(Van Marle et al., 1997)

Sticky[1]	Appearance, mouthfeel	(Van Marle et al., 1997)
Mealy[1]	Mouthfeel	(Van Marle et al., 1997)
Firm[1]	Mouthfeel	(Van Marle et al., 1997)
Earthy[2]	Flavor	(Baur, 1995)
Raw[2]	Flavor	(Baur, 1995)
Cereal[2]	Flavor	(Baur, 1995)
Potato skins[2]	Flavor	(Baur, 1995)
Stale[2]	Flavor	(Baur, 1995)
Starchy[2]	Flavor	(Baur, 1995)
Musty[2]	Flavor	(Baur, 1995)
Cardboard[2]	Flavor	(Baur, 1995)
Bitter[2]	Flavor	(Baur, 1995)
Oxidized[2]	Flavor	(Baur, 1995)
Beany[2]	Flavor	(Baur, 1995)
Buttery[2]	Flavor	(Baur, 1995)
Grainy[2]	Flavor	(Baur, 1995)
Gummy[2]	Flavor	(Baur, 1995)
Grassy[2]	Flavor	(Baur, 1995)
Lardy[2]	Flavor	(Baur, 1995)
Nutty[2]	Flavor	(Baur, 1995)
Tallow[2]	Flavor	(Baur, 1995)

[2] For French fried potatoes

other[2]	Flavor	(Baur, 1995)
Yellow[345]	Appearance	(Seefeldt, Tønning, & Thybo, 2011; Seefeldt et al., 2011)
Brown[5]	Appearance	(Seefeldt et al., 2011)
Glossiness[5]	Appearance	(Seefeldt et al., 2011)
Loose peel[5]	Appearance	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Reflection[4]	Appearance	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Discoloration[4]	Appearance	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Skin residual[5]	Texture	(Seefeldt et al., 2011)
Skin resistance	Texture	(Seefeldt et al., 2011)
Chewiness[54]	Texture	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Hardness[4]	Texture	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Fracturability[4]	Texture	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Graininess[3]	Texture	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Mealiness[345]	Texture	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Creaminess[345]	Texture	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Moistness[345]	Texture	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Adhesiveness[345]	Texture	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Vanishness[345]	Texture	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Potato taste[345]	Taste/ Flavor	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Sweetness[345]	Taste/ Flavor	(Seefeldt et al., 2011; Seefeldt et al., 2011)

[3] mashed

[4] boiled

[5] Oven-fried

Saltiness[4]	Taste/ Flavor	(Seefeldt et al., 2011)
Astringency[4]	Taste/ Flavor	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Butter[345]	Taste/ Flavor	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Reheated taste[345]	Taste/ Flavor	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Earthy/storage[345]	Taste/ Flavor	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Green taste[345]	Taste/ Flavor	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Bitterness[345]	Taste/ Flavor	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Off taste[345]	Taste/ Flavor	(Seefeldt et al., 2011; Seefeldt et al., 2011)
Skin color[6]	Appearance	(Montouto-Graña et al., 2002)
Surface wrinkling[6]	Appearance	(Montouto-Graña et al., 2002)
Surface roughness[6]	Appearance, Tactile/Texture	(Montouto-Graña et al., 2002)
Odor intensity[6]	Sniffing	(Montouto-Graña et al., 2002)
Internal color[6]	Appearance	(Montouto-Graña et al., 2002)
Moistness[6]	Texture	(Montouto-Graña et al., 2002)
Firmness[6]	Texture	(Montouto-Graña et al., 2002)
Internal color[4]	Appearance	(Montouto-Graña et al., 2002)
Odor intensity[4]	Sniffing	(Montouto-Graña et al., 2002)
Moistness[4]	Texture	(Montouto-Graña et al., 2002)
Pastiness[4]	Texture	(Montouto-Graña et al., 2002)
Chewiness[4]	Texture	(Montouto-Graña et al., 2002)
Sweet taste[4]	Taste	(Montouto-Graña et al., 2002)

[6] Raw potato

Flavor intensity[4]	Flavor	(Montouto-Graña et al., 2002)
Aftertaste persistence[4]	Aftertaste	(Montouto-Graña et al., 2002)
Flavor intensity[7]	Flavor	(Morris et al., 2010)
Sweetness[7]	Flavor	(Morris et al., 2010)
Savouriness[7]	Flavor	(Morris et al., 2010)
Creaminess[7]	Flavor	(Morris et al., 2010)
Off-flavor[7]	Flavor	(Morris et al., 2010)
Internal color[4]	Appearance	(Montouto-Graña et al., 2012)
Odor intensity[4]	Aroma	(Montouto-Graña et al., 2012)
Moistness in the mouth[4]	Texture	(Montouto-Graña et al., 2012)
Pastiness[4]	Texture	(Montouto-Graña et al., 2012)
Sweetness[4]	Flavor	(Montouto-Graña et al., 2012)
Acidity[4]	Flavor	(Montouto-Graña et al., 2012)
Flavor intensity[4]	Flavor	(Montouto-Graña et al., 2012)
Persistence[4]	Aftertaste	(Montouto-Graña et al., 2012)
White/yellow color[1]	Appearance	(Tobin et al., 2013)
Potato aroma[1]	Aroma	(Tobin et al., 2013)
Soapy (waxy on chew)[1]	Texture	(Tobin et al., 2013)
Floury (dry on chew)[1]	Texture	(Tobin et al., 2013)
Potato taste[1]	Flavor	(Tobin et al., 2013)
Sweetness[1]	Flavor	(Tobin et al., 2013)
Astringency[1]	Mouthfeel	(Tobin et al., 2013)

[7] Morris, Shepherd, Verrall, McNicol, and Taylor, 2010

Egumi or egomi[1]	Taste	(Sato et al., 2017)
Sweetness[1]	Taste	(Sato et al., 2017)
Saltiness[1]	Taste	(Sato et al., 2017)
Sourness[1]	Taste	(Sato et al., 2017)
Bitterness[1]	Taste	(Sato et al., 2017)
Umami[1]	Taste	(Sato et al., 2017)
Catch all/Acceptability[4]	Taste	(Morris et al., 2007)

Definitions and References for sensory terminology

Some work has been done to develop terminology to describe sensory properties of potatoes. However, only few authors provided definitions (Goldner et al., 2012; Kreutzmann, Bassompierre, Thybo, Buch, & Engelsen, 2011; Montouto-Graña et al., 2002; Seefeldt et al., 2011; Walter, 1987) and only one author provided references for attributes used in language development (Goldner et al., 2012). Some published papers citing the importance of definitions and references can be found (Heisserer & Chambers, 1993; Heymann, King, & Hopfer, 2014; Lotong V., Chun S.S., Chambers., & Garcia J.M., 2003; Murray & Delahunty, 2000; Talavera-Bianchi et al., 2010). Still, the number of authors who publish fully defined and references lexicons is low. Because descriptive analysis is an important tool to help determine or establish relationships with instrumental measurements (Foegeding & Drake, 2007), the correct and thorough definition of attributes play an important role in explaining principles behind measurements. The lack of universally accepted definitions of sensory attributes accentuated the need to include these definitions in publications for understanding and development of this field. Clearly defined terms/attributes enable consensus among panelists, reduces variability in identification of measuring principles (stimuli and/or characteristics) and intensity scores, facilitates alignment on qualitative and quantitative frame of reference, and serves a means of communication. Aforementioned features of definitions are being explained by examples in Table 1.4 (Chambers et al., 2016; Dooley, Adhikari, & Chambers, 2009; Drake, Gerard, Truong, & Daubert, 1999; Russell, Drake, & Gerard, 2006; Talavera-Bianchi & Chambers, 2008). Roudaut et al. (2002) evaluated the use of definitions, their nature and applications for the “crisp” attribute. Crispness was defined by using a cultivar of principles such as, force, noise, fracture, particle geometry and structure by various researchers. An interesting observation about the reported results in this publication was to ponder around whether these principles/results are the cause or consequences

of the definitions. Technically, verbalization comes after reality, so in an ideal situation 'results' should not be the consequence of the 'definitions'. Zannoni (1997) explained the approach of concept identification as a consequence of the definitions by stating that one should consider reality first and then the process of verbalization and cautioned to deal only with words can lead to great misunderstanding. Words/terms are used as a channel to communicate reality, and the process of verbalization is always as adaptation of perceived reality in order to match thinking and words (Zannoni, 1997). Providing definitions to the panel, from any source like published literature, developed database, manuals etc., could jeopardize their working and should be avoided. Published definitions in some potato or potato-based research papers were found to be ambiguous and questionable in some instances. For example, the attribute fracturability was previously defined as "the intensity of springiness of potato" (Seefeldt et al., 2011). It seems in this definition that the panel is measuring springiness but not fracturability, which is an entirely different sensory concept. Definition of fracturability from Stable Micro Systems is defined as "the tendency of a material to fracture, crumble, crack, shatter or fail upon the application of a relatively small amount of force or impact" while for springiness is "the rate at which a deformed material goes back to its un-deformed condition after deforming force is removed". This can be confusing for a panel to evaluate, creating incorrect results, and is likely to cause misinterpretation by the final lexicon user. Similarly, other definitions that can be considered as confusing or ineffective were skin residual, which was defined as "the intensity of tough peel to chew" (Seefeldt et al., 2011) and gumminess, defined as "amount of energy required to disintegrate sample for swallowing" (Walter, 1987) etc. Similarly, another well studied confusion was 'sour' and 'bitter' by O'Mahony et al. (1979), where use of wrong adjectives for 'sour' and 'bitter' tastes was highlighted. Subjects were found calling citric acid 'bitter' in this study. Such confusions or shortcomings can very well jeopardize the relation between sensory and instrumental properties, and compromise reliability

and reproducibility of results between independent labs. Generally, in descriptive analysis, definitions include a close description of a stimuli, a close procedure to evoke a response, and an exact procedure to manipulate the sample. The definitions help panelists both to structure their knowledge regarding the sensory space under analysis and the fit of lexical meaning to such conceptual structures (Giboreau et al., 2007). Definitions used in some studies (Kreutzmann et al., 2011; Seefeldt et al., 2011) were found to contain circularity, which means to the use of term(s) being defined as a part of definition, and were not corresponding to terminological requirements. Such definitions will be incompetent to provide correct descriptions that help clarify the nature of an attribute. For example, moistness was described by "the intensity of moistness in the mouth", sweetness was described by "the intensity of sweetness", astringency was described by "the intensity of astringency", and so forth. These definitions fail to add depth to the term and their existence is questionable. Other factors which should be of importance to the experimenter are source of variation, panel training and panel alignment. For example, Panelists (Goldner et al., 2012) and replications were found as significant source of variation, which should not be an ideal situation for experiment.

Table 1.4 Features of definitions with examples

S. No.	Features of Definitions	Attribute	Definition	Example
1.	Consensus among panelists	Caramel[8]	Aromatic associated with brown sugars.	Focus on aromatics specifically from brown sugar will help all panelists to think similarly and perform as unison.
		Almond[9]	The nutty/almond flavor of marzipan (Golden marzipan)	Focus on nutty attribute of Golden marzipan particularly will help panelists to perform in harmony.
2.	Variability reduction	Caramel[8]	Aromatic associated with brown sugars.	To use brown sugar as qualitative frame of reference for caramel attribute will help in inter-individual variability reduction for intensity scoring.
		Nutty[9]	The nutty/almond flavor of marzipan (Golden marzipan)	To use golden marzipan as qualitative frame of reference for nutty attribute will help in variability reduction for intensity scoring.
3.	Measuring principle	Viscosity[10]	The force required to move the product across the tongue.	Measuring principle for measuring viscosity is 'force to roll', like force to spread the product but not force to crush.
		Firmness[11]	Press your thumb all the way through the unworked sample.	How firmness was measured: compression with thumb or fingers or bite force with incisors or bite force with the molars or compression between the tongue and the hard palate[12].

[8] Talavera-Bianchi, and Chambers, 2008

[9] Rogers, 2018

[10] Lotong V., Chun S.S., Chambers E., and Garcia J.M., 2003

[11] Drake, Gerard, Truong, and Daubert, 1999

[12] Foegeding, and Drake, 2007

4.	Protocol to follow	Spreadability[13]	The ease in which the product can be manipulated on the surface of the forearm.	Here protocol is described by applying test sample on forearm and not on any body part.
		Tooth-etch[14]	A chemical feeling factor perceived as drying/dragging when the tongue is rubbed over the back of the tooth surface.	By rubbing tongue over the back of the tooth surface is protocol to measure tooth-etch.
5.	Alignment	Fruity[15]	Sweet, dark, fruity, floral, slightly sour, somewhat woody aromatics associated with blackberry[15].	Psychologically refer to this definition for fruity experience will help to establish a new common frame of reference (blackberry, in this case) for all panelists.
6.	Communication	Metallic[1410]	An aromatic and mouthfeel associated with tin cans or aluminum foil.	A clear attribute definition also facilitates comparison with other studies[12].
		Sweet[1016]	Taste associated with sugar solutions[10].	Sweetness can be compared by using definition.

[13] Dooley, Adhikari, and Chambers IV, 2009

[14] Talavera-Bianchi, Chambers IV, and Chambers, 2010

[15] Chambers IV, Sanchez, Phan, Miller, Civille, and Donfrancesco, 2016

[16] Russell, Drake, and Gerard, 2006

Type of scales found in previous potato or potato-based studies

Bipolar 7-point structured scale was used for consumer texture preference of baked potatoes (Spear et al., 2018). No information or figure of the scale was provided. Anchors used for this study seems arbitrary as "1" was marked as moist/dense/condensed, "3" was marked creamy/smooth, "5" was marked light/fluffy and "7" was marked dry/crumbly. As a bipolar scale, it usually is acceptable to have moist on one end and dry on the other end, but other descriptors such as dense and condensed versus crumbly are not appropriate, especially with consumers as it is unclear the interpretation and knowledge a naïve consumer may have. Similarly, creamy and smooth at one end are not exactly opposite to light and fluffy attributes. Any modification to existing scales or new scales needs to be validated. Selection of word anchors for rating scales often appear arbitrary, providing both opportunities and pitfalls (Stone, Bleibaum, & Thomas, 2012). By opportunities, the author refers to the use of words that are meaningful relative to the objective of study. An example would be the use of hedonic scale anchors, originally developed to assess acceptability (like extremely, like very much, and so on), for assessing degree of satisfaction (Pardo, Alvarruiz, Perez, Gomez, & Varon, 2000). No assumption was made in this study about distance between anchors thus assuming it does not have equidistant intervals providing a function more of an ordinal-type rating scale. However, Stone et al. (2012) described rating scales as tools that provide respondents with an unbroken continuum or with ordered categories along a continuum. Anchors used in this study reflect a broken continuum, as one end of scale is representing the moist attribute, and another end the dry attribute.

Improper use of terms "panelist" and "consumers" are cited in many studies (Spear et al., 2018). It is necessary to mention that generally, the term "panelist" is reserved for someone taking part in analytical sensory tests while term "consumer" is for someone taking part in a consumer

sensory study (Rogers, 2018). A summary table was prepared for the types of scales used in potato-based studies (Table 1.5).

Table 1.5 Summary of literature on number of panelists and type of scale used

Type of Assessors	Types of Scale used	Reference
Organoleptic test, Untrained panel (*N* = 15)	Category scale (4 categories)	(Raigond et al., 2014)
Consumer panel (*N* = 50)	9-point hedonic scale	(Pardo et al., 2000)
Experienced panel (*N* = 10)	1-9-point linear scale	(Thybo, Mølgaard, & Kidmose, 2002)
Trained panel (*N* = 10)	1-15-point unstructured line scale	(Thybo, Christiansen, Kaack, & Petersen, 2006)
Experienced panel (*N* = 16)	No information provided	(van Dijk et al., 2002)
Trained panel (*N* = 16-20)	150 mm/15 cm line scale	(Jansky, 2008)
Trained panel (*N* = not provided)	1-14 numerical scale	(Walter, 1987)
(*N* = 9-11)	Unstructured 15-point line scale	(Seefeldt et al., 2011)
Trained panel (*N* = 15)	Non-graded linear scale (10 cm)	(Ulrich et al., 2000)
Trained panel (*N* = 14)	No information provided	(Chabanet, 2000)
Trained panelists (*N* = 15)	5-point category scale	(Van Marle et al., 1997)
Experienced panel (*N* = 13)	10-cm unstructured intensity scale	(Montouto-Graña et al., 2002)
Trained panel (*N* = 9)	15-point line scale	(Kreutzmann et al., 2011)
Hedonistic applicability test, Expert panel (*N* = 3)	5-point scale	(Kreutzmann et al., 2011)
Texture profile and Descriptive analysis, Voluntary assessors (*N* = 12)	9-point intensity scale	(Goldner et al., 2012)
Trained panel (*N* = 10)	0-10-point linear scale	(Morris et al., 2010)
Trained panel (*N* = 12)	10 cm unstructured scale	(Montouto-Graña et al., 2012)

Consumer (N = 300), HUT method used	7-point hedonic scale	(Montouto-Graña et al., 2012)
Appropriateness evaluation (N = 32)	9-point scale; 1-3 as not appropriate, 4-6 as partly appropriate, 7-9 as very appropriate	(Seefeldt et al., 2011)
Trained panel	0 (poor) to 100 (good) scale	(Morris et al., 2007)

Qualitative consumer testing in potato or potato-based studies

Qualitative methods such as focus groups, interviews etc. can be used for exploration of new product prototypes. While product concepts are usually explored by a marketing research group, product development groups that are most often the primary clients of sensory evaluation services may need early consumer input on the direction and success or shortcomings of newly developed variations (H. T. Lawless & Heymann, 2010). Only few studies were found where focus group technique was used for getting insight about choice and purchase decisions (Fernqvist et al., 2015; Smith & Peavey, 1990). Compared to available other ready-to-eat starch sources such as pasta, preparation of potatoes needs planning, followed by pre-preparation steps such as washing, brushing, peeling and slicing of tubers, all of which adds inconvenience, time and labor-intensive exercises (Fernqvist et al., 2015). Other attributes which were reported to impact convenience negatively were peeling, cleaning of preparation tools limited after-cook shelf-life (need to eat it immediately before the eating quality gets bad) and affected taste quality after some time, needs adjustments in lunch box (less suitable for re-heating in microwave), bad quality in microwave, poor freezing, heavy to transport from purchase location, and limited durability (low frequency of consumption and longer storage period). Potato has a high glycemic index which can be considered as a negative health factor. Other factors that can be perceived as negative are low carbohydrate diet trends, the impression of a dull meal component and old lifestyle (Wechsler, 2011), the entry of a new generation of consumers with other food preferences (Spendrup & Ekelund, 2009), perceptions of being inconvenient, time-consuming preparation, , availability of other starch sources such as bread, rice and pasta (Fernqvist et al., 2015) etc., seems to have influenced the decrease of demand of potatoes in recent years. In contrast, published data also showed some positive perceptions regarding potato consumption from a health and nutritional point of view,

even in relation to the alternatives of rice and pasta (Fernqvist et al., 2015). This suggests that positive attitudes of potatoes as a healthy alternative may increase consumption.

Conclusion

Culinary quality of spuds is of prime importance for consumer acceptability and improvement of the potato crop. Preference for fresh tubers varies with the geographical location. Flavor and texture of cooked potatoes get heavily influenced by the chemical composition and the chosen method of cooking. Concept alignment of panelists is very important for descriptive analysis and references and clear definitions help to achieve this. Sensory science has been used frequently in the past, though not always appropriately, but still it holds its importance in final decision making. A case study of its successful use in potato acceptability here will be good example. Case was of *Solanum Phureja* cultivars, where National Research Council described this cultivar as "tasty" and having a "stronger flavor and firmer texture" than common potato based on culinary quality (De Maine, Carroll, & Torrance, 1993).

Purpose of this research investigation

This experiment has three general objectives: (1) To provide a communication channel by developing standandardized language to help streamline processes and provide actionable concepts to food and plant scientists. (2) To investigate the use of consumers to describe sensory properties of potatoes by using two methods: open ended and CATA. Both methods will be compared for their capacity of information generation, difficulty and actionability. (3) To identify existing potato consumer segments in the population and explore differences and similarities among segments.

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Chapter 2 - Development of a lexicon to describe the sensory characteristics of a wide cultivar of Potatoes

Introduction

Potatoes (*Solanum tuberosum*) have been a commodity of interest for many years to farmers, commercial growers, plant breeders, food processors and consumers. Caloric and nutritional value, as well as the immense diversity of size, shapes, skin and flesh color, aroma, taste, texture and cooking methods have been one of the reasons for its vast popularity and acceptability around the world. People from different cultures, geographical locations, and climates have their own preferences for the color, aroma, flavor and texture of potatoes. These consumer preferences can only be investigated and quantified, if one has the language to communicate these preferences into business or production. The desire to assess cultivar flavor and use this information in breeding programs to improve the market value of potatoes has been expressed previously (Jansky, 2008). Currently, huge emphasis is being placed on fresh potato marketing strategies and changing consumer attitudes to prevent fresh potato consumption to decline. Understanding the sensory characteristics of potatoes is important for successful communication among stake holders and to further explore consumer food choices and behavior understanding. Adding new and improved cultivars with respect to yield, climate and disease resistance are continually investigated and developed to improve production and replace older cultivars. These varietal enhancements cause changes in sensory properties of the final product, and thus highlighting the importance of sensory research to understand the effects of physiological changes on sensory responses.

Lexicons are standardized vocabularies of perception (aroma, flavor, aftertaste, texture) (L. J. Lawless & Civille, 2013) that facilitate communication across sensory analysts, biochemists and

plant breeders, product developers, marketing professionals and suppliers at multiple points and locations. This need of communication between the 'subjective pleasures of eating and quality evaluation' to the 'objective evaluation for quality' leads to the use of sensory testing in agricultural produce. Objective evaluation of the sensory quality of potatoes initiated the use of trained panelists in potato aroma, flavor and texture evaluation. Initially, identification of off-flavors was the key objective of sensory evaluation in potatoes. However, in the past few decades, change is happening to include more complete sensory profiles of potatoes by using trained panelists. Ulrich and coworkers (2000) used a trained panel to profile the aroma and flavor modalities of three cultivars of German potatoes, viz. (or namely), *Adretta*, *Likaria* and *St 1365* (Ulrich, Hoberg, Neugebauer, Tiemann, & Darsow, 2000). Ulrich and coworkers (2000) used eight descriptors, viz., sweet-like, earthy, burnt, fodder, untypical, musty, fruity and typical, to profile aroma of boiled potatoes (Ulrich et al., 2000). Similarly, Bough (2017) used sweet, fruity, lemon, umami, buttery, creamy, earthy, woody, bitter and off-flavors other than bitter descriptors to profile cooked potato flavor for the further aroma biomarker identification by correlating these descriptors with the instrumental data (Bough, 2017). Few other attempts to profile aroma and flavor of potatoes have been documented previously (Chabanet, 2000; Gilsenan, Burke, & Barry-Ryan, 2010; Jansky, 2008). Many of the abovementioned attempts to objectively describe the sensory quality of tubers used semi-trained or un-trained panelists, used hedonic scales and ratings as part of the sensory evaluation, and used a limited vocabulary for description lacking details on definitions and references. Limited vocabulary poses many pragmatic challenges such as, encourages dumping of concepts (such as, no descriptor available for identified concept), hides unique characteristics, encourages merging of concepts (results in combination or integrated term generation (such as, merging of viscosity and oiliness into creamy concept), which are not appreciated in language development (Civille & Lawless, 1986) and makes difficult to identify a

construct. As the importance of comprehensive lexicons has been identified to improve and facilitate communication between stake holders, lexicons are being developed and extensively used in both academia and industry for a cultivar of product categories. For example, lexicons have been developed to describe body odors (Allen, Havlíček, Williams, & Roberts, 2018), dog food (Di Donfrancesco, Koppel, & Chambers, 2012), lip products (Dooley, Adhikari, & Chambers, 2009), textiles (Nagamatsu, Abreu, & Santiago, 2016), etc. Some other specific lexicons further delve into more precise and complex attributes, such as "green" (Hongsoongnern & Chambers, 2008), "beany" (Vara-Ubol, Chambers, & Chambers, 2004), "nutty" (Miller, Chambers, Jenkins, Lee, & Chambers, 2013). The style of these lexicons is helpful to further clarify complex attributes (L. J. Lawless & Civille, 2013).

This study was designed to develop a complete lexicon to comprehensively describe the sensory characteristics of potatoes accounting for a wide cultivar of potato cultivars and prepared under two cooking methods, using a highly trained descriptive panel.

Material and Methods

Fifty-five cultivars of potatoes were used for the lexicon development process (Table 1). Thirty cultivars of these potatoes were provided by the San Luis Valley Research Center at Colorado State University, while the remaining twenty-five cultivars were provided by the Hermiston Agricultural Research and Extension Center at Oregon State University. All cultivars were shipped within a week after harvesting. Samples were shipped in burlap bags, placed inside carton boxes. All samples were stored in a walk-in refrigerator with temperature and humidity controlled at 40-41 °F (4-5 °C) and 91-95% humidity, respectively.

Table 2.1 Potato cultivars used for lexicon development

S. No.[19]	**Clone**	**Type**	**Origin**
1	Ranger Russet	Russet	Oregon
2	Russet Burbank	Russet	Oregon
3	Russet Narkotah	Russet	Oregon
4	Castle Russet	Russet	Oregon
5	AO06191-1 Russet	Russet	Oregon
6	CO08155-2RU/Y	Russet	Colorado
7	CO05068-1RU	Russet	Colorado
8	AC05039-2RU	Russet	Colorado
9	Canela Russet	Russet	Colorado
10	Rio Grande Russet	Russet	Colorado
11	Russet Nugget	Russet	Colorado
12	Atlantic	Chip	Oregon
13	Snowden	Chip	Oregon
14	Pike	Chip	Oregon
15	Lamoka	Chip	Oregon
16	Chipeta	Chip	Colorado
17	Winterset	Chip	Colorado
18	CO98012-5R	Red	Colorado
19	CO99076-6R	Red	Colorado
20	CO00277-2R	Red	Colorado

21	Colorado Rose	Red	Colorado
22	Rio Colorado	Red	Colorado
23	Sangre	Red	Colorado
24	Crimson King	Red	Colorado
25	CO05037-2R/Y	Yellow	Colorado
26	CO05037-3W/Y	Yellow	Colorado
27	AC05175-3P/Y	Yellow	Colorado
28	CO99045-1W/Y	Yellow	Colorado
29	CO97232-2R/Y	Yellow	Colorado
30	AC99330-1P/Y	Yellow	Colorado
31	Masquerade	Yellow	Colorado
32	POR11PG62-3	Fingerling	Oregon
33	Russian Banana	Fingerling	Oregon
34	POR12PG28-3	Fingerling	Oregon
35	CO00405-1RF	Fingerling	Colorado
36	CO08029-1RF/R	Fingerling	Colorado
37	CO08062-3PF/P	Fingerling	Colorado
38	CO12117-4RF/R	Fingerling	Colorado
39	CO12125-3PF/P	Fingerling	Colorado
40	AllBlue	Purple	Oregon
41	Purple Majesty	Purple	Oregon
42	Purple Pelisse	Purple	Oregon
43	POR11PG7-1	Purple	Oregon

44	CO05028-4P/PY	Purple	Colorado
45	Purple Majesty	Purple	Colorado
46	Jester	Specialty	Oregon
47	Vermillion	Specialty	Oregon
48	Cheshire	Specialty	Oregon
49	Amarosa	Specialty	Oregon
50	Jelly	Specialty	Oregon
51	Magic Molly	Specialty	Oregon
52	Yellow Fin	Specialty	Oregon
53	Valery	Specialty	Oregon
54	#390	Specialty	Oregon
55	CO07131-1W/Y	B Size	Colorado

Sample Preparation for mashed and air-fried potatoes

Potatoes can be prepared in different ways. Mashing was selected because preliminary research showed that mashing was a method that maximized attribute differentiation between products. Air-frying was incorporated to add a dry cooking method and include attributes that appear due to browning and caramelization. Samples were taken out of the walk-in refrigerator in the evening before the test day and stored in the dark at room temperature (22-25 °C). Mashed potato samples were washed, peeled, sliced (Vollrath, Redco® Instacut™ 5.0, 1236 N. 18th Street, Sheboygan, WI 53081-3201), and diced into ½" cubes for boiling. Diced potatoes were boiled for optimum tenderness (checked with fork) with respect to cultivar and mashed by using handheld ricer (OXO® 3-in-1 Adjustable Potato Ricer, OXO Consumer Care Center Chambersburg, PA, USA). Three tablespoons of boiled potato water were added back into the mashed potato for the purpose of a consistent, smooth texture while being stirred. Sixty to seventy grams of product were served in glass jars (2.3" diameter and 2.1" height) over two hot ceramic tiles covered in aluminum foil to keep the mash potatoes warm during evaluation. Watch glasses were used to cover the sample before evaluation. A paper towel sheet (Bounty) was used over hot ceramic tiles to prevent sliding. Square steel pans of 8" length × width were used to hold the hot aluminum foil covered ceramic tiles. Ceramic tiles of 5.9" length×width were pre-heated in convection oven at 400 °F for about 1 h 30 min.

Similar steps up to slicing were followed for the preparation of air-fried potatoes. Sliced potatoes were trimmed for 2" length and uneven ends were removed. Forty slices of each cultivar were prepared. The 40 slices were then allowed to soak for 25 minutes in distilled water before air frying. After soaking, slices were patted with paper towels and coated with 1 ½ teaspoon of canola oil (Crisco® Pure canola oil, J.M. Smucker Company, Oreville, OH – 44667, USA). Coating was done manually in a wide mouth bowl and subsequently these coated slices were placed on crisper

tray (Royal copper crisper air fry pan, Kitchen Royale's, -) for air frying. Slices were baked in convection oven at 425 °F for 30 min or until golden brown color. Each pan was carrying 20 slices and direction of pan with respect to fan (facing fan inside oven) was rotated after 15 min.

Panelists

Five highly trained panelists from the Center for Sensory Analysis and Consumer Behavior (CSACB), Kansas State University, Manhattan, Kansas, participated in this study. All these panelists had been through 120 h of sensory descriptive analysis panel training with a cultivar of food products. This training included acuity tests for basic tastes, odors, texture, mouthfeel and descriptive capabilities. Moreover, the panelists had extensive experience in descriptive analysis with each panelist having conducted more than 1,000 hr of sensory testing/evaluation on a cultivar of food products including fresh produce.

Development of language and validation

Consensus method of descriptive analysis was used for language development. This method involves group discussion to improve the decision-making process in selecting and/or changing terms, definitions and references. The use of consensus method to provide a source list of technical terms has been documented previously for the description of a category of products such as coffee (Chambers et al., 2016), fruit juice (Koppel, Anderson, & Chambers IV, 2015), cheese (Talavera & Chambers, 2016; Talavera-Bianchi & Chambers, 2008), leafy vegetables (Talavera-Bianchi et al., 2010), etc. Three orientation sessions were held for panelists, where few samples, representing each potato category were presented. An extensive literature search revealed a list of label(s) used previously for potatoes' description, which were provided to the panelists in the first orientation session. Panelists were instructed to include all modalities (appearance, aroma, flavor, texture, mouthfeel and aftertaste) in the evaluation. A 15-point scale with 0.5 increments

was used for intensity quantification of taste concepts. Cucumber, hot water and steamed towels were used for palate and nostril cleansing, respectively.

Sample evaluation

Mashed potato samples were served in mason jars, covered with watch glass on a hot ceramic bed of two bricks. Samples were evaluated first for aroma, followed by flavor, texture, mouthfeel and aftertaste. Appearance was quantified at the end so that panelists can evaluate aroma, flavor and texture without any delay. Three samples per day (110-115 min per session per day) were served for evaluation. Samples were randomly coded using 3 digits and served randomly. If a new term was found, the panel would discuss the term and if agreed, the term would be added to the lexicon with a definition and references.

Air-fried potato samples were also served in glass mason jars on a hot ceramic bed of two bricks. Three mason jars per panelist were provided for each product. Three slices were served for texture evaluation with no watch glass on top, whereas four slices were provided for aroma and flavor evaluation in mason jars with watch glass on top. Two slices were provided for appearance in uncovered glass mason jars. Texture modality was evaluated first, followed by aroma and flavor. Appearance modality was evaluated at the end.

Data analysis

Generated data from consensus based descriptive analysis was analyzed by Principal component analysis (PCA) on covariance matrix by using JMP Pro 14.1.0 (SAS, Cary, NC, USA). Terms for the description of potatoes with definitions and references developed by the panelists. Both mash and air-fry methods are included.

Table 2.2 Terms for the description of potatoes with definitions and references developed by the panelists. Both mash and air-fry methods are included

S.No.	Term/Label	Definition	Reference(s) and Intensities
Appearance			
1	Yellow[17]	Yellow color	Pantone Coated Plus Series Pantone Coated Plus Series – 7401CP = 3.0 Pantone Coated Plus Series – 7403CP = 9.0
2	Purple[17]	Purple color	Pantone Coated Plus Series Pantone Coated Plus Series – 2351 UP = 4.0 Pantone Coated Plus Series – 2356 UP = 9.0
3	Dullness[17]	The amount of gloss or shine perceived on the surface of the product.	Kroger Sour Cream=3.0 Saltine crackers = 13.0
4	Smoothness[17]	Degree of to which the sample feels smooth and free of lumps/particulates as opposed to	Kozy shack Rice pudding = 3.0 Musselman's Apple Butter = 6.0

[17] Same for Air-fry method. No superscript implies that the term was only developed for mashed potato process.

		lumpy, rough, grainy, gritty, and/or sandy.	Philadelphia Cream Cheese = 13.0
5	Gritty	The perception of small, hard, sharp particles reminiscent of sand, or granules in pears	Quaker Yellow Corn Meal = 11.0
Aroma			
6	Sweet aromatics[17]	Aromatics associated with the impression of sweet substances.	Lorna Doone Cookies = 3.0
7	Sour aromatics[18]	The perception of/or combination of sour taste and aromatics associated with sour substances such as buttermilk.	Hiland cultured low-fat buttermilk = 5.0
8	Sweet potato	The sweet, heavy, rounded, somewhat nutty impression associated with the meat of a baked sweet potato.	Baked sweet potato = 9.0
9	Musty earthy	The aromatics associated with raw potatoes and damp humus, slightly musty notes.	Fresh Mushroom= 8.0
10	Beany	Aromatics associated with processed legumes.	Kroger Pinto Beans=6.0
11	Potato[17]	The starchy, slightly metallic, cooked vegetable-like character	Kroger Idaho Boiled Potato (*Russet Norkotah*) = 9.0

		associated with the meat of a boiled potato.	
12	Earthy[17]	Somewhat sweet, heavy aromatics associated with decaying vegetation and damp black soil.	Potting Soil = 11.0
13	Cooked[17]	Musty, brown, metallic, earthy aromatics associated with the peel of a baked potato.	Cooked Potato peel = 8.0
14	Cardboard[17]	The flat aromatics that may be associated with cardboard or paper packaging.	Cardboard pieces soaked in water =7.5
15	Brothy[17]	Savory, salty, and somewhat flat, brothy aromatics/flavors associated with juices from cooked seafood, meat, and/or vegetables.	2 Button Mushroom Broth = 3.0 (a) 2 Button Mushroom + 2 medium Shrimp Broth = 6.0 (a) 4 Button Mushroom + 4 medium Shrimp Broth = 12.0 (a)
16	Metallic	An aromatic associated with an oxidized silver utensil when rubbed inside the mouth.	The Lid of Green Giant Kitchen sliced green beans = 6.0

17	Buttery	Aromatics associated with butter.	Land O Lakes unsalted butter = 11.0
18	Cauliflower	The somewhat sharp, mild bitter and pungent taste associated with cooked cabbage and cauliflower or of *Brassicaceae* family.	Boiled Cauliflower = 9.0
19	Vegetable complex	A general term to describe a combination of cooked vegetable aromatics that may include celery, carrot, corn, potato or other vegetables.	
20	Mustard	Distinct, sharp, pungent taste and aroma, with bitter taste and heating sensation, gives buzz in the nose.	Mustard oil = 12.0
21	Raw potato peel	Musty-dusty, slightly green and damp impression associated with fresh potato peels.	Raw Potato Peel= 4.0
22	Toasted[18]	Aromatics associated with products that have a brown impression.	Crushed cheerios = 7.0

[18] Only for Air-fry method.

23	Heated oil[18]	Thick, heavy aroma impression commonly associated with heated oil.	Wesson vegetable oil = 7.0
Flavor			
24	Overall potato ID[17]	The starchy, slightly metallic, cooked vegetable-like character associated with the meat of a cooked potato.	Baked Potato = 8.0
25	Overall sweet impression[17]	A combination of sweet taste and all sweet aromatics.	1.5% C&H Golden Brown Sugar in Water = 2.0
26	Raw potato[17]	An impression of being uncooked.	Potato meat = 8.0
27	Starchy[17]	Flavor associated with starch and starch-based ingredients.	American Beauty Elbo-Roni = 8.0
28	Cauliflower	The somewhat sharp, mild bitter and pungent taste associated with cooked cabbage and cauliflower or of *Brassicaceae* family.	Boiled Cauliflower = 8.0
29	Cardboard[17]	A flat flavor note associated with cardboard or paper packaging that may be associated with a stale characteristic.	Mission Tortilla white flour = 6.0 (f)
30	Umami[17]	Savory, salty, and somewhat flat, brothy aromatics/flavors	2 Button Mushroom Broth = 3.0

		associated with juices from cooked seafood, meat, and/or vegetables.	2 Button Mushroom + 2 medium Shrimp Broth = 6.0 4 Button Mushroom + 4 medium Shrimp Broth = 12.0
31	Beany	A slightly brown, musty, slightly nutty and starchy flavor associated with cooked beans.	Kroger Pinto Beans = 5.5
32	Cooked	Musty, brown, metallic, earthy aromatics associated with the peel of a baked potato.	Cooked Potato peel=8.0
33	Toasted[18]	Aromatics associated with products that have a brown impression.	Gold Medal All-Purpose Flour = 5.0
34	Sweet[17]	A fundamental taste factor of which sucrose is typical.	1% Sucrose Solution = 1.0 2% sucrose solution= 2.0
35	Sour[18]	A fundamental taste sensation of which sodium chloride is typical.	0.15% NaCl solution = 1.5 0.20% NaCl solution = 2.5
36	Bitter[17]	The fundamental taste factor of which caffeine or quinine is typical.	0.005% Caffeine Solution = 1.0[17] 0.010% Caffeine Solution = 2.0[17] 0.020% Caffeine Solution = 3.5

37	Metallic[17]	The impression of slightly oxidized metal such as iron, copper and silver spoons.	0.10% KCl solution = 1.5 0.50% KCl = solution = 2.0
38	Musty earthy	The aromatics associated with raw potatoes and damp humus, slightly musty notes.	Fresh Mushroom= 8.0
39	Astringent	Drying puckering or tingling sensation on the surface and/ or edges of the lips, tongue and mouth.	0.03% Alum solution = 1.5 0.05 % Alum Solution = 2.5
40	Salt[17]	A fundamental taste sensation of which sodium chloride is typical.	0.15% (1.5 intensity) NaCl Solution 1.5 0.20% (2.5 intensity) NaCl Solution = 2.5
41	Eggy	Aromatics/flavors associated with cooked whole chicken eggs, with savory, earthy, salty, buttery, and sulfur overtones. May also include sweet, metallic, and cardboard notes.	Warm chopped hard boiled eggs= 3.0 (f)
42	Earthy[17]	Somewhat sweet, heavy aromatics associated with decaying vegetation and damp black soil.	Potting Soil = 11.0

43	Nutty[17]	A light brown, nut-like impression.	Kretschmer Wheat germ = 7.5
44	Vegetable complex	A general term to describe a combination of cooked vegetable aromatics that may include celery, carrot, corn, potato or other vegetables.	
45	Raw potato peel	Musty-dusty, slightly green and damp impression associated with fresh potato peels.	Raw Potato Peel= 4.0
46	Sweet potato	The sweet, heavy, rounded, somewhat nutty impression associated with the meat of a baked sweet potato.	Baked sweet potato = 9.0
Texture			
47	Initial crispness[18]	Expressing light, dry and thin texture as of crackers or potato chips, one that snaps easily while emitting a relatively loud, high-pitched noise on biting with the molars at first bite of tip of sample.	Cheerios = 4.5 Cheetos cheese puffs = 7.5 Potato chips = 10.5
48	Particle size[17]	Size of particles within the starchy mouth coating. These	Corn starch in water = 2.0

		may be small (powdery), medium (grainy). [18]Size of particles within the starchy mouth coating, following by 5 to 7 chews. These may be small (powdery), medium (grainy).	Mussleman's Apple butter = 5.0 Cooked cream of wheat = 8.0 Kozy Shack Rice Pudding = 12.0
49	Particle amount[17]	The perception of small pieces relatively harder than surrounding product. [18]The perception of small pieces relatively harder than surrounding product, following by 5 to 7 chews.	Hunt's Snack Pack Tapicoa Pudding = 2.0 Kozy Shack Rice Pudding = 8.0
50	Particles/Residuals[17]	The amount of small pieces of sample remaining in mouth just after swallowing. This does not incorporate tooth packing and refers only to particulate matter on mouth surfaces other that in and between the molar teeth. It may include fibers, flakes or granules.	Cheerios = 3.0 Wheaties=7.0

51	Mealy[17]	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.	Musselman's Unsweetened Applesauce = 5.0 Del Monte Diced Pears = 11.0
52	Lumpiness	The number of lumps present if sample is not dissolving uniformly. [None……>Many]	Kozyshack Tapioca pudding = 4.0 Hiland small curd cottage cheese = 7.5
53	Smoothness	Degree of to which the sample feels smooth and free of lumps/particulates as opposed to lumpy, rough, grainy, gritty, and/or sandy.	Musselman’s Apple Butter = 6.0 Kroger sour cream=14.0
54	Firmness[17]	The force required to bite completely through the sample with the molar teeth. Evaluate on first bite down with the molars.	Philadelphia cream cheese = 4.0 Mozzarella Cheese = 8.0

55	Adhesiveness	The degree to which the product sticks to the mouth surfaces. Judged at its highest intensity.	Musselman's Apple Butter = 3.5
56	Tender[18]	Force required to bite through with the incisors. It is not force measurement but easy to bite through.	Boiled egg-white portion = 2.0 Oscar Mayer Angus beef (uncured) Hot dog = 6.0
57	Chew count[18]	Number of chews required to masticate the sample and bring it into a state ready to swallow. The sample is chewed on one side of the mouth only.	Pepperidge Bordeaux cookie = 3.5 (8 chews = 3.0) Thomas English muffin tops = 7.5 (15 chews = 7.0)
58	Fibrous	The perception of filaments or strands of muscle tissue or plant fiber.	Tyson thin sliced chicken breast (boneless, skinless) = 7.5

Note: Tale a sip of water before testing cohesiveness of mass.

59	Cohesiveness of mass[18]	The degree to which the mass holds together during mastication after 5 to 7 chews.	Wheaties = 2.5 Cheerios = 7.0 Sara Lee butter pound cake = 9.0

Mouthfeel – Rinse with hot water before mouthfeel evaluation.

60	Mouth-drying	A drying puckering or tingling sensation on the surface and/or edge of the tongue and mouth.	0.05% Alum Solution = 2.5 0.07% Alum Solution = 3.5

61	Metallic	The impression of slightly oxidized metal such as iron, copper, and silver spoons.	0.10% Potassium Chloride Solution = 1.5 0.50% Potassium Chloride Solution = 2.0 1.0% Potassium Chloride solution = 2.5
62	Moistness[18]	The perceived amount of moisture in the product (dry to wet) during mastication, following by 5 to 7 chews.	Triscuit original (sea salt) = 1.5 Egg white portion = 5.0
63	Oily mouthfeel[18]	Producing the sensation of the presence of thin oily coating in the oral cavity surface during mastication.	Cool whip = 6.0 Fritos corn chips (scoops) = 9.0
Aftertaste – Evaluate the sample 15 seconds after swallow.			
64	Bitter	The fundamental taste factor of which caffeine or quinine is typical.	0.005% Caffeine Solution = 1.0 0.010% Caffeine Solution = 2.0 0.020% Caffeine Solution = 3.5
65	Metallic	The impression of slightly oxidized metal such as iron, copper, and silver spoons.	0.10% Potassium Chloride Solution = 1.5 (f)

			0.50% Potassium Chloride Solution = 2.5 (f)
66	Starchy	Degree to which sample mixes with saliva to form a starchy, pasty slurry that coats mouth surfaces during mastication	American Beauty Elbo-Roni = 8.0

Results and Discussion

Sixty-six attributes and their definitions were identified by the trained panel for the description of potatoes (including both mashed as well as air-fried). Each attribute has its corresponding definition and assigned reference standards shown in Table 2. Lexicon included five appearance attributes, eighteen aroma attributes, nineteen flavor attributes, twelve texture attributes, four mouthfeel and three aftertaste attributes respectively.

Initial search for available descriptors

A list of attributes from literature review was provided to the panelists on the first day of orientation to help panelists look for concepts found by other researchers in potatoes. Few of these concepts were incorporated into the study whereas a majority of these concepts were found not appropriate. For example, brown, reflection, burlap, barnyard, artichoke, celery, herbaceous, chestnut, mushroom, straw, fodder, burnt, stale, oxidized, grassy, lardy, tallow and savouriness concepts were rejected by the panelists. Major reason for this rejection was the not availability of definitions and references to identify signal and manipulation procedures to follow. Various authors in sensory science (Chambers IV et al., 2016; L. J. Lawless & Civille, 2013; O'mahony, Rothman, Ellison, Shaw, & Buteau, 1990) have extensively documented the importance of definitions and references previously.

Lexicon development and attribute relationships

Consensus method of language development helped panelists to discuss freely about number of attributes that could describe the potatoes and removed redundant attributes by agreement. During the lexicon development process, full profiles were developed for each of the potato cultivars. Appearance was described by using five attributes, namely, yellow, purple, dullness, smoothness and gritty. The definition of ‘shine or gloss’ (measured in dullness descriptor) came from inherent shine or gloss of waxy starches (higher amylopectin content), and similar

descriptors were found in literature for this concept, such as, reflection (Seefeldt, Tønning, & Thybo, 2011; Seefeldt, Tønning, Wiking, & Thybo, 2011). Thomas and Atwell (1999) found that starches from a native waxy corn were more translucent (higher transmittance) and have surface shine. Thybo et al., (2000) used 'reflection from surface' (degree of loose reflecting starch granules on the surface) as a concept for distinguishing potato texture and found that mealy and grainy cultivars had high reflection from starch granules (Thybo, Bechmann, Martens, & Engelsen, 2000). Measured dull appearance could be related to the instrumental measure of percent transmittance and turbidity for comparison. Large size starch granules showed higher transmittance values (Singh, Kaur, & Singh, 2004). Purple majesty sample from Colorado was found with highest dullness while Russian banana, Vermillion, Jelly and Valery were found with lowest dullness. In a previous study, mealy potato cultivars were observed to contain higher starch, amylose content and higher percentage of large starch granules (Kaur & Singh, 2016) and possibly could be a reason of high dullness. Gelatinization of starch granules leads to swelling and partly or complete solubilization (depending upon type of starch and cooking method used), generating a system where few remnants of granules can be found to a system in which practically all the starch is soluble. These two physiological concepts of starches were described by using gritty (remnants of granules) and smoothness (solubilized starch) descriptors. Waxy potatoes have a smooth texture with a moist gummy mouthfeel compared to dry and particulate mouthfeel of mealy potatoes (McComber, Horner, Chamberlin, & Cox, 1994). A significant negative correlation was found between smooth appearance and mealy texture (-60%), whereas positive correlation was found between smooth appearance and smooth texture (+39%), respectively. Similar results were documented previously where potato texture was defined into two contrasts, namely, smooth to mealy (Mayo Clinic, University of California, Los Angeles, & Dole Food Company, 2002; Thomas & Atwell, 1999) and obtained negative correlation between smooth and mealy in this

study confirming two contrasts (mealy and waxy starches) of starch type. Other descriptors, which were used for appearance, were yellowness (Seefeldt et al., 2011; Thybo, Christiansen, Kaack, & Petersen, 2006), intensity of white/yellow color (Montouto-Graña, Fernández-Fernández, Vázquez-Odériz, & Romero-Rodrıguez, 2002; Tobin, Moane, & Larkin, 2013), brown (Seefeldt et al., 2011), reflection (the intensity of reflection on the peeled side of boiled potato) (Seefeldt et al., 2011; Seefeldt et al., 2011), loose peel (Seefeldt et al., 2011), discoloration (Seefeldt et al., 2011; Seefeldt et al., 2011) and glossiness (Seefeldt et al., 2011). Van Marle et al., (1997) used waxy, crumbly, sticky, breakable and mashable appearance attributes for texture evaluation of steam-cooked potatoes (Van Marle, de Vries, Ria van der Vuurst, Wilkinson, & Yuksel, 1997). Mealy and crumbly appearance has been previously found associated with mealy texture (Van Marle et al., 1997). Visual cues and texture evaluation certainly shared some overlap in cognitive perception, indicating that perceptions are interrelated and not strictly classified into appearance, aroma, and texture modalities. Indeed, visual cues certainly give better outline of texture and/or mouthfeel than that of aroma because of the visibility of signal of interest.

Some aroma concepts were observed in almost all cultivars, such as potato aroma, cooked aroma, cardboard notes, umami notes (except Valery cultivar) and earthy notes (in 36 cultivars) and eventually these concepts could be categorized as major concepts/notes which provide identity to the potatoes. Earthy, nutty and buttery have been previously identified as character-impact compounds, giving principal sensory identity to the potatoes (McGorrin, 2007). Adhikari et al., (2011) found 12 major attributes in beef evaluation (Adhikari et al., 2011). Other notes, which were found in more than five cultivars but not in all cultivars, were musty-earthy notes (14 cultivars), cauliflower notes (10 cultivars), vegetable complex notes (6 cultivars) and raw potato peel aroma notes (15 cultivars). Impressions which were found unique with respect to cultivars were beany notes (Rio Colorado, Atlantic, Russet Norkotah, CO08062-3PF/P, POR12PG28-3 and

CO12117-4RF/R cultivars), buttery notes (Russian banana, Jester and POR11PG62-3 cultivars), eggy notes (Magic molly cultivar), metallic notes (Russian banana, Lamoka, AC99330-1P/Y and AO06191-1 cultivars), raw potato notes (POR11PG62-3 and CO05037-3W/Y cultivars), and sweet potato notes (Cheshire and Amarosa cultivars). Heated oil, toasted, umami, cooked, earthy and cardboard aromatics were identified in all air-fried preparation of potatoes.

Flavor of the test cultivars was verbalized by using 22 descriptors, of which sour and toasted were exclusive to air-fried method preparation. Some impressions, which were found in almost all cultivars were overall potato ID, starchy flavor, cardboard, umami, salt, cooked, astringent notes, bitter, metallic, earthy and raw potato. Some other notes which were found in many cultivars were cauliflower, (13 cultivars) nutty (25 cultivars) and musty-earthy (11 cultivars). Unique flavor notes identified in few cultivars were beany notes (Rio Colorado, CO08062-3PF/P and POR12PG28-3 cultivars), eggy (Lamoka cultivar), sweet (Lamoka cultivar), overall sweet impression (7 cultivars), vegetable complex flavor (CO05068-1RU and CO05028-4P/PY cultivars), raw potato peel (6 cultivars) and sweet potato notes (CO07131-1W/Y). Agreed-on nature of consensus methodology (Chambers IV, 2018) for attribute selection may cause dumping of some concepts, particularly those identified by one of the panelists. For example, Russet nugget, CO05037-3W/Y samples were found having mustard notes by only one of the panelists but not by all of them, and thus, it was dumped subsequently. However, panelists later found cauliflower note concept in one of the three cultivars, viz., Chipeta, Crimson king and Purple majesty, which has been previously found share some of the mustard note concepts. Both cauliflower and mustard descriptors have been used previously in the description of broccoli (Hansen, Laustsen, Olsen, Poll, & Sørensen, 1997). The French panelists have previously cited cauliflower notes in potatoes, and used mashed potatoes for the description of cauliflowers (Engel, Baty, le Corre, Souchon, & Martin, 2002). In nutshell, both panelists were using different reference

standards for the same concept, depending upon their collected odor memory. It transpired later that one of the panelists was from Punjab, India, where mustard green is used a lot in cooking, which could be a possible reason for the mustard choice as reference. Similarly, some other concepts, which were vocalized by few panelists, were acorn squash concept in Valery sample and aromatic sweet baked notes in CO05068-1RU sample.

Other notes, which were not found in this study were woody, lemon and fruity (Bough, 2017). Bough (2017) found lemon notes only in Fortress russet potato cultivar compared to fruity notes which were found in all test samples, such as Masquerade, Red luna, Yukon gold etc. Though terpene hydrocarbon, i.e., limonene compound has been previously found mentioned (via instrumental analysis) in raw, boiled, baked, French-fried, chips and dehydrated potatoes (Maga, 1994), but this was first time it was mentioned through descriptive analysis. Limonene provides a mild, minty, citrus-like odor (Porat, Deterre, Giampoli, & Plotto, 2016). Moreover, terpenes such as 3-carene and α-copaene have been found associated with citrus, pine notes (Bough, 2017). No lemon aroma or flavor were found in either one of 55 cultivars tested in this study. Woody character has been previously used as a more general term engulfing phenolic, pine, cedar, and oak-type notes (L. J. Lawless, Hottenstein, & Ellingsworth, 2012; Noble et al., 1987). Chambers et al., (2016) found a woody, slightly lemony impression in nutmeg (Chambers IV et al., 2016). It transpired that lemony appeal found in literature could be more associated with woody character. The selection of lemon slice as reference for lemon flavor in potatoes could not be justified as such because potatoes are not as such high in lemon flavor. Subtle notes of lemon, cedar or pine may be present but not such notes were found in tested 55 cultivars. Similarly, fruity attribute has been also reported in three German potato cultivars, namely, Adretta, Likaria and St 1365, but the nature of panelists used in both of these abovementioned studies was found not appropriate as either training period or references or definitions were missing.

Aroma/Flavor terms generated

Terms generated for aroma and flavor were compared below with the previous findings:

Sweet aromatics – Sweet odor quality was reported in sniffed (Gas chromatograph/Olfactometry) boiled potato aroma (Mutti & Grosch, 1999). These sweet aromatics were described as sweet, peach like, coconut like and honey like. Overall, the sweetness of the aroma could be the base, engulfing head notes of fruits or sugars. Valery and AC05039-2RU was reported to contain highest sweet aromatics.

Sweet potato – Only one sample, i.e., CO07131-1W/Y, was reported to contain this flavor note. No previous information about this concept in potatoes was found in literature. Though, sweet potato aroma has been previously found associated with carrot and dried apricot notes (Leksrisompong, Whitson, Truong, & Drake, 2012).

Musty-earthy – A negative correlation (-60%) was observed between musty-earthy and earthy variables. Damp, heavy soil has pleasant sweet aroma impression, which was absent in musty-earthy notes reference standard, namely mushrooms, and this could be a reason for this association. Raw white potato has been used previously as reference standard for musty-earthy in bean studies (Vara-Ubol et al., 2004).

Beany – Beany attribute was described as having 'notes of cooked beans' in this study. Ulrich et al., (2000) used beany and cooked descriptions associating with 2-pentylfuran in potatoes (Ulrich et al., 2000). In legumes, beany taste has been found associated with off-flavors (in Western consumers), such as in soy and pea (Roland, Pouvreau, Curran, van de Velde, & de Kok, 2017). Low correlation was observed between beany, umami and nutty (24% and 20%, respectively). Beany attribute has been also previously considered as an integrated or combination term rather than a single term (Vara-Ubol et al., 2004), engulfing brown, green pod, musty, nutty, powdery, starchy notes. Rio Colorado, Atlantic, Russet Norkotah, CO08062-3PF/P, POR12PG28-3,

CO12117-4RF/R, Ranger Russet, Snowden, Russet Burbank, Purple majesty, Pike and Cheshire cultivars were found beany.

Potato – Methional has been found to be associated with potato and earthy aroma (Oruna-Concha, Duckham, & Ames, 2001; Whitson, Miracle, & Drake, 2010). All samples were reported in this study for potato aroma. Bough (2017) found a sulfur containing methional compound by HS-SPME GC-MS in baked and boiled potatoes, responsible for potato, musty and fatty notes (Bough, 2017).

Earthy – Earthy aroma has been reported previously as an important characteristic feature of potatoes (Bough, 2017; Buttery & Ling, 1973; Jansky, 2010; Mazza & Pietrzak, 1990; Seefeldt et al., 2011). Ether (2-ethylfuran, 2-pentylfuran), alcohol (1-octen-3-ol), nitrogenous pyrazines (2-isopropyl-3-methoxypyrazine) and aldehydes (2-4-decadienal) have been found coinciding with earthy notes (Bough, 2017; Jansky, 2010). Earthy notes were found negatively correlated to musty-earthy (-60%) and positively correlated to cauliflower (35%) and umami notes (20%), respectively. Not all cultivars were reported to contain earthy aroma and flavor, such as Jester, Vermillion, Lamoka, Masquerade, AC99330-1P/Y, Jelly, Winterset, Rio Colorado, Colorado Rose, Russet Burbank, Snowden etc.

Cooked – Methional has been previously found associated with cooked potato flavor (Jansky, 2010; Oruna-Concha et al., 2001). All cultivars were found to contain cooked aroma and flavor (except, Ranger Russet, Snowden, Russet Burbank, Purple Majesty, Pike and Cheshire.

Cardboard – A positive correlation between musty-earthy and cardboard (46%) could be explained by musty notes in both variables. Cardboard pieces in water and chopped fresh mushroom were provided for reference. Cardboard notes have been extensively found in the literature and were identified as an off-odor in boiled potatoes (Blanda, Cerretani, Comandini, Toschi, & Lercker, 2010).

Umami – A positive correlation between umami and potato variables (50%) was observed. Both mushroom and potato are good source of umami compounds, which could be a possible reason for this association. Ribonucleotides act as precursors for flavor potentiators, known as umami compounds. Potato tubers have higher levels of 5' ribonucleotides than any other plant food (Jansky, 2010).

Metallic – γ-Octalactone odorant was found associated with metallic notes in boiled potato (Mutti & Grosch, 1999). Only cultivars, who found to have metallic aroma were Russian banana, Lamoka, AC993301P/Y and AO06191-1. Though, metallic flavor was found in almost all cultivars. Mineral salts, found in potatoes could be a reason for this taste.

Buttery – Buttery attribute has been used previously in the description of potato flavor (Bough, 2017; Seefeldt et al., 2011; Seefeldt et al., 2011). Aldehydes (1-nonanal, benzaldehyde, (E)-2-heptenal, pentanal, 2-phenylacetaldehyde) and alcohol ((Z)-2methyl-2-penten-1-ol) were found coinciding with the buttery flavor. Buttery aroma was found only in 3 cultivars, viz., Russian Banana, Jester and POR11PG62-3.

Cauliflower – Mustard family (*Brassicaceae*), is characterized by the presence of glucosinolates and other sulfur-containing compounds, whose enzymatic breakdown results in the release of pungent odors associated with cabbage, cauliflower, horseradish, rapeseed and mustard. Selection of cauliflower concept by the panelists as a measure (unintentional) of abovementioned sulfur containing compounds could be based on their learning of cruciferous vegetables as a reference of sulfurous notes. Presence of sulfur containing compounds in the volatiles, such as methanethiol, dimethyl disulfide, dimethyl trisulphide and dimethyl tetrasulfide have been reported previously for sulfury, cabbage-like notes (Bough, 2017; Dresow & Böhm, 2009; Mutti & Grosch, 1999). Few cultivars tested sulfurous in this study were CO12125-3PF/P, CO07131-1W/Y, CO97232-2R/Y, CO05037-3W/Y, CO07131-1W/Y, AC05175-3P/Y, POR12PG28-3, Colorado Rose,

Russian Banana, Sangre, Atlantic, Castle Russet, All Blue, Purple Majesty, Pike and Cheshire. Low to moderate correlation observed between cauliflower, earthy (35%), umami (25%) and sweet potato (41%) notes.

Vegetable complex – Referencing to definition of vegetable complex, stimuli of focus was 'combined aromatics of cooked vegetables, that may include celery, carrot, corn, potato and other vegetables', cooked and not green/raw notes were focused for this concept. Boiled potato aroma has been previously found containing vegetable notes such as of cabbage and cucumber-like (Mutti & Grosch, 1999).

Mustard – Mustard family includes cauliflowers and do share notes for sulfurous compounds and glucosinolates. Mustard and cauliflower notes compared above. See cauliflower term.

Raw potato peel – A positive correlation was observed between musty-earthy and raw potato peel (42%) variables. Green, uncooked impression of raw potato has been previously documented by 'Green descriptor' in boiled potatoes (Mutti & Grosch, 1999). Hexanal was found responsible for green descriptor origin.

Toasted – High sugar content or carbohydrates in the presence of heat gave toasted taste, which was measured by this 'toasted' concept in air-fried potatoes. All samples were found to contain toasted aroma and flavor by air-frying method.

Heated oil – Fried potatoes enjoy huge demand and this concept was specifically developed by the panelists to profile events occur during frying. Cooked, heated oil impression was identified, defined and scored in air-fried potatoes. All air-fried samples were reported to contain this impression.

Overall potato ID – Consumers have expectations about gustatory experiences of a product, which develop gradually over time, and these expectations serve as a reference point for their choice decisions. To measure how one sample is close to these developed expectations (in this case, how

one sample is potatoey), this concept was generated and scored by the panelists. This concept would engulf overall experiences associated with potatoes, and might be a layman's term equivalent. Sample which were found far from the expectations of being potato (low potato ID score), were Ranger Russet, Russet Burbank, Snowden and Cheshire.

Overall sweet impression – Important aroma compounds are produced in potatoes either by lipid degradation, maillard reaction and/or by sugar degradation (Oruna-Concha, Bakker, & Ames, 2002), which gave sweet impression to potatoes. This sweet impression of volatile and non-volatile constituents was measured under 'overall sweet impression' and cultivars such as Valery, Magic Molly, CO99076-6R, CO12125-3PF/P, CO07131-1W/Y and Cheshire were reported to contain this concept.

Raw potato – Impression of uncooked potato was measured under this label. Sometimes, due to many processing related reasons, or even due to some inherent nature, samples could end-up having uncooked notes.

Starchy – Human subjects have been proved capable of describing the taste of oligomers (7 to 14 degree of polymerization) as 'starchy' (Lapis, Penner, & Lim, 2016), giving an indication that panelists described 'starchy' concept used in this study could be same as used for oligomers. Starch-based foods such as rice have been previously described by using starchy attribute (Suwansri, Meullenet, Hankins, & Griffin, 2002). A positive correlation was found between starch and cooked (52%), starchy and buttery (38%), starchy and cardboard (40%), while a negative correlation was found between starchy and nutty (-38%), starchy and overall sweet impression (-27), starchy and bitter (-27%). All samples were reported starchy.

Sweet – Potato tubers contain low levels of sugars such as glucose, fructose and sucrose. Sweet odor quality was reported in sniffed boiled potatoes aroma passed through gas chromatograph/olfactometry (GC/O) in previous study (Bough, 2017). High ratings of sweet taste

were found in Masquerade cultivar, however, no sweet aromatics and/or sweet taste was found in this study.

Bitter – Toxic glycolalkaloids in wild potato tubers produce a strong bitter taste, providing protection against pests and disease (Jansky, 2010; Valkonen, Keskitalo, Vasara, Pietilä, & Raman, 1996). This bitterness of glycoalkloids was tracked under bitter concept and few cultivars which were not found bitter at all were, Russian Banana, Vermillion, POR11PG7-1, Colorado Rose, Chipeta, Pike and Cheshire. Bitter found correlated with cooked (-25%), starchy (-26%), salty (+67%), metallic (+61%) and astringent +76%).

Astringent – Mouth drying or puckering property of glycoalkloids (α-chaconine and α-solanine) was trapped by this concept. The few cultivars which were not reported astringent were Vermillion, Colorado Rose, Chipeta, Pike and Cheshire. A positive correlation between phenolic compounds and astringency has been reported previously (Jansky, 2010; Mondy, Metcalf, & Plaisted, 1971). Moderate correlation was found between astringency and salty (79%), astringency and bitterness (76%) and astringency and metallic (44%). Low negative correlation between astringency and sweet potato aroma (-31%) was found.

Salty – Salt attribute has been previously used in steamed potatoes (Sato et al., 2017). All cultivars were found salty except Vermillion, Colorado Rose, Chipeta, Pike and Cheshire.

Eggy – Sulfurous compounds such as hydrogen sulfide and methanethiol (Jo et al., 2013) could be a reason behind this concept development. Lamoka cultivar was found to contain eggy notes. Eggy was found correlating with cooked (30%), cardboard (33%), metallic (44%) and sweet notes (100%). Panelists found discriminating between two sources of sulfurous compounds, eggy and cauliflower.

Nutty – Strecker aldehydes, 2/3-methylbutanal and 2-methylpropanal were found previously responsible for nutty flavor in cheese (Avsar et al., 2004) while 2-4-nonadienal, o-

methylacetophenone, fufurals, benzaldehyde and 2-isopropyl-1-3-methoxypyrazine were found responsible for nutty flavor in boiled potatoes (Bough, 2017). Chestnut-like nutty flavor has been reported earlier in Japanese boiled Inca-no-mezame potato cultivar (Kobayashi et al., 2008). All cultivars were found nutty in this study. A low positive correlation was found between nutty and earthy (25%), nutty and raw potato peel (25%), nutty and raw potato aroma (29%), nutty and umami (28%), while a negative correlation was found between nutty and starchy (-39%), nutty and cardboard (-24%).

Bitter, metallic and starchy aftertastes were reported in mashed potato. Metallic, mouth drying/astringent, oily and moistness were identified as mouthfeel attributes to describe the sensations after stimuli intake. Details for developed descriptors are below:

Bitter (AT 15s) – Previous opinion of phenols being responsible for bitterness was rejected by Sinden et al., (1976) and showed that glycoalkloids correlate with taste perceptions of burning and bitterness. Highest bitter aftertaste was reported in Russet Burbank, Snowden and Chipeta cultivars. Some of these cultivars might have received less attention in breeding for selection against bitter and other off flavors (Bough, 2017).

Metallic (AT 15s) – Medium to high glycoalkaloids have been previously found associated with metallic aftertaste in potatoes (Woolfe & Poats, 1987). Russian banana and Snowden cultivars were reported with highest metallic aftertaste.

Starchy (AT 15s) – Starchy aftertaste have been previously found associated with starchy foods such as noodles, rice (Meullenet, Marks, Hankins, Griffin, & Daniels, 2000). Russet Norkotah and Vermillion cultivars were reported with lowest score for starchy aftertaste.

Texture Terms generated

Potato texture has been an important quality aspect for cooked and processed potatoes. Different sensation mechanisms such as mechanoreceptors, thermoceptors, nociceptors and

proprioceptors, help deliver a kind of composite texture sensation specific to test food. Texture played an important role in quality measurements and consumer choice of cultivars for different preparations. Since samples were not visually blinded, visual and hearing cues could be a reason for developed vocabulary. Eight attributes in mashed potatoes and ten attributes in air-fried potatoes were identified by panelists to describe the texture of 55 cultivars. Previous experience of panelists with texture evaluation helped selecting attributes for the description of potatoes. Some obvious concepts identified by panelists were mealy, particle size, lumpiness, smoothness and adhesiveness. Other attributes were generated after discussion among panelists. An extensive literature search was conducted to pool available descriptors of fried potatoes, and terms such as tender and crispness were borrowed from this search. Compared to aroma and flavor attributes, all texture attributes were used extensively for all 55 cultivars. Thus, all attributes could qualify as major texture notes for potatoes. Thybo and Martens (1998) used descriptive analysis technique to document the texture of six cultivars of potatoes (Thybo & Martens, 1999). A set of texture terms such as hardness, fracturability, firmness/cohesiveness, adhesiveness, springiness, graininess and dryness were used to profile the texture modality. Similarly, Van Marle et al. (1997) used waxy, crumbly, sticky, firm, moist, grainy and mealy mouthfeel attributes to evaluate the texture of cooked potatoes (Van Marle et al., 1997). Similar descriptors such as, firm, crumbly, moist, sticky, grainy, waxy, mealy and mashable, were used by van Dijk et al. (2002) for texture evaluation (van Dijk et al., 2002). Other studies where texture descriptors where used can be assessed in research databases (Chabanet, 2000; Faulks & Griffiths, 1983; Gilsenan et al., 2010; Martens & Thybo, 2000; Thybo et al., 2000).

Initial crispness – Initial crispness was measured immediately after air-frying since the distribution of moisture and oil content affects crispness (Primo-Martín & Van Vliet, 2009). Initial crispness has been measured previously for battered snacks (Noble et al., 1987; Primo-Martín &

Van Vliet, 2009; Primo-Martín & Van Deventer, 2011). Moderate correlation was found between initial crispness and firmness (53%) , initial crispness and tenderness (60%), initial crispness and chew count (64%), initial crispness and particle size (54%), initial crispness and residuals (49%), initial crispness and cohesiveness (40%), initial crispness and moistness (-55%).

Particle size – Starch granules vary with respect to shape and size, such as rice starch has polygonal granule shape and size of 3-8 μm, whereas potato starch has oval and spherical shape with size of 15-75 μm). Similar term, granule size has been used previously by Seefeldt et al. (2011) in mashed potatoes (Seefeldt et al., 2011). Highest particle size score was found with Russian Banana, Jester and CO12125-3PF/P cultivars whereas lowest with Pike cultivar. A negative correlation was found between particle size and particle amount (-39%).

Particle amount – Remnants of starch granules were measured by this developed term and a correlation with instrumental measurement (micrographs) of intact starch granules could be explored. Lowest particle amount was recorded with Canela Russet cultivar.

Residuals – Fiber, flake or granular residuals remaining in the mouth were measured in this concept. Highest residuals were found in CO12125-3PF/P sample whereas lowest residuals in Amarosa and Pike cultivars.

Mealy – Biologically, starches are granular, and this concept was measured by mealy attribute. Mealy attribute has been used extensively in potato texture studies (Seefeldt et al., 2011; van Dijk et al., 2002; Van Marle et al., 1997). Almost all tested cultivars were found moderately mealy, except CO12125-3PF/P, which was found highest in mealy attribute. No mealiness reported in AC05175-3P/Y.

Lumpiness – Degree of lumps in the mashed potatoes were measured in this concept. No lumpiness reported in Purple Majesty and Pike cultivars, whereas highest lumpiness reported in CO12125-

3PF/P. A high positive correlation of 79% was found between lumpiness and particle size, seems that if higher particle size of starches yields more lumps.

Smoothness – Amylopectin improves the smoothness of the paste (Cornell, 2004) and this concept was measured under this label. Highest smoothness was found with Russet Nugget and AC05175-3P/Y cultivars.

Firmness – Hardness/Firmness of cooked starches has paramount importance in the mouthfeel and amylose fraction of starches has proved significant role (Li, Fitzgerald, Prakash, Nicholson, & Gilbert, 2017) in determining the hardness of cooked starches. Amylose content positively correlates with hardness and negatively correlates with the stickiness (Li, Prakash, Nicholson, Fitzgerald, & Gilbert, 2016; Li et al., 2017). Similar term, hardness has been used previously in both mashed and fried potatoes (Seefeldt et al., 2011). A positive correlation between firmness and adhesiveness (58%) was found in this study. Cultivars such as Masquerade, Winterset, Rio Colorado, AC99330-1P/Y, AC05039-2RU, CO08029-1RF/R, AO06191-1, CO05068-1RU, CO00405-1RF, CO98012-5R were found high in firm texture, and may be postulate high in amylose content.

Adhesiveness – Stickiness of the cooked starches play an important role, such as in cooked rice, was measured under this label. Higher amylopectin content and higher the proportion of short amylopectin chains in the leachate create greater opportunity for bonding and molecular interaction, and eventually causing more force to be needed to apart cooked grains (Li et al., 2017). Seefeldt et al. (2011) have used adhesiveness term previously in mashed potatoes (Seefeldt et al., 2011). Winterset cultivar was found with highest adhesiveness property compared to others, while Pike and Vermillion cultivars were found with lowest adhesiveness. Thus, it may postulate that Winterset cultivar might have higher amylopectin leaching or higher short chain amylopectin leach-out. Moderate relation (58%) with firmness was found.

Tender – This concept was added to evaluate fried samples. Jowitt (1974) defined tenderness as the textural property manifested by a low resistance to breakdown on mastication, but the signal used in this study for measuring tender was different and defined as "the easiness to break through". Extensive discussion with the panel was done before explaining, training and selecting references for this measurement. Peas, egg-white and gelatin snacks were presented for training and signal identification. Later, the panel selected egg-white and hot dog for tender reference. Canela russet sample was found with highest score for tenderness.

Chew count – Chewy texture is an important property in finished fried, roasted and/or grilled potatoes, which was measured under this developed label, chew count. Similar term, chewy has been used previously in oven-fried potatoes (Seefeldt et al., 2011). Castle Russet cultivar was found with highest chew count, while Russet Norkotah and Valery were found with lowest chew count.

Fibrous – This attribute was added to score fibers in the sample. Only CO05068-1RU cultivar was found fibrous in nature.

Cohesiveness of mass – This concept was used to measure the holding of mass.

Mouth-drying – Mouthfeel characteristics are tactile, but often tend to change less dynamically than most other oral tactile texture sensations (H. T. Lawless & Heymann, 2010). Mashed potatoes were leaving dry sensation in the mouth, which was scored under this label. Russet nugget sample was reported with highest mouth-drying capacity. A positive correlation was found between phenolic content and astringency (82%) (Umar Lule & Xia, 2005), and tannic acid (Sinden, Deahl, & Aulenbach, 1976) was found earlier responsible for astringency.

Metallic – Oxidized metallic mouthfeel was measured under this attribute. Snowden and Russian Banana cultivars were found with highest metallic mouthfeel.

Moistness – Inherent and absorbed moisture (boiling) of potatoes gave a moist feel, which was measured under this label. Starch granules absorb moisture and swell, gave wet/moist texture. Moist attribute has been used previously in mashed and oven-fried potatoes (Seefeldt et al., 2011).

Oily mouthfeel – Fried products leave oily mouthfeel, which was scored under this attribute. CO8062-3PF/P cultivar was found with highest oily mouthfeel.

Attribute relationship and sensory profiles

About 39% of total variation in the cultivars could be described by using aroma, flavor and aftertaste attributes (Fig. 2.1). From the size of the coefficients, the first component dominated by musty-earthy aroma, must-earthy flavor, earthy flavor and earthy aroma, while second component by cooked aroma, cooked flavor, starchy flavor, overall potato ID and umami. About 70% of total variation in the tested potatoes can be explained by using appearance and textural attributes (Fig. 2.2). First component was found dominating by yellow and purple appearance of potatoes, while second component by textural attributes, such as smoothness, lumpiness and particle size.

Limitations of the study

This study was evaluated under consensus, so no replications were included in the design. This makes it impossible to assess variability in the evaluation. Additionally, the researchers using descriptive analysis method should also be aware of an inherent problem of this method, called "self-fulfilling prophecy", highlighted by Dijksterhuis and Byrne (2005), which suggests that this method always gives data and indeed this data always make sense (Dijksterhuis & Byrne, 2005). Thus, it would be the responsibility of the researcher for the validity and reliability of the data. Training of the panel, clear boundaries indexes of attributes, use of references, number of panelists, type of scale, experience of the panel and competency of the panel leader affects the reliability and validity of the obtained results. Woody, vegetable complex, nutty and beany notes could be further tested for 2nd-tier terms, such as birch, oak, pea, carrots, peanut, walnut, black beans, etc. Readers

should also note that the developed lexicon is based on the lexicon of perceptual words available within the English language itself and should not be taken as an axiom. Other languages or cultures might have more words (or signs) for the intended concept and indeed different references for those concepts.

Conclusion

Sixty-six attributes were identified, defined and referenced by a highly trained panel to describe the potato category by using appearance, aroma, flavor, texture, mouthfeel and aftertaste modalities. Fifty-five cultivars of potatoes from Colorado and Oregon regions were collected and used for lexicon development. This lexicon of potato work can be used in correlations with instrumental data, product development, quality control as well as basic research. While this lexicon is comprehensive, at this time, the lexicon can be expanded further and include “shelf-life” and other preparation methods such as baking, dehydrated etc.

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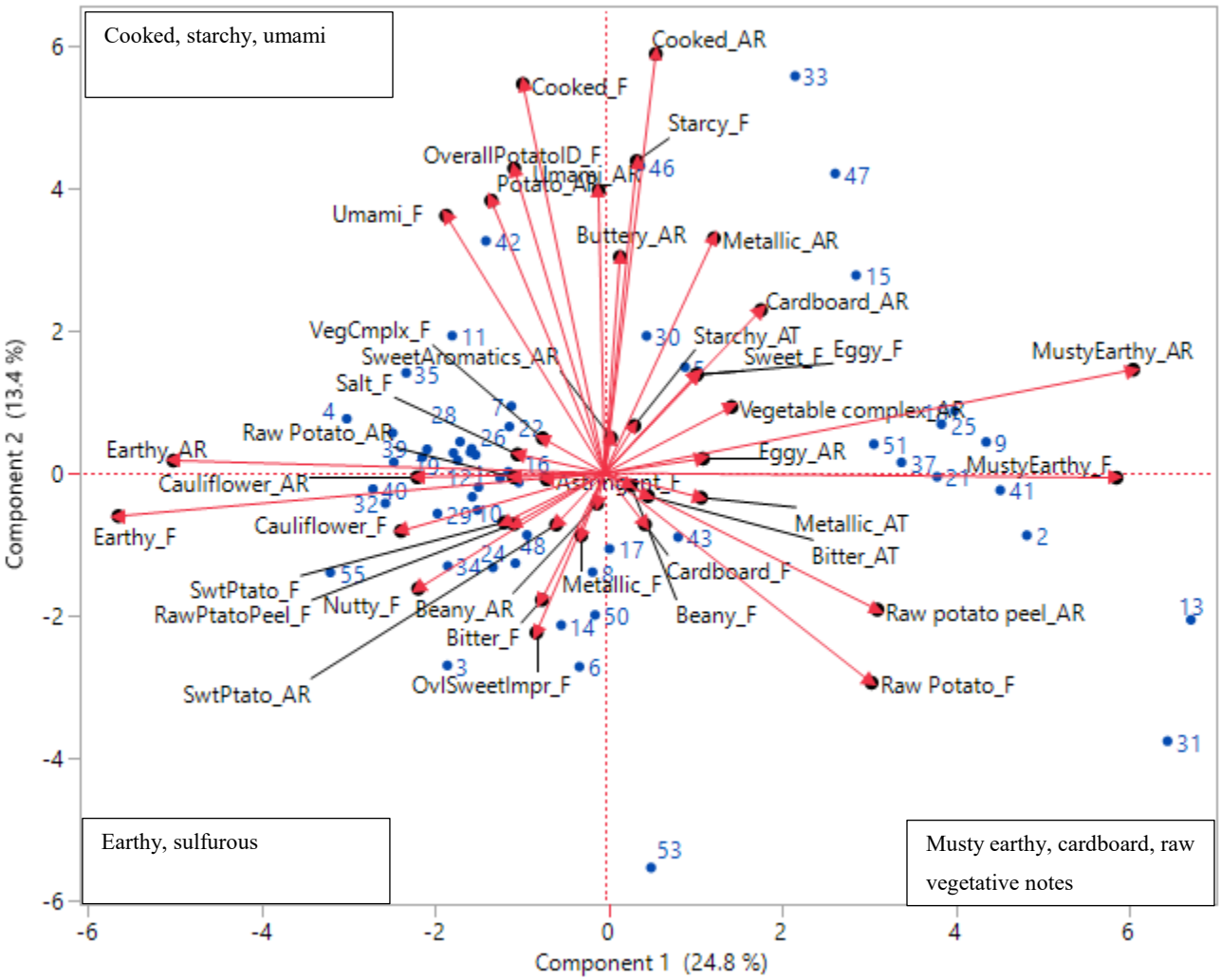
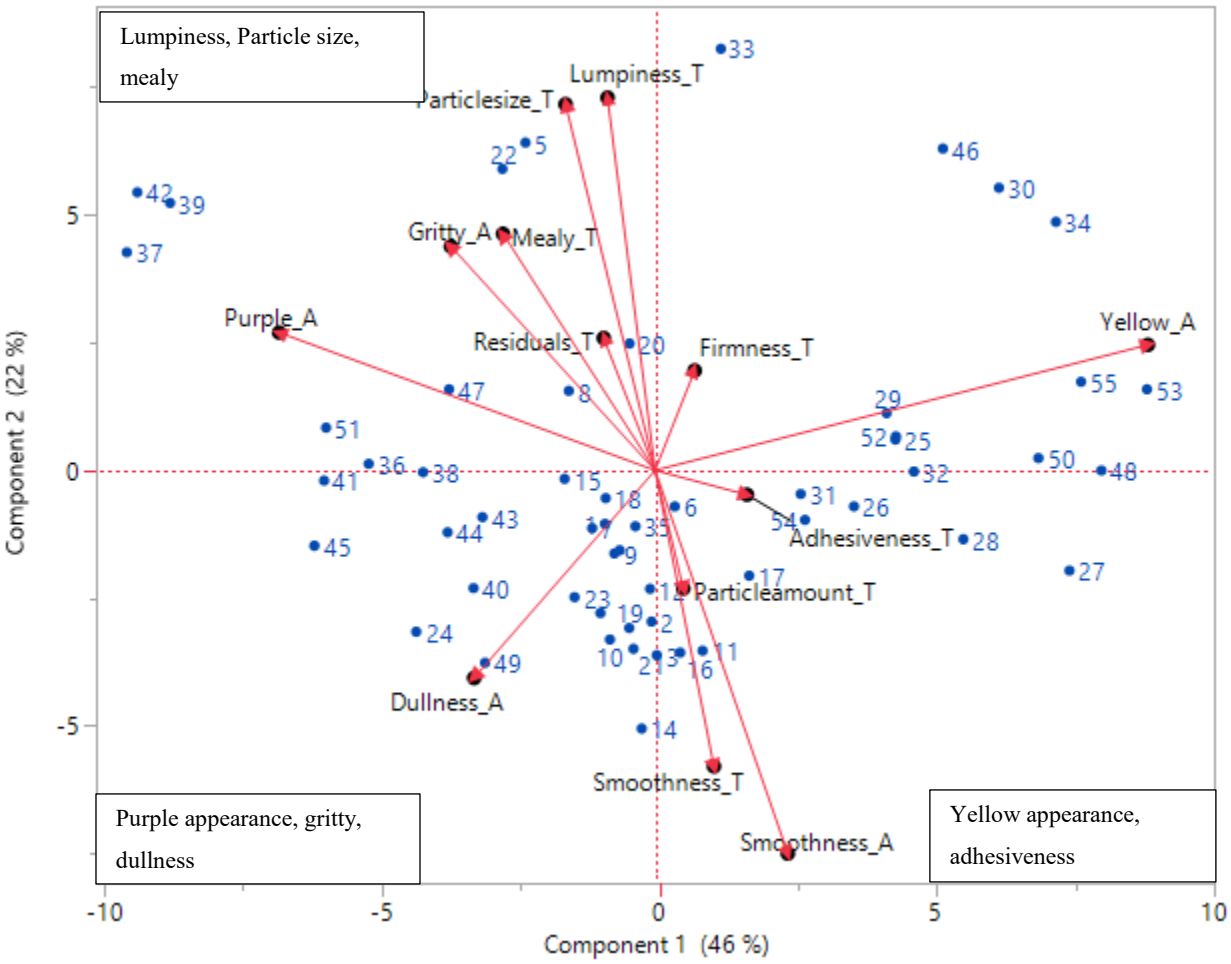
Fig. 2.1 Representation of the 55 cultivars of potatoes and associated aroma, flavor and aftertaste descriptors on the first and second dimensions of the PCA[19]



[19] Numbers shown in the PCA figures correspond to S. No. in Table 2.1.

Fig. 2.2 Representation of the 55 cultivars of potatoes and associated appearance and textural descriptors on the first and second dimensions of the PCA[19]



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Chapter 3 - Open-ended questions do generate more information than CATA, but at a cost: A study with mashed potatoes

Introduction

Potatoes have been one of the top priority crops for worldwide farmers and consumers, but a shift in consumption has been observed in past three decades. This shift in consumption affected potato industry adversely, and in result, huge emphasis is being placed on fresh market tuber quality (Bough, 2017; Taylor, McDougall, & Stewart, 2007), flavor biomarkers (Bough, 2017) and marketing strategies (Sharma et al., 2019; Sharma, Sastry, Chambers IV, & Talavera, 2019) to develop and commercialize better tasting potato cultivars. Color, flavor and texture are important sensory attributes of potato cultivars for consumer acceptability. Consumers commonly base purchasing decisions of a potato cultivar mainly on textural qualities desired. Changes in consumption are usually attributed to changes in lifestyle, habits, relative prices, income levels, convenience, or consumer tastes and texture (Morris & Taylor, 2019; Richards, Kagan, & Gao, 1997). Wood and co-workers (2017) found a positive association between consumption and taste (Wood, Carragher, & Davis, 2017). In addition, taste was cited as a factor in the success of a recently released cultivar, Cooperation 88, in China (Li et al., 2011).

The understanding of food acceptability by consumers is critical for companies to thrive in business and in the past, many perceptual mapping techniques have been used to tap this objective. Traditional mapping techniques such as factor analysis and multidimensional scaling are not a direct measure of food acceptability, rather a measure of "construct" behind obtained product map. The limitations of the traditional approaches to the construction of perceptual maps such as identification and selection of attributes, panel training, etc., can be overcome by allowing the subject to describe and evaluate products explicitly in his or her own terminology. Consumers'

description of a test stimuli is more of a "word" rather than "term" (Khan, 2016), and due to the nature of a word, consumer-based techniques have a drawback of being polysemous (i.e. have several meanings) and difficult to interpret. Still, they are direct, straightforward and extensively used previously for the description of the test samples (Ares et al., 2017; Jaeger et al., 2018; Swaney-Stueve et al., 2019). Open-end and check-all-that-apply techniques (CATA) are the two most widely used methods of consumer-derived description of test stimuli. Open-end questions have been used previously in the description of smoked pork (Sharma, Swaney-Stueve, Severns, & Talavera, 2019), milk desserts (Ares, Giménez, Barreiro, & Gámbaro, 2010) and apples (Symoneaux, Galmarini, & Mehinagic, 2012) etc. Similarly, CATA has been used previously in the description of chocolates (Ares, Barreiro, Deliza, Giménez, & Gambaro, 2010), ice cream (Dooley, Lee, & Meullenet, 2010), strawberries (Oliver, Cicerale, Pang, & Keast, 2018) etc. Open-ended questions has been previously found advantageous over CATA for endorsing more options, fine differentiation and deep processing of the response option (Smyth, Dillman, Christian, & Stern, 2006). Hypotheses tested in this study are: (1) Open-ended question pose a more cognitive challenge than CATA, (2) Consumers generated description would be as efficient as trained panel, and (3) Open-ended and CATA methodologies will give similar results.

The aim of the present work is to evaluate the use of open-ended and CATA methods to assess and discuss the information provided by each technique.

Material and methods

Sample preparation and serving

Potatoes were breed and harvested by the San Luis Valley Research Center at Colorado State University, and the Hermiston Agricultural Research and Extension Center at Oregon State University. A highly trained descriptive panel at the Center for Sensory Analysis Center and Consumer Behavior at Kansas State University first generated sensory profiles for fifty-five

different potato cultivars. Modalities including appearance, aroma, flavor, and texture were evaluated. After the descriptive profiles were generated, a subset of 12 samples was selected to minimize consumer fatigue but still represent a diverse set of cultivars and sensory properties (Table 3.1). All cultivars were stored in walk-in refrigerator with temperature and humidity controlled at 40-41 °F (4-5 °C) and 91-95% humidity. Potatoes were peeled, diced into cubes and kept immersed in cold water until ready for cooking to minimize browning. When ready, samples were transferred to a jacketed cooking kettle (Cleveland, Model – KET-6-T, Cleveland Range Ltd., Toronto, Canada) and boiled until samples cubes were tender. The cooking temperature for doneness was 175 °F. When done, samples were drained and mashed using a ricer (Stainless steel potato ricer, 25 oz. capacity, WebstaurantStore, Lancaster, PA). A portion of the boiling water was saved for the final mixing. Once mashed, samples were transferred to the mixer and added 2.5 US cup (40 tablespoon/15.5 lbs of boiled potato mass) of the saved boiling water until fully mixed (Globe, Model – SP 30, Globe food equipment company, Dayton, OH). Samples were separated in portions based on serving design, packed and vacuum sealed (VacMaster, Model – VP325, 5200 W 110th Suite 200, Overland Park, KS, USA), and kept frozen (5-10 °F) until the day of testing. On the day of testing, a braising pan with tilting skillet (Cleveland, Model – SEL-30-T1, Cleveland Range ltd., Toronto, Canada) was used for thawing samples and steam table (Duke manufacturing, Model – E304 M, 2305 N Broadway, St. Louis, MO 63102) with counter tops was used for holding warmed samples before serving. An amount of 42 g/serving was served to consumers. Samples were served plain (no condiments or additional flavors added). Serving temperature was 145 to 155 °F.

Table 3.1 Cultivars used in study

S. No.♥	Clone	Type	Origin
1	CO05068-1RU	Russet	Colorado
2	Canela Russet	Russet	Colorado
3	Atlantic	Chip	Oregon
4	CO99076-6R	Red	Colorado
5	Rio Colorado	Red	Colorado
6	AC99330-1P/Y	Yellow	Colorado
7	Masquerade	Yellow	Colorado
8	Russian Banana	Fingerling	Oregon
9	POR12PG28-3	Fingerling	Oregon
10	Purple Majesty	Purple	Oregon
11	Vermillion	Specialty	Oregon
12	Valery	Specialty	Oregon

Participant recruitment

A total of N = 96 participants from the Kansas City area were screened for equal representation of gender at the Center for Sensory Analysis and Consumer Behavior in Kansas State University, Olathe. A wide age distribution of participants ranging from above 18 years to 75 years was allowed in view of capturing consumer attitudes and behaviors towards changes happening in potatoes. There were two questionnaires tested (open ended and CATA) so participants were divided into two groups, one for each questionnaire. For open-ended

♥ Numbers shown in the MFACT plots correspond to S. No. in Table 1.

questionnaire, N = 48 participants of which 28 male and 20 females participated while for CATA questionnaire N=48 participants of which 22 male and 26 females participated. Age distribution of participants for both open-ended and CATA questionnaires is presented in Table 3.2. Consumers were potato purchasers and were screened for food allergies, employment and participation in consumer research in past 3 months.

Table 3.2 Age distribution of participants

Age distribution	**Number of participants**	
	Open-ended method (*N* =48)	**CATA method (*N* =48)**
18 to 24	0	1
25 to 34	6	12
35 to 44	14	7
45 to 54	14	9
55 to 64	8	14
65 to 74	7	5

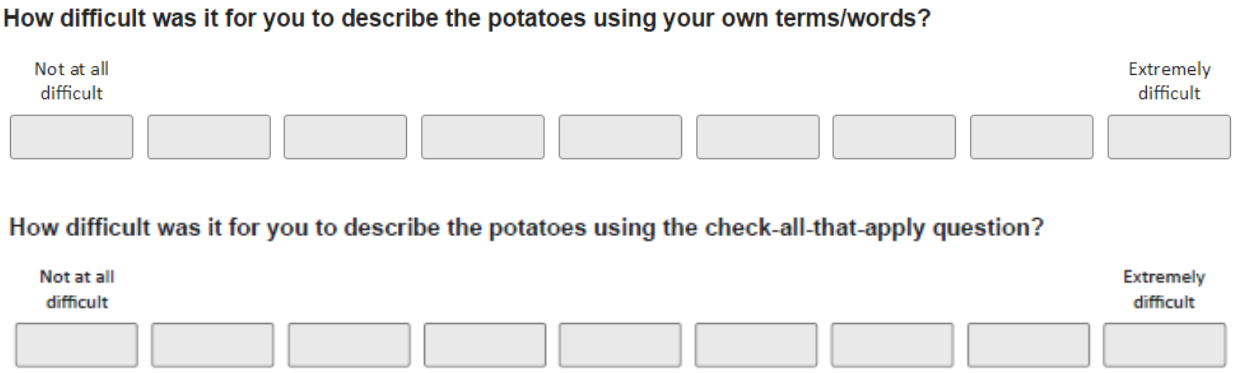
The study was conducted under an Institutional Review Board (IRB) using approved protocol, and subjects were paid for their participation. Informed consent was obtained by participants prior to product evaluation. Compusense Cloud (Compusense, Inc., Guelph, Ontario, Canada) was used for recruitment, screener and questionnaire preparation as well as data collection.

Questionnaire

The questionnaire was developed to investigate differences in terminology generation and usage for the description of potatoes. Two types of questionnaires, one with open-ended and one with check-all-that-apply (CATA) methodology, were prepared to investigate the differences. In

the beginning of the questionnaire, participants were asked to evaluate overall, appearance, aroma, taste, flavor and texture liking on a 9-point hedonic scale. Following the hedonic questions, participants were asked for open-ended or CATA question depending on the type of questionnaire assigned to assess their perceptions about each product. CATA terms were selected based on initial experiment, where high intensity traits (HITS) method was used with consumers for terminology generation (Ciccone, 2019). For both open-ended and CATA questions, a small introduction statement was used, stating, "The following question is very important to understand the characteristics of potatoes. Please take your time when answering it", since Smyth (2009) showed previously that a motivating instruction can be helpful to improve the quality of answers (Smyth, Dillman, Christian, & McBride, 2009). Similar introductory statements were used for other two open-ended questions, stating, "The following question is very important to understand the AROMA AND FLAVOR (or TEXTURE) of potatoes. Please take your time when answering it". First, an open-ended question was asked to get an idea of the categories of responses, as it was hypothesized that respondents will use those terms which are most distinguishing for them. Other two open-ended questions were asked to delve into more specific categories such as flavor and texture. Open-ended and CATA methodologies were tested for their inherent difficulty to use by consumers on a 9-point category scale (Fig. 3.1).

Fig. 3.1 Hybrid 9-point category scales used for measuring inherent difficulty of open-end and CATA methods



Design of experiment

Crossover design was used for two-day consumer study experiment, in a view to achieve a full crossover where each assessor evaluates each sample in a sequential monadic presentation. A crossover design has each treatment given once to each subject and has each treatment (mash potato) occurring an equal number of times in serving position (Oehlert, 2000). Crossover design has subject and time as blocks.

Data analysis

Cochran's Q test was used for CATA generated data. Consumers were assumed as experimental unit (EU) in this study and since all treatments (12 potato cultivars) were tested on consumers, causes the assumption of independence of observations to be violated. Therefore, one cannot use chi-square test. Cochran's Q test investigates differences between treatments for crossover studies with binary outcomes (like multiple choice questions or checked/unchecked CATA question (Meyners, Castura, & Carr, 2013). For exploratory purposes, correspondence analysis (CA) was applied to visualize the relationship between consumer terminologies (Sharma et al., 2019) in a two-dimensional space. The 9-point hedonic score data for overall liking was incorporated into the analysis as frequency data by counting top three anchor points (7, 8 and 9 on

9-point scale) data into ‘Like’ whereas bottom three anchor points (1, 2, and 3 on 9-point scale) data into ‘Dislike’. The evoked descriptions from the open-ended question were qualitatively analyzed (Sharma et al., 2019). Terms with similar meanings were grouped into respective categories (Table 3.3). Frequencies in each category were determined by counting the number of consumers that used those words to describe the samples.

Table 3.3 Words used for open-ended questions

Words used	**Redundant words**
Authentic	Real, realistic
Average	Mediocre
Bland	Blah, Meh
Chemicals	Plastic
Crumbly	Falls, fells, weak
Disgusting	Bad, nasty, weird, yuck
Fibrous	Fiber
Grainy	Gritty
Hard	Stiff, solid
Lumpy	Lumps, clumps, clumpy
Mealy	Grainy, gritty, coarse
Moist	Wet
Pleasant	Nice
Potatoey	Homemade
Stiff	Firm
Tasty	Delicious, yummy

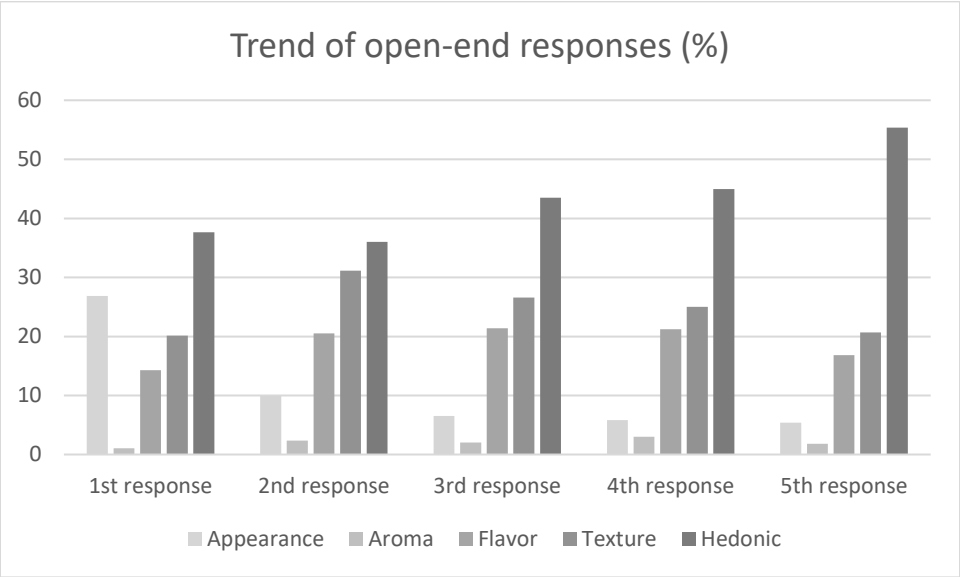
Thick	Dense
Thin	Watery, runny
Unnatural	Artificial, fake

Penalty-lift analysis was performed to study which CATA words positively or negatively drove liking acquisition and to what extent (Waehrens, Grønbeck, Olsen, & Byrne, 2018). Multiple Factor Analysis for contingency tables (MFACT) was performed to study the relationship between open-ended question(s) and CATA question (Sharma et al., 2019).

Results

Open-end results

Fig. 3.2 Types of consumer responses to open-ended question

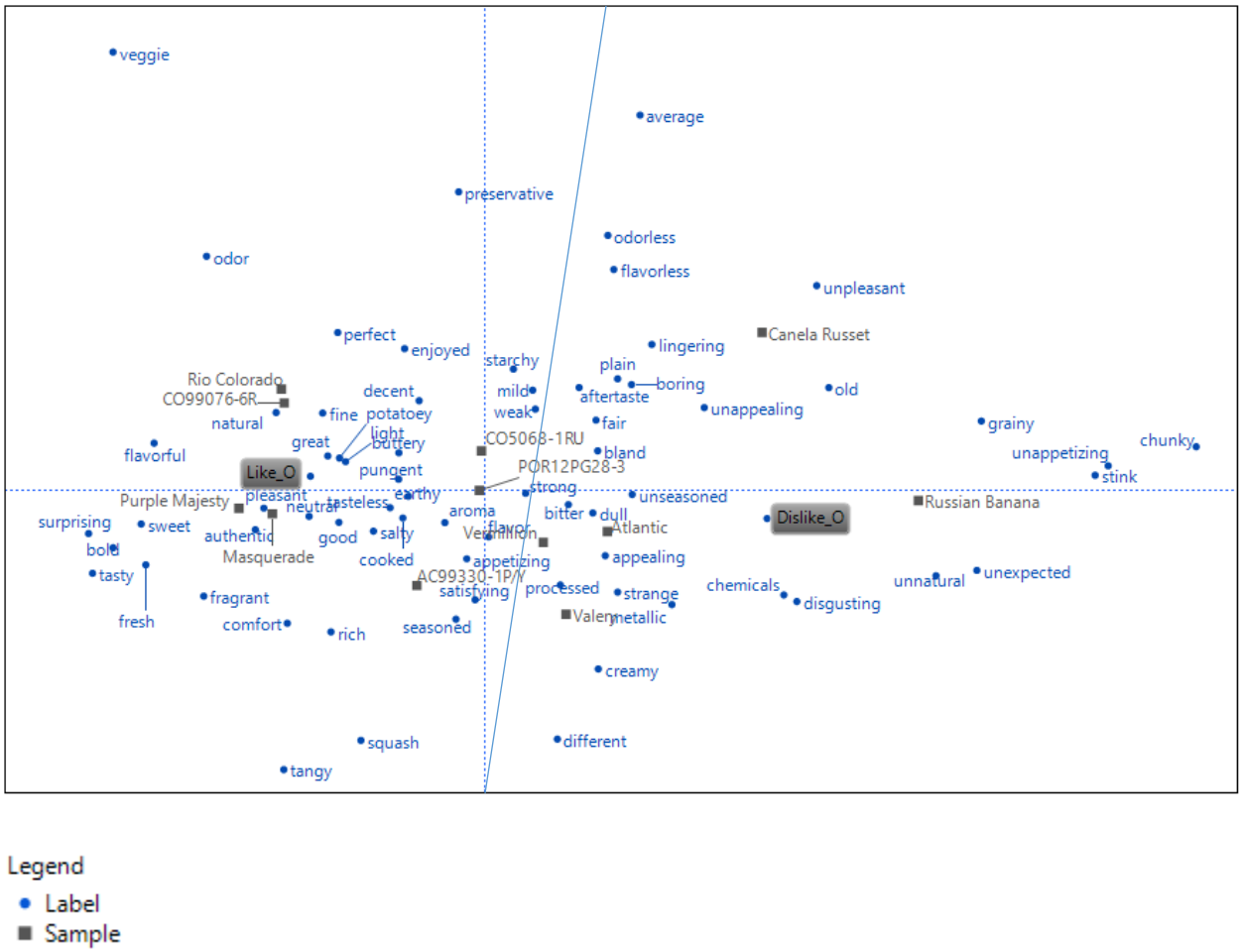


Note – The above responses were based on the following question: "If you have to describe the characteristics of these potatoes to a friend, what FIVE WORD/TERMS would you use?". Five separate boxes were provided for consumers to write their answers. Responses were mandatory.

The first box was mostly used for appearance and hedonic terms, whereas hedonic, texture and flavor associated terms were found leading in all other 4 response spaces. This trend confirms that minimal thinking-based choice decisions always lead at first place. Ciccone (2019) found that consumers used more texture terms compared to aroma and flavor with respect to describing potatoes. More concrete definitions with respect to texture (Ciccone, 2019), visual ques and tactile sensation of the textural attributes help consumers explain stimuli. Previous research (Christian & Dillman, 2004; Israel, 2006) found that larger space for comment encouraged longer answers, so thus it was assumed that higher number of boxes would yield same results. However, from obtained results (Fig. 3.2), it appeared that the use of hedonic terms was highest after fourth open-

box. Frequency of technically categorized flavor and texture terms seems similar in third and fourth response, followed by an obvious decline in fourth response box.

Fig. 3.3 Representation of the words from open-ended question for the description of AROMA and FLAVOR of Potatoes on the first and second dimension of the Correspondence analysis



Legend
- Label
- Sample

Note – The above responses were based on the following question: "Please describe the taste (AROMA and FLAVOR) of these potatoes by using FIVE WORDS/TERMS".

After the general category's responses, consumers were asked more specifically about aroma/flavor and texture attributes. This information was analyzed using correspondence analysis (Figures 3.3 and 3.4). For aroma/flavor, the first dimension (horizontal) pulls apart flavorful, sweet, potatoey, buttery, natural, light, cooked and salty impressions from processed, bland,

flavorless, bitter, grainy impressions. The first dimension explained about 30% of inertia (variance/variation). Words such as preservative, average, creamy, flavorless, veggie, odorless, mild and flavor were well represented on second dimension (Table 3.4). The quality of the representation of the words was measured by squared cosines. The profiles did not differ as much vertically as horizontally, as indicated by the much lower percentage of inertia the second axis (12.8%). The third dimension additionally adds 10% of inertia, but similar position of the row profiles (samples) was obtained. Closeness between tasty, sweet, potatoey, fresh and bold words indicated that they have similar column profiles for frequency (Fig. 3). Looking only at the profiles' positions for a moment, the groups farthest apart were CO99076-6R, Rio Colorado, Masquerade and Purple majesty on the left side, opposed to Russian Banana, Canela Russet, Atlantic, Vermillion and Valery, on the right side. Points or markers lying close together share similar either row or column profiles. As the profiles become dissimilar, such as Masquerade and Russian Banana, the markers become further apart. Masquerade, Purple majesty, CO99076-6R and Rio Colorado cultivars were found to have strikingly different row profiles with respect to Russian Banana and Canela Russet. From attribute perspective, layout of Russian Banana and Canela Russet seems corresponding to off-flavor attributes. Closeness of dislike to grainy, stink, unnatural, disgusting, flavorless, average, odorless, starchy, bland and plain words indicated that they have similar column profiles for frequency. Tangy, squash and veggie words were located far away from the origin, and they could be misinterpreted as having stronger implications to the derived space. However, the frequency for these words was less (below 10) compared to some other words, which were closer to origin, thus interpretation based on these attributes could be suspicious. Emotion describing words were found in open-end description of aroma and flavor, such as enjoy, surprising, bold, comfort, dull, boring, pleasant etc. Words which could qualify as being actionable to work upon by product development were sweet, bitter, sour, salty, metallic,

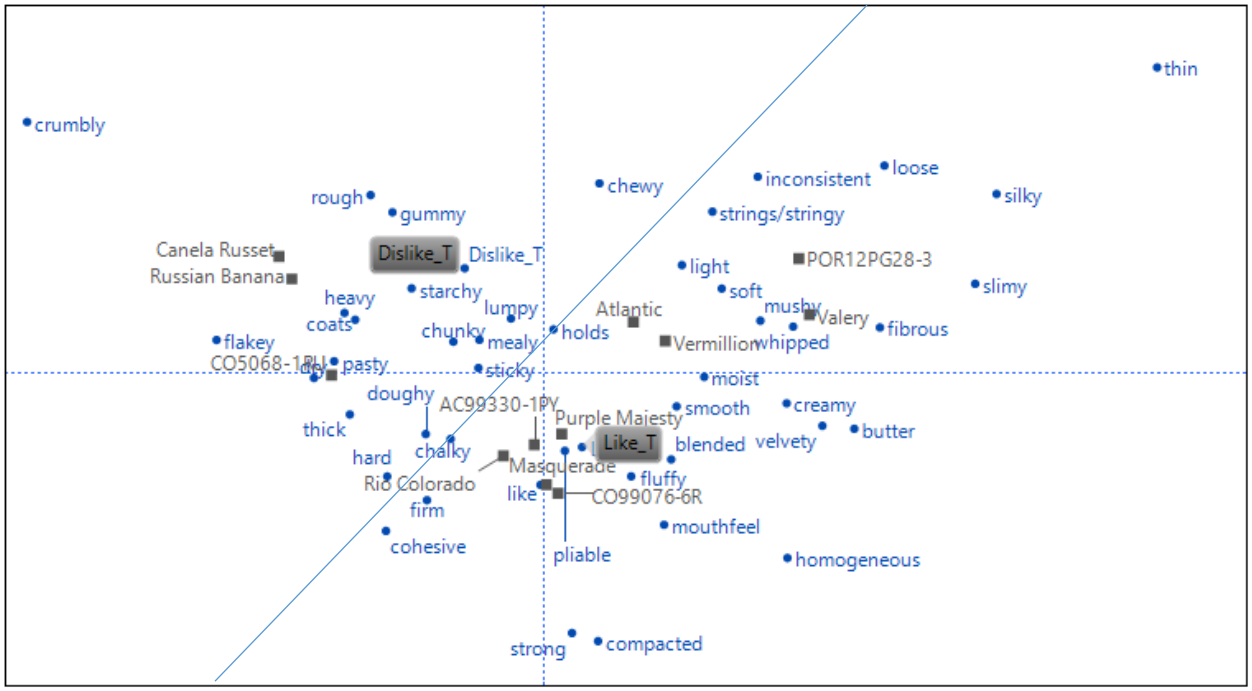
pungent, lingering/aftertaste, bland, plastic, creamy, chemical, grainy, processed, earthy, squash, and tangy. Words which could qualify under hedonic words were also found such as, good, average, fair, authentic, etc. Aroma and flavor liking from 9-point hedonic scale was found associated towards Rio Colorado, CO99076-6R, Masquerade and Purple majesty cultivars. Red potato cultivars, namely, Rio Colorado and CO99076-6R were found to be highly liked for aroma and corresponding with positive words such as enjoyed, surprising, perfect, great, decent etc. Russets, namely Canela russet and CO05068-1RU were found corresponding to bland, plain, mild, flavorless, odorless, unpleasant impressions. Cultivar POR12PG28-3 was not explained by either sets of point (row and column), and hence lies on the origin of the axes.

Table 3.4 Quality of representation of the words used by consumers on first, second and third dimensions[20]

Dimension 1		**Dimension 2**		**Dimension 3**	
Words	**cos^2**	**Words**	**cos^2**	**Words**	**cos^2**
Authentic	.59	Aroma	.35	Decent	.48
Bland	.47	Average	.73	Metallic	.51
Bold	.30	Creamy	.52	Perfect	.35
Chemicals	.37	Flavor	.40	Rich	.40
Chunky	.49	Flavorless	.47	Seasoned	.63
Disgusting	.63	Mild	.42		
Flavorful	.37	Odorless	.44		
Good	.41	Preservative	.78		
Grainy	.55	Veggie	.47		
Natural	.44				
Old	.30				
Pleasant	.73				
Potatoey	.52				
Stink	.47				
Strong	.48				
Tasty	.63				
Unappetizing	.63				
Unnatural	.57				

[20] If a variable (word used by consumer) is well represented by two dimensions, the sum of the cos^2 is closed to 1. Only words which have cos^2 value above 0.3 were mentioned in the table.

Fig. 3.4 Representation of the words from open-ended question for the description of TEXTURE of potatoes on the first and second dimension of the Correspondence analysis

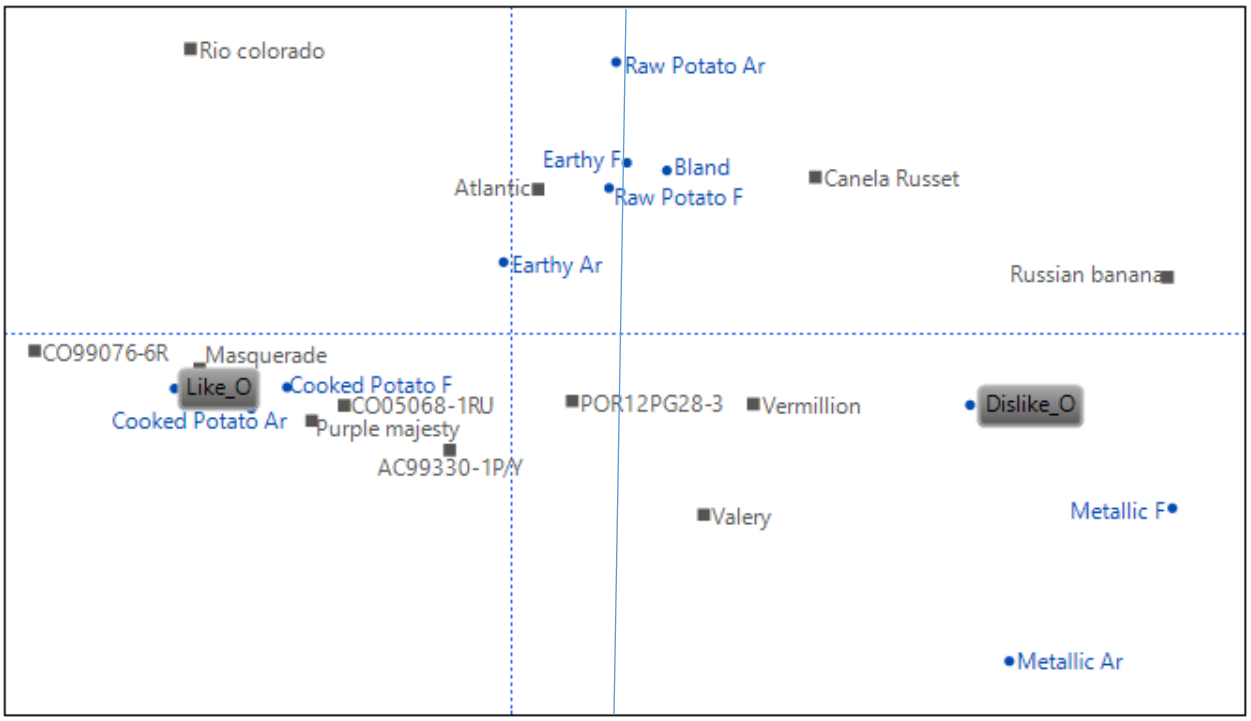


Note – The above responses were based on the following question: "Please describe the TEXTURE of these potatoes by using FIVE WORDS/TERMS".

About 57% of variation was explained by first and second dimensions (40 and 17%, respectively), when using textural attributes to describe potatoes (Fig. 3.4). By looking at column profile positions, three or four groups of texture appeared (Fig. 3.4). Atlantic, Vermillion, POR12PG28-3 and Valery cultivars were found having a strong correspondence with soft, mushy, thin, fibrous and light texture, while russets such as Canela russet and CO05068-1RU cultivars were found corresponding with the flakey, crumbly, mealy, starchy, chunky and lumpy texture. Fingerlings such as Russian banana and POR12PG28-3 were found corresponding to two opposite contrasts of texture. Other cultivars (Red and Yellow cultivars), which were most liked by consumers because of their texture, were corresponding with smooth, creamy, fluffy, cohesive, thick, firm and hard texture.

CATA results

Fig. 3.5 Representation of the words from check-all-that-apply question for the description of potatoes on the first and second dimension of the Correspondence analysis



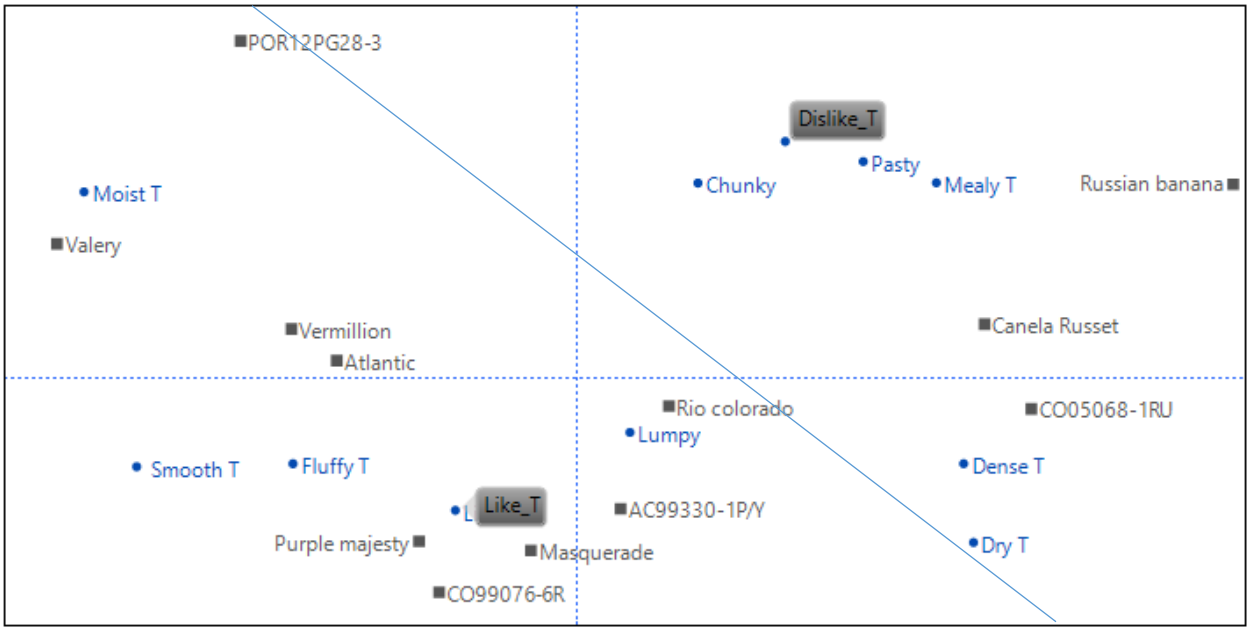
Note – The above responses were based on the following question: "How would you describe these potatoes? Check all that apply".

Table 3.5 Contingency table for the mashed potatoes with CATA derived attributes

Products	Attributes													
	Mealy T	**Fluffy T**	**Smooth T**	**Moist T**	**Dense T**	**Cooked potA**	**Cooked potF**	**Metallic F**	**Metallic A**	**Raw potA**	**Raw potF**	**Earthy A**	**Earthy F**	**Dry T**
AC99330-1P/Y	7	5	19	14	30	21	26	6	6	8	14	10	12	14
Atlantic	12	16	22	26	13	19	21	5	2	17	18	10	12	13
CO05068-1RU	21	5	5	8	34	22	26	4	3	11	10	8	10	25
CO99076-6R	8	12	23	17	22	24	33	0	0	8	10	10	10	15
Canela Russet	17	8	6	7	26	13	17	8	3	14	17	14	18	21
Masquerade	9	10	21	13	20	24	30	4	2	8	14	9	13	17
POR12PG28-3	12	6	20	35	9	23	22	3	5	10	14	10	13	1
Purple majesty	6	11	23	17	15	25	29	4	3	8	11	16	10	18
Rio Colorado	16	7	9	18	26	22	27	0	2	17	15	13	20	13
Russian Banana	28	3	2	3	34	8	17	12	7	15	17	10	18	23
Valery	7	12	24	35	6	17	22	9	8	9	9	8	12	2
Vermillion	13	11	21	25	10	20	22	9	8	11	15	14	17	9
Total	**156**	**106**	**195**	**218**	**245**	**238**	**292**	**64**	**49**	**136**	**164**	**132**	**165**	**171**

About 82% of variation can be explained by using first two dimensions (69 and 13%, respectively) (Fig. 3.5). The closeness of the metallic aroma and flavor to dislike implied that these impressions share common column profiles. Metallic flavor has been previously reported as a defect or off-note in oils, cereals, dairy and beer (Lawless et al., 2004), and the obtained results could be due to this previous association rather than an actual cause of dislike. Metallic aftertaste has been previously found associated with samples high in glycolalkaloids content (Woolfe & Poats, 1987). Similarly, the close proximity of samples Masquerade, CO99076-6R and Purple majesty implied that the profiles of these points were similar. Cooked potato aroma and flavor were found sharing similar column profiles with consumer's liking. Cooked potato flavor word was found most closely associated (294 times) of all the available words with the potatoes, followed by cooked potato aroma (238 times) (Table 3.5). Participants used the 'other' option 101 times to record their choice response for the description. Among 'other' selections, most countered word participants used was bland (19 times), color (11 times), chunky (9 times), lumpy (8 times), tasty (6 times), pasty, aftertaste and off-smell (4 times), astringent (3 times), starchy and slimy (2 times), broccoli and squash (1 time). 'Cooked potato aroma and flavor' words are character-impact (McGorrin, 2007) words, which provide identity to the cooked potatoes, thus, obviously would be checked at a first glance with minimal thinking. However, these words could be less actionable.

Fig. 3.6 Representation of the words from check-all-that-apply question for the description of TEXTURE of the potatoes on the first and second dimension of the Correspondence analysis



The first two dimensions explained about 81% of variation, being 63% on first and 18% on second dimension (Fig. 3.6). Mealy, chunky and pasty texture were found sharing similar column profiles to consumer's dislike. Compared to metallic flavor, mealy texture could be more obvious to consumers and obtained correspondence (mealy with dislike) seems holding real measurement. Visible cues help classify texture compared to aroma and flavor, which could be a reason for better discriminating with texture modality attributes. Mealiness is an important attribute for some crops such as apples, tomatoes, pears, etc. and it has shown to have a negative effect on consumer liking. For example, mealy apples were found less liked by British, Canadian (Bowen, Blake, Tureček, & Amyotte, 2019) and Danish consumers. Indeed, mealiness in apples was considered a negative quality attribute associated with fluffy appearance, stale flavor, floury and granular texture. On contrary, other results were found where mealy apples were liked, especially by Spanish consumers (Carbonell, Izquierdo, Carbonell, & Costell, 2008). Purple majesty, CO99076-6R and Masquerade cultivars were found strongly corresponding with liking.

Russets, namely, CO05068-1RU and Canela Russet were found to have a strong correspondence with dense and dry texture. Russets have been previously found associated with dry character and particulate (mealy) mouthfeel, acknowledging to increased volume of gelatinized starch. Contrarily, moist, smooth, cohesive, gummy and creamy mouthfeel have been previously found associated with waxy red-skinned cultivars (McComber, Horner, Chamberlin, & Cox, 1994). Mealy texture was found sharing similar column profile with consumers dislikes, whereas smooth, fluffy and moist texture were found sharing similar column profiles with consumer likes. Choice of potatoes based on end use demands both mealy and waxy types. Therefore, it would be misleading to conclude that waxiness drives liking. Mealy potatoes are preferred for baking, frying, chipping, mashing purposes whereas waxy cultivars are preferred for sautéing, creamed, and potato salads. However, mealy potato texture, indeed in mashed potatoes was not liked by respondents based on the results. Some unique concepts such as squash and broccoli were found related to AC99330-1P/Y and Atlantic cultivars respectively. Chunky word used by consumers provided another option associated with pasty and mealy notes. It was also found that participants liked Purple majesty, but some participants found it hard to accept its color.

Table 3.6 shows the results from the overall analysis, based on Cochran's *Q* test. Effective sample size (i.e., the number of consumers showing at least some variation between products regarding the respective attributes) varied from 21 (metallic aroma) to 48 (cooked potato flavor). Lowest number of respondents observed with metallic flavor attribute implied that either respondents were not familiar with the meaning of this attribute, since they scored same intensity for all samples, or they were not able enough to decipher intensity of this attribute with regard to samples. On contrary, highest number of effective sample size observed with cooked potato flavor means that respondents were familiar with the meaning of this attribute and were differentiating intensity with respect to samples. Tested potato cultivars were different on almost all attributes

except, raw potato aroma/flavor and earthy aroma/flavor being non-discriminating, meaning that these were present in in all samples similarly. With the number of non-discriminating attribute small, all attributes were retained in the analysis even though these attributes might contain just random noise.

Table 3.6 Uncorrelated *p*-values from Statistical testing for overall product differences

Attributes from CATA	***p*-value**	**Effective sample size**	**Required sample size > 24♣**
Mealy texture*	**0.000**	46	552
Fluffy texture*	**0.009**	33	396
Smooth texture*	**0.000**	43	516
Moist texture*	**0.000**	47	564
Dense texture*	**0.000**	46	552
Cooked potato aroma*	**0.005**	45	540
Cooked potato flavor*	**0.009**	48	576
Metallic flavor*	**0.001**	34	408
Metallic aroma*	**0.015**	21	252
Raw potato aroma	0.091	39	468
Raw potato flavor	0.425	45	540
Earthy aroma	0.562	42	504
Earthy flavor	0.132	42	504
Dry texture*	**0.000**	43	516

♣ Under the null hypothesis of no difference between potatoes, Cochran's *Q* statistic is asymptotically χ^2-distributed and χ^2-approximation would be only acceptable if the corrected number of respondents (Effective sample size) times the number of samples is at least 24.

* Indicates significant differences at α=5% by Cochran's *Q* test.

Table 3.7 Cultivar differences from statistical testing based on CATA derived data♦

Attribute	AC99330-1P/Y	Atlantic	CO05068-1RU	CO99076-6R	Canela Russet	Masquerade	POR12PG28-3	Purple majesty	Rio Colorado	Russian Banana	Valery	Vermillion
Mealy texture	0.146^{ab}	0.250^{abc}	0.438^{bc}	0.167^{ab}	0.354^{abc}	0.188^{abc}	0.250^{abc}	0.125^{a}	0.333^{abc}	0.583^{c}	0.146^{ab}	0.271^{abc}
Fluffy texture	0.104^{a}	0.333^{a}	0.104^{a}	0.250^{a}	0.167^{a}	0.208^{a}	0.125^{a}	0.229^{a}	0.146^{a}	0.063^{a}	0.250^{a}	0.229^{a}
Smooth texture	0.396^{bcd}	0.458^{cd}	0.104^{ab}	0.479^{d}	0.125^{abc}	0.438^{bcd}	0.417^{bcd}	0.479^{d}	0.188^{abcd}	0.042^{a}	0.500^{d}	0.438^{bcd}
Moist texture	0.292^{abc}	0.542^{cd}	0.167^{ab}	0.354^{abcd}	0.146^{ab}	0.271^{abc}	0.729^{d}	0.354^{abcd}	0.375^{abcd}	0.063^{a}	0.729^{d}	0.521^{bcd}
Dense texture	0.625^{de}	0.271^{abc}	0.708^{e}	0.458^{abcde}	0.542^{bcde}	0.417^{abcde}	0.188^{ab}	0.313^{abcd}	0.542^{cde}	0.708^{e}	0.125^{a}	0.208^{abc}
Cooked potato aroma	0.438	0.396	0.458	0.500	0.271	0.500	0.479	0.521	0.458	0.167	0.354	0.417
Cooked potato flavor	0.542	0.438	0.542	0.688	0.354	0.625	0.458	0.604	0.563	0.354	0.458	0.458
Metallic flavor	0.125	0.104	0.083	0	0.167	0.083	0.063	0.083	0	0.250	0.188	0.188
Metallic aroma	0.125	0.042	0.063	0	0.063	0.042	0.104	0.063	0.042	0.146	0.167	0.167
Raw potato aroma	0.167	0.354	0.229	0.167	0.292	0.167	0.208	0.167	0.354	0.313	0.188	0.229
Raw potato flavor	0.292	0.375	0.208	0.208	0.354	0.292	0.292	0.229	0.313	0.354	0.188	0.313
Earthy aroma	0.208	0.208	0.167	0.208	0.292	0.188	0.208	0.333	0.271	0.208	0.167	0.292
Earthy flavor	0.250	0.250	0.208	0.208	0.375	0.271	0.271	0.208	0.417	0.375	0.250	0.354
Dry texture	0.292^{abc}	0.271^{abc}	0.521^{c}	0.313^{bc}	0.438^{c}	0.354^{c}	0.021^{a}	0.375^{c}	0.271^{abc}	0.479^{c}	0.042^{ab}	0.188^{abc}

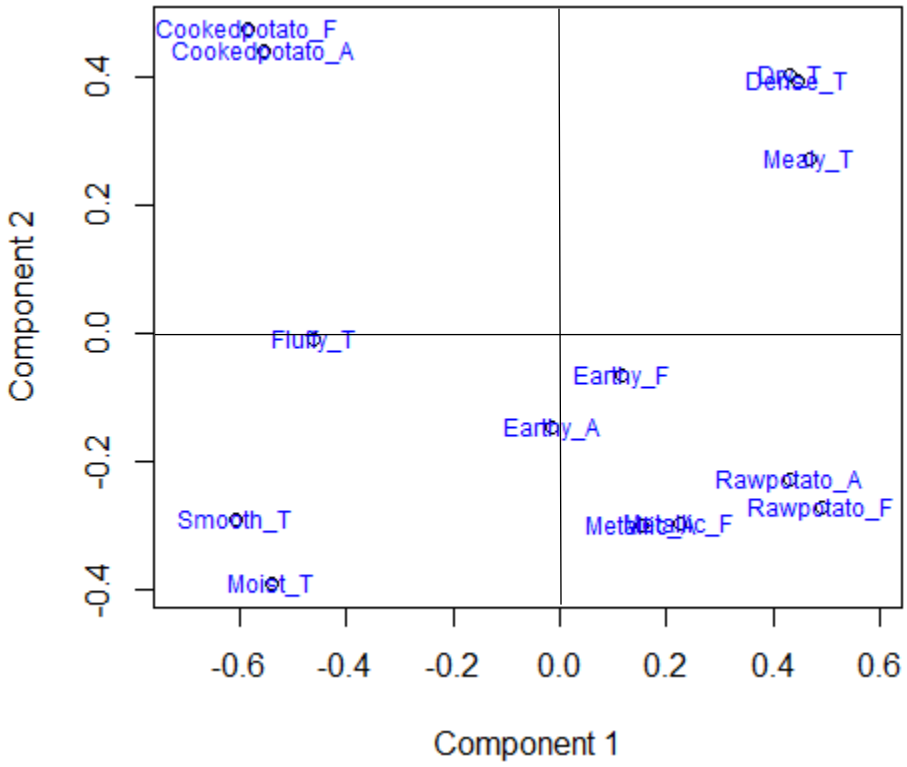
♦ Data points with different superscripts implies significant difference within same row ($p < 0.05$) by McNemar (Bonferonni) *post-hoc* test

McNemar (Bonferroni) post-hoc test for each pair of tested potato cultivars revealed significant differences for all pairs of cultivars across all textural attributes except fluffy (Table 3.7). No significant differences were observed for the aroma or flavor attributes. Purple majesty was found significantly different ($p<0.05$) from Russian banana cultivar on mealy and smooth textural attributes. Fingerlings such as POR12PG28-3 and Russian banana were found statistically different on moistness, being POR12PG28-3 high in moistness or lowest in dryness. Russet, namely CO05068-1RU was statistically different in denseness from all other cultivars.

Relationship among CATA attributes

Attributes like metallic aroma/flavor were found frequently coelicited (Fig. 3.7), likewise, raw potato aroma/flavor, cooked potato aroma/flavor, dry/dense texture. It infers that these attributes were typically checked together. Other attributes which were used independently to characterize the potato samples were fluffy, smooth, moist, mealy, and earthy aroma and earthy flavor. The word 'independently' means that respondents checked an attribute singly from other attributes, just like if they have clear understanding of which concept to click or choose. On contrary, by looking at coelicited responses, it seems that different labels (such as metallic aroma and flavor) were measuring same concept (metallic), which could be avoided in future studies. Attributes in the center of the plot were found not well represented in these two dimensions. The distance between attributes revealed that one could use either of coelicted attributes for future research questions rather than using both.

Fig. 3.7 Multidimensional scaling on distances between attributes based on the φ-coefficient.



Drivers of liking

Fig. 3.8 Significant (p-value <0.05) impact of CATA generated attributes on overall liking by Penalty-lift analysis

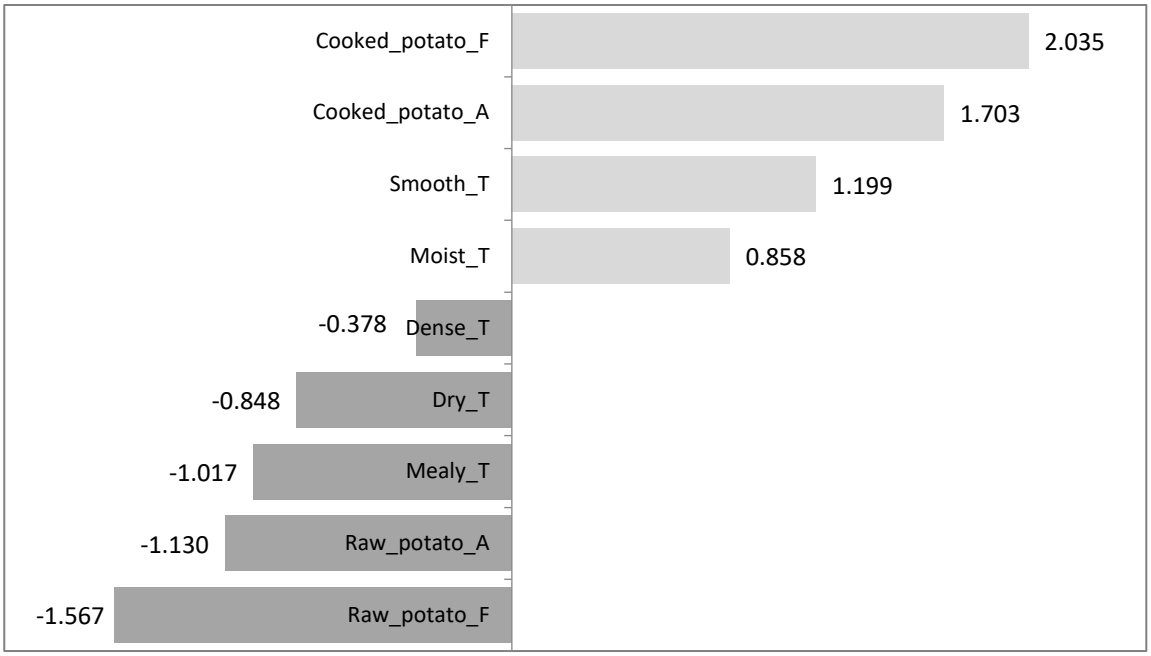


Fig. 3.9 Significant (*p*-value <0.05) impact of CATA generated attributes on aroma liking by Penalty-lift analysis

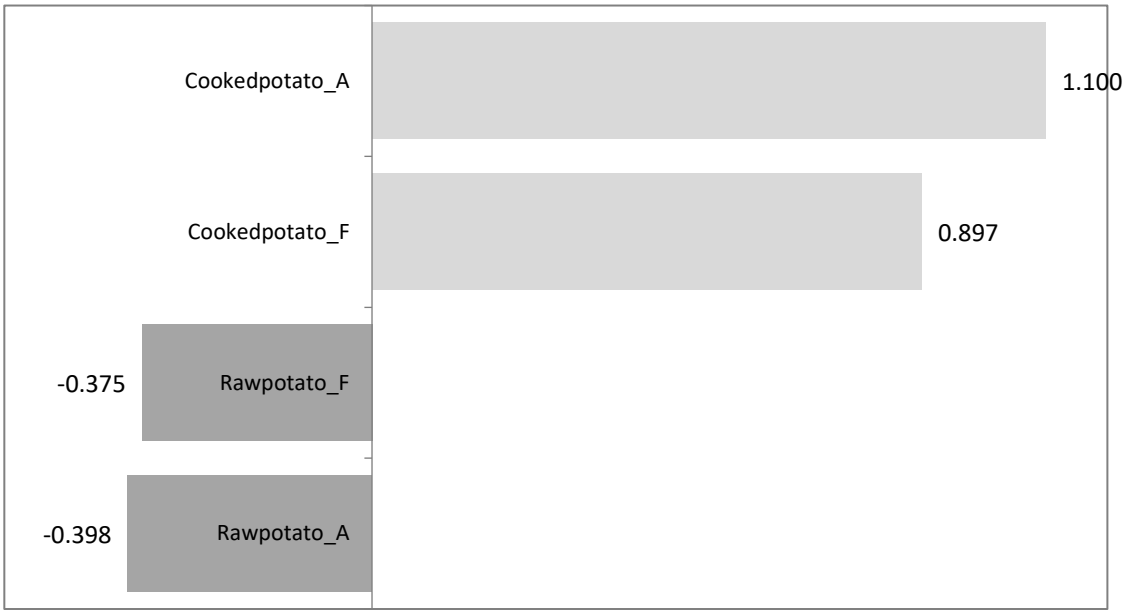


Fig. 3.10 Significant (*p*-value <0.05) impact of CATA generated attributes on flavor liking by Penalty-lift analysis

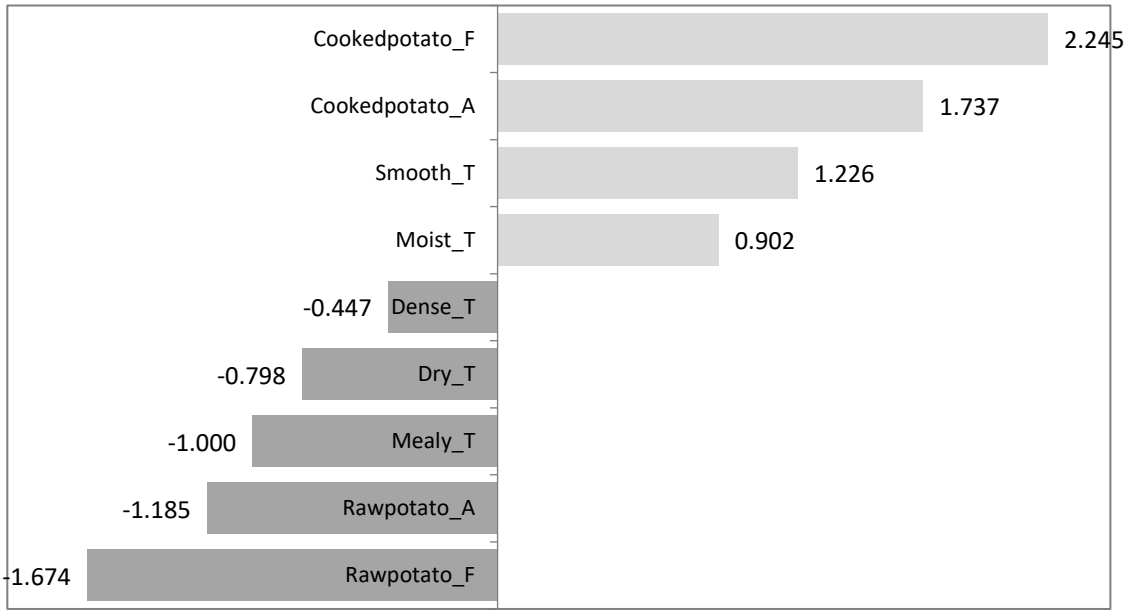
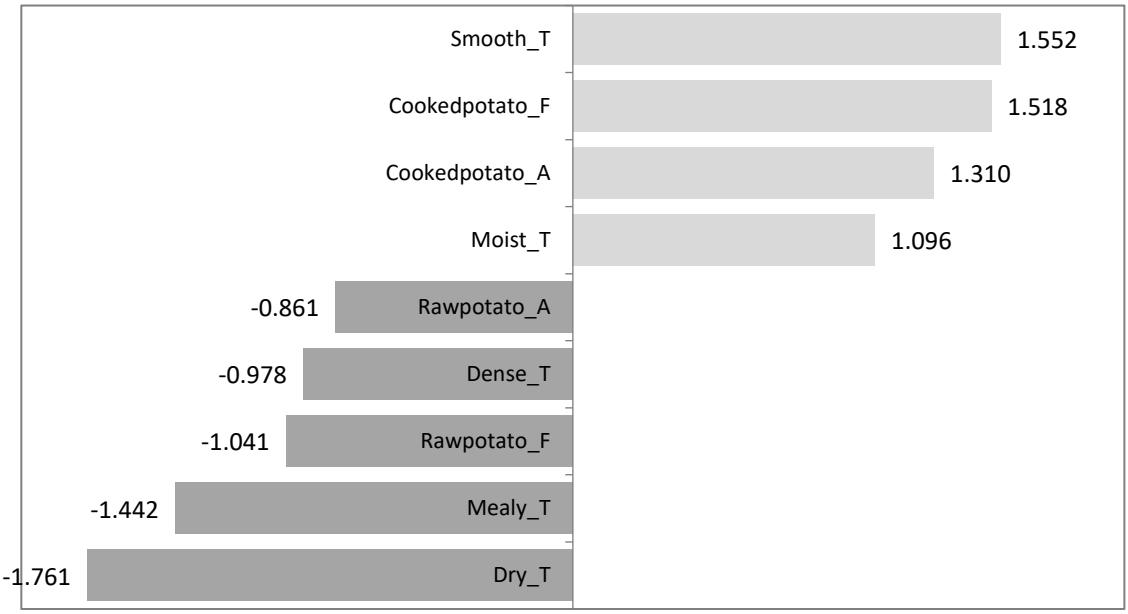


Fig. 3.11 Significant (*p*-value <0.05) impact of CATA generated attributes on texture liking by Penalty-lift analysis



Cooked potato flavor, followed by cooked potato aroma, smooth and moist texture were found significant drivers of liking (Fig. 3.8 to Fig. 3.11), whereas raw potato flavor and aroma, mealy, dry and dense texture were found negatively driving the overall liking. Similar results were obtained with correspondence analysis (Fig. 3.5 and Fig. 3.6).

Fig. 3.12 Mean drop in overall liking as a function of the percentage of consumers that checked an attribute

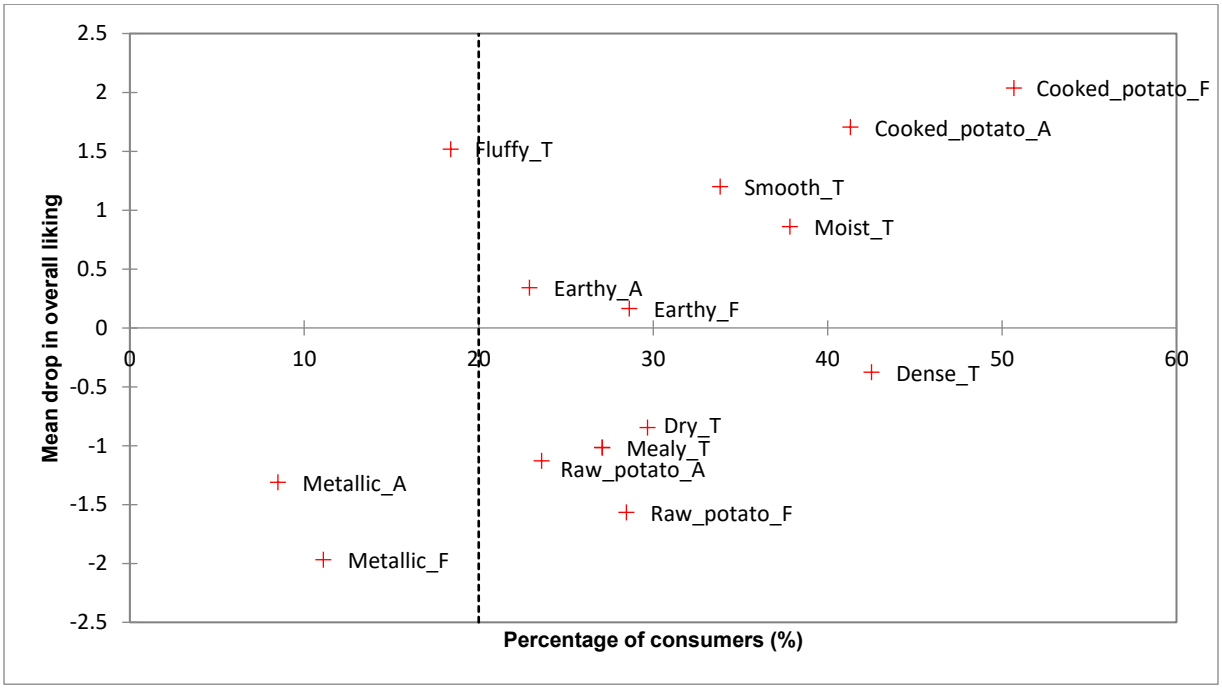
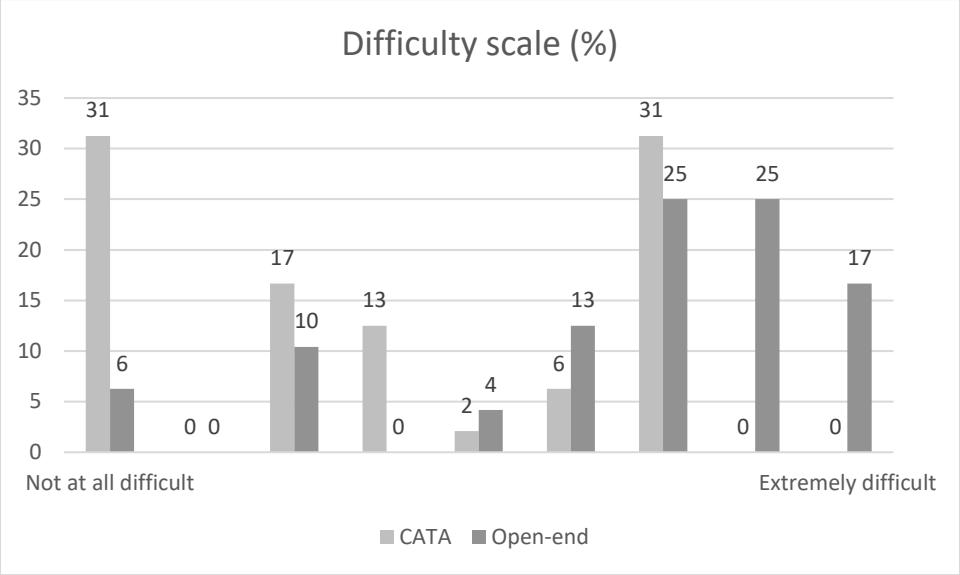


Fig. 3.12 (See Appendix for related figures) show the mean drop in overall liking as a function of the proportion of consumers that checked an attribute differently to liking. As shown, the penalty analysis enabled the identification of directions for product liking. In the case of overall liking, the attributes with the highest mean drop were cooked potato flavor and aroma, smooth and moist texture, meaning that these characteristics had the biggest positive effect on liking. By looking at Table 5 it seems clear that it is necessary for potatoes to have typical potato aroma (238 times cited) and flavor (292 times cited) for liking.

Comparison between Open-ended and CATA methodologies

Fig. 3.13 Open-end and CATA comparison



About 67% of respondents found open-ended question was difficult [sum of top 3 anchor points, 7 (25%), 8 (25%) and 9 (17%)] for them (Fig. 3.13). Compared to open-ended question, only 31% of respondents found that CATA question was difficult for them [sum of top 3 anchor points, 7 (31%), 8 (0%), 9 (0%)]. Most participants who scored 7 on a difficulty scale for CATA method were in the age of 55 above (66%). Cognitive function of separating categories seems affected with the age, and this might be an indirect index of mental processing measure. The measure of difficulty appears increases with ageing. Previously, old age has been associated with slower performance, poorer memories and efficiency (Denis C. Park – the basic mechanisms accounting for age-related decline in cognitive function).

Fig. 3.14 Representation of the groups/blocks of variables, i.e., CATA derived and Open-end derived (Aroma/Flavor (a) and Texture (b)), on the first and second dimensions of the MFACT♥

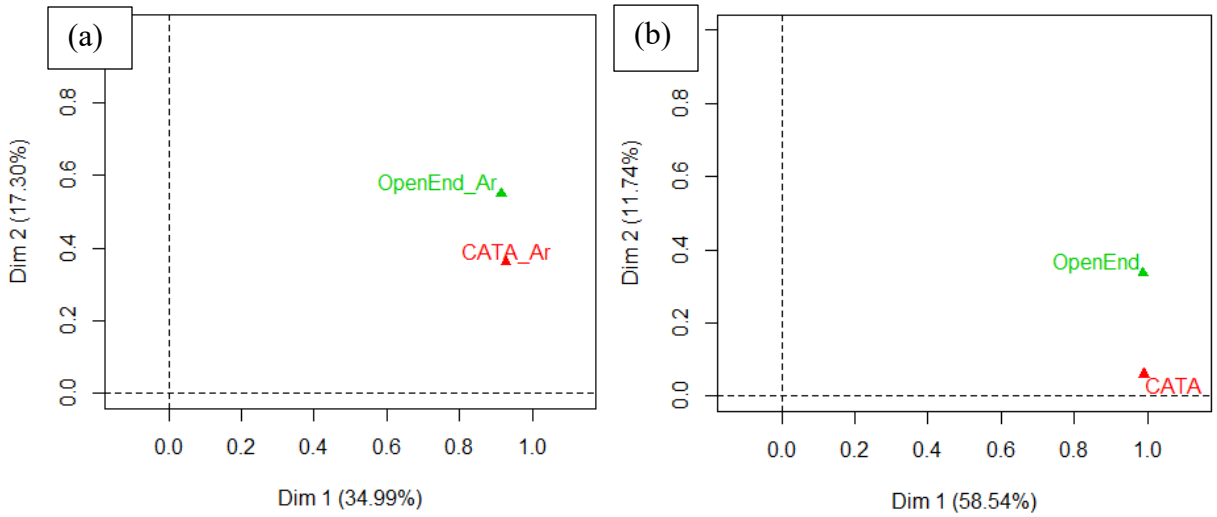
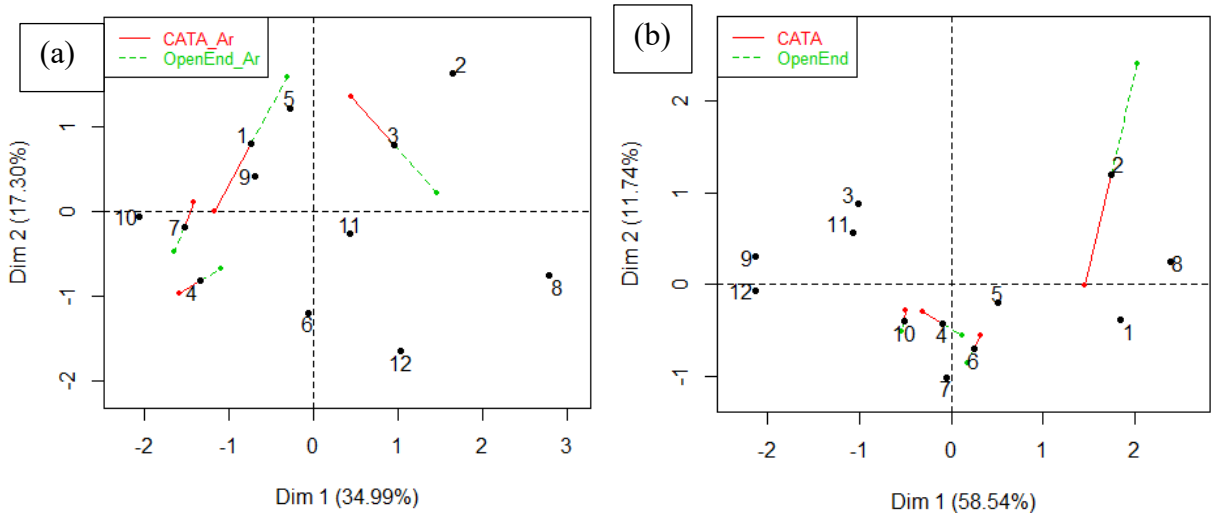


Fig. 3.15 Partial representation [(Aroma/Flavor (a) and Texture (b)] of the 12 potato samples described using CATA and Open-end methods on the first and second dimensions of the MFACT♥



About 70% of the variation was explained by first and second dimension (Fig. 3.14), when texture-based words generated by consumers were used for MFACT analysis. Both methods were found highly correlated (closer to 1.0) on first dimension issued by MFACT, but not as much on

second dimension. Therefore, the structure induced by Open-end method on sample layout would be bit different from CATA. Similarly, the layout of both methods for aroma and flavor-based findings was not exact replica of each other, but still compared to texture it was in more agreement (Fig. 3.15). Overall, aroma and flavor variability of potatoes was accounted for 50% by the obtained words from consumers in the MFACT analysis. Cultivars such as CO05068-1RU and Atlantic were found highly variable across both methods with respect to the description provided by the respondents. Similarly, large difference in the description of Canela Russet texture was found which resulted in large variation from the barycenter (common center), showed by red and green colored lines in MFACT plots (Fig. 3.15 b). Both methods, were found not providing similar information for this sample.

Discussion

Compared to CATA, open-ended questions brought richness of responses as more diversified set of answers were obtained. Though, words used by consumers in open-end questions for potato aroma and flavor description were found not sorting out clearly into any distinct groups, the position of the words in the layout suggests four general categories:

i. Potatoes with bland, flavorless, plain, boring, mild, fair, aftertaste and lingering taste

ii. Potatoes with processed, metallic, disgusting, unnatural, chemicals, bitter, dull and strange taste

iii. Potatoes with fragrant, fresh, sweet, authentic, bold, cooked, rich and pleasant taste

iv. Potatoes with potatoey, flavorful, natural, light, buttery taste

Textural differences observed in tested potato cultivars would correspond to starch content and type, dry matter or solids, consistency and preparation method. Potato texture was found to be more than just previously thought of mealy and waxy texture. This finding revokes the previous

assumption that potato texture can be adequately described on a single continuum of mealy and waxy. Broadly, four textural constructs were found with open-ended responses,

i. Mealy construct was found corresponding with starchy, coarse, heavy, flakey, crumbly and lumpy words

ii. Waxy construct was found corresponding with doughy, thick, hard, firm, cohesive and chalky words

iii. Fibrous construct was found corresponding with mushy, stringy, soft, thin, whipped and light words

iv. A Smooth construct was found corresponding with creamy, smooth, blended, fluffy, mouthfeel, homogeneous and compact words

Amount of starch, type of starch, size of chains and shape of starch granules, all affect potato texture. Salaman (1926) described four textural categories of potatoes, namely, floury (often burst spontaneously, crumble easily), close (do not burst, readily break, do not crumble), waxy (firm flesh, only breaks down by kneading) and soapy (same as waxy, but also watery and translucent) (Furrer, Chegeni, & Ferruzzi, 2018; Salaman, 1926). Mealy texture has been previously found associated with dry, starchy, floury, high specific gravity, light, fluffy and delicate texture (Finamore & Stevens, 2001; McComber et al., 1994). The findings from our study align with these conclusions. Similarly, waxy construct has been also previously found associated with cohesiveness, denseness, moistness, smaller specific gravity, smoothness and gummy mouthfeel (Jansky, 2010; McComber et al., 1994; Pavlista, 1997). Current findings align with those conclusions as well. No information about fibrous texture with respect to potatoes was found in literature. However, trained panel used residuals and fibrous attributes in this study for scoring fibers in the mashed and air-fried samples (Sharma et al., 2019), respectively. Fourth construct

seems to share some properties with the waxy construct, and possibly, it could be corresponding to medium starch potatoes, whose starch content falls in-between mealy and waxy. However, this conclusion needs information from starch content to support this statement.

Higher dry matter content has been previously found associated with Russets (Bali et al., 2018), which could make consumers feel thick and heavy characteristics in these types of potatoes. Russets have been previously found mealy or starchy (Bough, 2017), low in moisture content and have a fluffy, dry texture. Correspondence of Canela russet and CO05068-1RU cultivars with mealy, starchy, dry, dense and flakey impressions make them align with previous findings. Red and yellow cultivars, Rio Colorado, CO99076-6R, AC99330-1P/Y and Masquerade appeared in-between mealy and waxy lines and were found very close to mid-west consumer's texture liking. Consumer liking for texture found to be dependent upon geographical and cultural differences. For example, dry boiled potato texture is preferred in Scotland, whereas a waxy texture is preferred in the Netherlands (Sharma et al., 2019; Taylor et al., 2007). Red and yellow flesh cultivars were termed waxy for their smooth texture (Bough, 2017; McComber et al., 1994), while white flesh potatoes tend to be mealy (Bough, 2017; Pavlista, 1997). Specialty, purple, fingerling and chip cultivars were found as waxy cultivars based on consumer generated description. Purple Majesty was found not highly mealy by Bough (2017). Knowledge of amount of starch and amylopectin in these cultivars will further strengthen these findings.

Non-volatile soluble matrix-associated components such as sweet, bitter, salty, metallic, pungent and creamy were found contributing in flavor of potatoes, along with volatile components. No single description about umami was noticed with consumer's open-end methodology, possibly because it is unknown to them and they are dumping it into potatoey or some other attribute. Earlier in 1970s, it was suggested that the flavor of boiled potatoes was largely due to amino acids, some

of which were well known for umami-like perception (Taylor et al., 2007). Bitter taste sensation of potato glycolalkaloids was found corresponding to consumers' dislike. Potato glycolalkaloids at elevated levels have been previously found responsible for bitter, burning, scratchy or acrid sensations (Taylor et al., 2007). Purple and yellow flesh cultivars, Purple majesty and Masquerade, have been previously found less bitter and sweeter compared to chip and specialty cultivars (Bough, 2017). Variation accounted by consumers related to potato aroma and flavor was found smaller when compared to texture, implying the smaller contribution of volatile olfactory components. Existing subtle differences with respect to those volatile components and/or human olfactory and cognitive make-up is not rich enough to separate these nuances effectively. Contribution of olfactory components have been questioned previously (Solms & Wyler, 1979). Specialty, chip and fingerlings were found disliked by consumers due to metallic, bitterness, unnatural and chemical taste. Less attention by breeding programs on bitterness and other off-flavors in colored and specialty cultivars was found responsible for higher intensity of these sensations and inconsistencies of these sensations (Bough, 2017). Metallic taste sensation perceived by consumers, which was found related to dislike, needs further research to test if consumers were really aware of "what constitutes metallic taste?". Metallic taste can be perceived in the mouth either via the taste of metal ions on the tongue or through retronasal odor perception of carbonyls (produced by lipid oxidation, catalyzed by metals in the mouth) (Ömür-Özbek, Dietrich, Duncan, & Lee, 2012).

Limitations of this study

Structure of the scale used to assess cognitive challenge posed by two methodologies could be a limiting factor of this study, since this was not validated if it was actually measuring difficulty

signal or just noise. The selection of CATA terms was aided by the concerned researchers, which eventually brings subjective bias and consequently, would be an additional limitation of this study.

Conclusion

Open-end do generate more responses compared to CATA, but data is more broad and processing is extremely more cumbersome. Open-ended responses were found rich of information with respect to taste and texture in mashed potatoes. However, on an average open-ended questionnaire took more time (4 min 44 sec) than CATA questionnaire (2 min 04 sec) to complete the task. Terms that contributed to liking were sweet, natural, potatoey, and cooked potato taste whereas terms that contributed to dislike were grainy, unnatural, metallic, and unnatural taste. Smooth and moist texture of potatoes was liked by consumers. Amount of information generated by CATA method was lower compared to open-ended method. Two words measuring same concept under different labels, such as metallic aroma and metallic flavor for metallic concept, showed another drawbacks of CATA method. Metallic taste and aroma was found disliked by CATA questions, but if consumers are aware of metallic taste stimuli perceptions is a question. CATA question was found more difficult by consumers in the higher age category.

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Chapter 4 - Segmentation of potato consumers based on sensory and attitudinal aspects

Introduction

Historically, we make what we love to eat, and this phenomenon has been proven a success for companies that target segmentation of consumers based on their individual preferences. Consumer liking of products can be measured by acceptance tests and the 9-point hedonic scale has been arguably the most useful sensory method for measuring product liking. Widespread usage, easy to comprehend, easy to describe with minimal instructions, high signal-to-noise ratio, stability and reproducibility are some of the reported features of the 9-point hedonic scale. In addition to measuring liking ratings to compare acceptance among different products, it is often desirable to relate higher/lower liking with sensory or instrumental results for benchmarking, optimization, reformulations, documentations and category appraisals. Preference mapping is a collection of statistical tools used to graphically illustrate the relationships between consumer hedonic liking and sensory data. Since consumers vary in their liking patterns and purchase decisions depending upon many latent factors, it is often an oversimplification to deliver results based on overall means of consumer data, which may lead to a misrepresentation of the results. Therefore, they are often divided into segments or groups of different liking patterns, which can be measured by Internal (IPM) and/or External Preference Mapping (EPM). An important area for strategic product development is the identification of these possible consumer segments (Westad, Hersleth, & Lea, 2004) and their drivers of liking (Meyners, 2016; Oliver, Cicerale, Pang, & Keast, 2018). Segmentation of consumers based on liking ratings has been used extensively in consumer studies (Bonany et al., 2014; Bowen, Blake, Tureček, & Amyotte, 2019; Oliver et al., 2018). PLSR

and LSA were found previously offering advantages over EPM, and similar drivers of liking were found by both methods (Liggett, 2010).

Potato is the most consumed vegetable worldwide, and among the most versatile and palatable of foods (Bamberg & Greenway, 2019). Consumer preference for new crop cultivars is an essential factor in product adoption and delivering on the traits desired by consumers are likely to be necessary for high nutrient potatoes to succeed commercially (Morris & Taylor, 2019). Taste and or texture have been cited as important factors along with convenience in fresh potato consumption (Dukeshire, MacPherson, Veitch, & Wang-Pruski, 2016; Fernqvist, Spendrup, & Ekelund, 2015; Karadas, Kumlay, Eyduran, & Gursoy, 2017; Morris & Taylor, 2019). Wide gaps in existing understanding of potato taste and its relation to consumer preferences have been documented extensively in recent time (Jansky, 2010; Morris & Taylor, 2019). Cheng et al (2001) found that potato choices and factors that affect those choices differ significantly between consumers in different regions. Together, hedonic liking and sensory data will result in the development of consumer-driven improvements in potatoes, resulting in better sensory qualities.

Attitudinal and lifestyle factors have been previously found strongly affecting acceptability (Urala & Lähteenmäki, 2007). Supplementing preference mapping findings with attitudinal measurements will be of importance to both sensory and marketing sections. Rationale behind sensory findings can be better supported with attitude measurements because this helps in making better decisions with respect to individual's circumstances (Blythe, 2008). Consumer purchasing behavior was found to be a constantly changing entity due to changes in both economic and non-economic factors (Fearne, 1992) and hence segmentation of consumers based upon their food orientations, particularly attitudes, will have a critical position in product marketing and nutrition education.

The objectives of this study were as:

i. To understand consumer segments of potatoes and sensory drivers of liking through a preference mapping technique.

ii. To explore consumer attitudes and purchase making decisions in regard to potatoes.

Materials and methods

Sample preparation and serving

Potatoes were breed and harvested by the San Luis Valley Research Center at Colorado State University, and the Hermiston Agricultural Research and Extension Center at Oregon State University (Table 4.1). For detailed information about sample preparation, please refer to Sharma et al. (2019).

Table 4.1 Cultivars used in the study

S. No.	Clone	Type	Origin
1	CO05068-1RU	Russet	Colorado
2	Canela Russet	Russet	Colorado
3	Atlantic	Chip	Oregon
4	CO99076-6R	Red	Colorado
5	Rio Colorado	Red	Colorado
6	AC99330-1P/Y	Yellow	Colorado
7	Masquerade	Yellow	Colorado
8	Russian Banana	Fingerling	Oregon
9	POR12PG28-3	Fingerling	Oregon
10	Purple Majesty	Purple	Oregon

11	Vermillion	Specialty	Oregon
12	Valery	Specialty	Oregon

Participants recruitment

Potato consumers from the Kansas City area (N = 95, Male = 50, Female = 45) were screened for a 2-day study at the Center for Sensory Analysis and Consumer Behavior (CSACB) in Kansas State University, Olathe (Table 4.2). Consumers were screened to be fresh produce purchaser (minimum 50 – 99%), frequency of purchase (minimum once a month to weekly) and consumer of potatoes (minimum 1-2 times/week). Compusense Cloud (Compusense, Inc., Guelph, ON, Canada) was used for screening and execution data collection.

Table 4.2 Age distribution of participants (*N* = 96)

Age distribution	**Number of participants**
18 to 24	1
25 to 34	18
35 to 44	21
45 to 54	23
55 to 64	22
65 to 74	12
75 or above	0

Questionnaire

The questionnaire was developed to probe consumer segmentation based on their liking patterns and compare available segmentation techniques. Consumers were asked for liking/disliking on 9-point hedonic scale overall and for appearance, aroma, flavor and texture at the beginning of the questionnaire. Other important questions were also asked to probe consumer behavior with respect to potato purchase decisions, namely, ranking most important to least important factors when purchasing potatoes, ranking the most liked to least liked cooking method, etc. Varietal information available in the market and its role in purchase decisions was probed by asking consumers "which cultivars do you normally purchase? Please check all that apply" question. In addition, several agree/disagree statements were asked to assess consumer behavior, social image of potatoes among consumers, social issues and sentiments associated with potatoes and attitudes or opinions towards dynamics of potato. All agree or disagree questions were asked on 7-point scale, with anchors "strongly disagree, disagree, somewhat disagree, neither agree nor disagree, somewhat agree etc. Statements were not randomized for agree/disagree questions.

Design of experiment for Consumer study

Twelve potato samples were evaluated by consumers over two consecutive days (six samples each day). The design was balanced over the two days where each sample appears on each position the same number of times (Oehlert, 2000). The crossover design has subject and day as blocks.

Descriptive analysis

Consensus based descriptive analysis methodology was used for sensory profiling. Five highly trained panelists from the Center for Sensory Analysis and Consumer Behavior (CSACB), Kansas State University, Manhattan, Kansas, participated in this study. A 15-point scale with 0.5

increments was used for intensity quantification of taste concepts. Cucumber, hot water and steamed towels were used for palate and nostril cleansing, respectively. Details about this methodology can be found somewhere else (Sharma, Chambers IV, Sastry, Swaney-Stueve, Sathuvalli, Holm, and Talavera, 2019).

Statistical analysis

Consumer generated data was analyzed by a "mixed effects" analysis of variance (ANOVA) model that included potatoes and days as "fixed effects" and respondents/consumers as a "random effect". Data was analyzed by PROC MIXED procedure of SAS university edition (SAS, Cary, North Carolina, USA). Statistically significant differences in mean hedonic liking intensities between potato types were identified by Tukey-Kramer post hoc test. Null hypothesis (H0) for the experiment was that all potato cultivars will be equally liked by the consumers, and thus experimentwise Type I error rate was of interest to the authors. Controlling the *experimentwise* error rate at $\alpha = 0.05$ would necessarily control the *comparisonwise* error rate at no more than 0.05. Tukey-Kramer was used here as post hoc test, but any other test can be used which controls experimentwise error rate. To evaluate the variability between products with respect to consumer liking data, internal preference mapping (IPM) was conducted by using JMP Pro 14.3.0 (SAS, Cary, North Carolina, USA). Principal component analysis was done on covariance by using consumer hedonic data and for the reason to explain the differences in liking between samples, sensory (Trained panel data) data was used as supplementary variables within the hedonic space. Hierarchical cluster analysis (HCA) was used to explore and group consumers based on shared characteristics of liking scores for each product by using JMP Pro 14.3.0 (SAS, Cary, North Carolina, USA). Ward method was used to measure the distance between clusters.

Results

Table 3 shows the results of fixed effects and their significance. Overall, appearance and aroma were found not significantly (α=0.05) affected by time period variation compared to other modalities (Table 4.3).

Table 4.3 Fixed effects testing for overall responses irrespective of method of response collection♥

Modality measured	Fixed Effects	F-value	Pr > F
Appearance liking	Time Period/Day	1.70	0.0679
	Treatment	66.01	**<.0001**
Aroma liking	Time Period/Day	1.43	0.1535
	Treatment	5.62	**<.0001**
Overall liking	Time Period/Day	1.90	**0.0357**
	Treatment	10.22	**<.0001**
Flavor liking	Time Period/Day	2.25	**0.0104**
	Treatment	12.25	**<.0001**
Texture liking	Time Period/Day	1.88	**0.0382**
	Treatment	6.45	**<.0001**
Aftertaste liking	Time Period/Day	2.32	**0.0081**
	Treatment	8.69	**<.0001**

♥ Type 3 test of fixed effects obtained by using REML estimation method in the mixed procedure of data analysis, where respondents were treated as random effect and potato cultivars, time period as fixed effects.

From method comparison point, open-end methodology seems very sensitive to day-to-day variation compared to CATA. All time period variations were found significant except for texture (Table 4.4). CATA method was found quite robust to day-to-day variation, since all effects were found non-significant. Consequently, open-end method could be a good choice for context effect experiments where one expects change in decision making with respect to context. Open-ended question was used previously to examine the coffee consumption contexts (Spinelli et al., 2017).

Table 4.4 Fixed effects testing for method (Open-end and CATA) comparison♥

Modality measured	**Fixed Effects**	**Open-end method**		**CATA method**	
		F-value	**Pr > F**	**F-value**	**Pr > F**
Appearance liking	Time Period/Day	1.43	0.1545	0.58	0.8479
	Treatment	18.86	**<.0001**	55.99	**<.0001**
Aroma liking	Time Period/Day	2.10	**0.0189**	1.28	0.2352
	Treatment	3.42	**<.0001**	3.72	**<.0001**
Overall liking	Time Period/Day	2.01	**0.0255**	0.94	0.4976
	Treatment	5.89	**<.0001**	6.02	**<.0001**
Flavor liking	Time Period/Day	2.29	**0.0099**	0.82	0.6184
	Treatment	7.89	**<.0001**	5.45	**<.0001**
Texture liking	Time Period/Day	1.46	0.1413	1.67	0.0766
	Treatment	3.02	**0.0007**	4.04	**<.0001**
Aftertaste liking	Time Period/Day	2.51	**0.0044**	1.52	0.1199
	Treatment	6.64	**<.0001**	2.90	**0.0010**

Table 4.5 Consumer acceptance results by treatment/cultivar type♦

	Cultivar type	9-point Hedonic Liking (Least square means)					
		Appearance	**Aroma**	**Overall**	**Flavor**	**Texture**	**Aftertaste**
1	Russian Banana	6.36^{ab}	5.15^{bcd}	3.84^{d}	3.85^{f}	4.35^{c}	4.08^{e}
2	Vermillion	3.03^{e}	5.00^{d}	4.80^{bc}	5.13^{bcde}	5.59^{ab}	5.17^{abcd}
3	Atlantic	6.85^{a}	5.71^{abc}	5.15^{abc}	4.99^{cde}	5.59^{ab}	4.77^{cde}
4	POR12PG28-3	4.07^{d}	5.50^{abcd}	4.85^{bc}	4.91^{de}	4.83^{bc}	5.03^{abcd}
5	Valery	4.69^{cd}	4.99^{d}	4.99^{abc}	5.01^{cde}	5.52^{ab}	5.00^{bcd}
6	Rio Colorado	6.27^{ab}	5.81^{ab}	5.73^{a}	5.73^{abcd}	5.63^{ab}	5.49^{abc}
7	CO99076-6R	6.67^{ab}	6.05^{a}	5.77^{a}	5.77^{abc}	5.85^{a}	5.49^{abc}
8	Purple Majesty	3.11^{e}	5.76^{abc}	5.45^{ab}	5.94^{ab}	5.74^{a}	5.80^{a}
9	AC99330-1P/Y	5.07^{c}	5.28^{bcd}	5.44^{ab}	5.57^{abcd}	5.66^{ab}	5.51^{abc}
10	CO05068-1RU	6.14^{ab}	5.69^{abcd}	5.41^{ab}	5.35^{abcd}	5.19^{abc}	5.18^{abcd}
11	Masquerade	5.93^{b}	5.69^{abcd}	5.81^{a}	6.00^{a}	5.79^{a}	5.76^{ab}
12	Canela Russet	6.49^{ab}	5.06^{cd}	4.46^{cd}	4.39^{ef}	4.84^{bc}	4.60^{de}

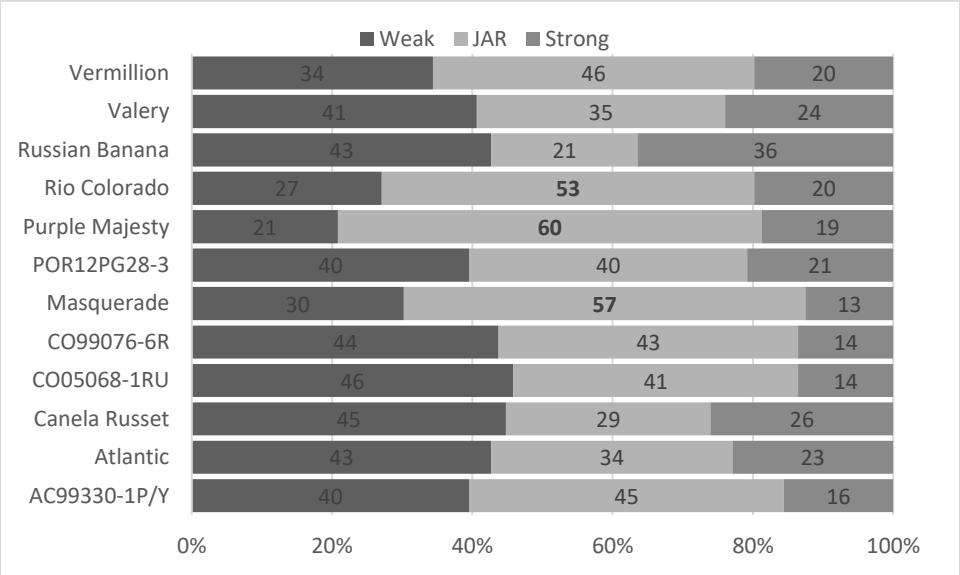
Appearance liking differed across potato cultivars (Table 4.5). Atlantic cultivar flesh color (white) was found most liked by the respondents while Vermillion least. Purple colored Purple Majesty and pink to reddish colored Vermillion cultivars were found least liked, followed by bright mango yellow colored POR12PG28-3 and Valery. Red skin cultivar CO99076-6R was found to

♦ Means estimated using REML estimation method in a mixed effect model, where respondents were treated as random effect and potato cultivars, time period as fixed effects. Data points with different superscripts implies significant difference within column at $p < 0.05$ by Tukey-Kramer *post hoc* test.

contain most liked aroma among all cultivars tested while Valery and Vermillion least. Statistically, no significant difference in aroma was found among CO99076-6R, Rio Colorado, Purple Majesty, Atlantic, CO05068-1RU, Masquerade and POR12PG28-3. Overall liking response showed Masquerade was most liked while Russian Banana was least liked among tested cultivars. Similar results were found for flavor liking. Red skin CO99076-6R cultivar was found most liked for its texture while Russian Banana was least liked. Purple Majesty was found having most liked aftertaste while Russian Banana had least liked.

Majority of respondents reported “weak” flavor for all cultivars except Purple Majesty, Masquerade and Rio Colorado cultivars, which were lower in “weak” flavor and higher in “just about right” flavor (Fig. 4.1). In general, “just about right” score of 70% is assumed acceptable, but it should be kept in mind that potatoes were served without any salt or condiments, which could be a reason for lower JAR score and higher “weak” perception. The only cultivar which had reported “much too strong” flavor by more than 10% of respondents was Russian Banana. Unique flavor of Russian banana cultivar could be responsible for “strong” flavor perception.

Fig. 4.1 Consumer FLAVOR JAR by cultivar type ($N = 96$)



JAR scale data was related (Fig. 4.2 to 4.3) with hedonic liking intensity as an insight about the consumer's cognitive meaning of JAR with respect to hedonic liking. It was assumed that the hedonic liking would be directly proportional to JAR proportion and found that depending upon the modality measured, hedonic liking meaning was very much similar to JAR meaning (Fig. 4.5).

Fig. 4.2 Relation between JAR of FLAVOR and OVERALL LIKING (*N* = 96)

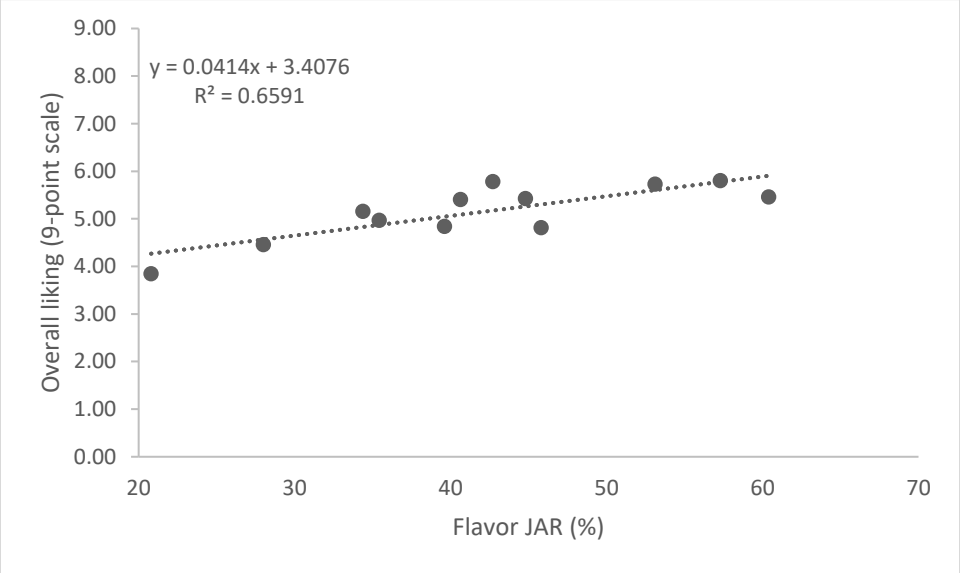
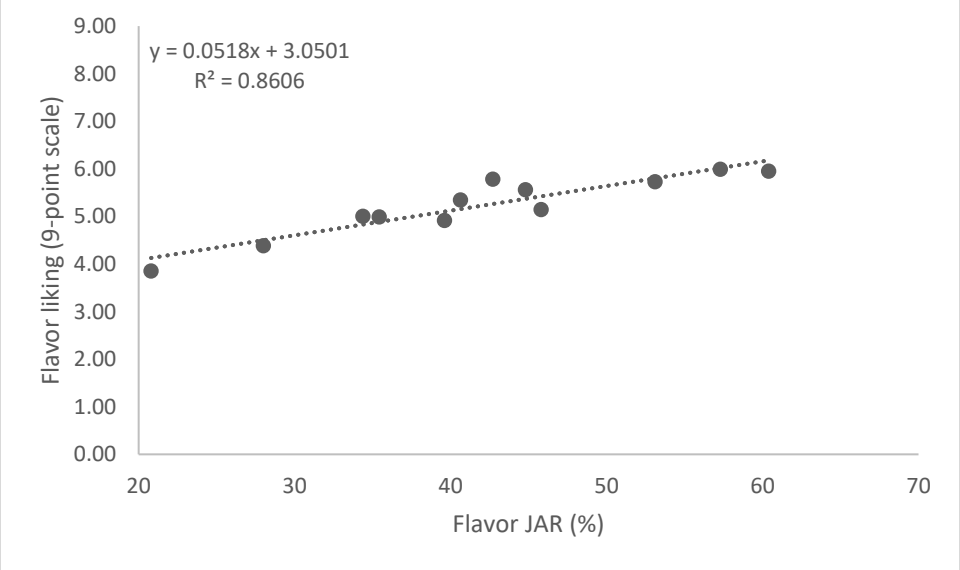
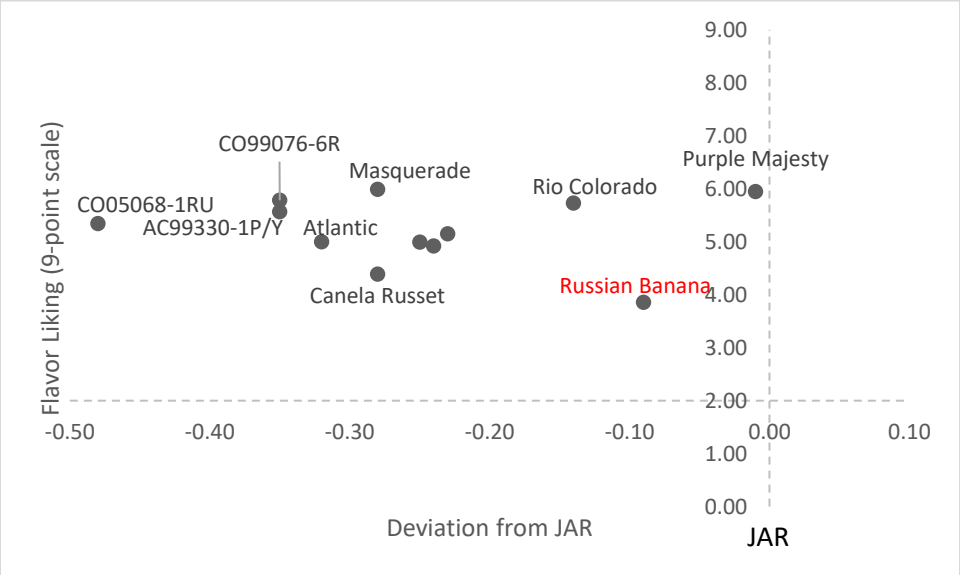


Fig. 4.3 Relation between JAR of FLAVOR and FLAVOR LIKING (*N* = 96)



JAR data can also be visualized by the extent of deviation of positive (slightly or much too strong) and negative (slightly or much too weak) anchors from JAR anchor (Gacula Jr, Rutenbeck, Pollack, Resurreccion, & Moskowitz, 2007), as shown in Fig. 4. Purple Majesty flavor was found very close to 'just about right' whereas CO05068-1RU was found have highest deviation from 'just about right'. Equal strong responses for both weak and strong anchors, highlighted in Russian Banana cultivar, caused wrong interpretation of this sample by this method. Russian Banana had lowest percentage (21%) of JAR responses (Fig. 4.1). However, Fig. 4 showed this sample very close to JAR anchor. This interpretation problem has been highlighted previously (Gacula Jr et al., 2007). Another problem found was high weightage for "much too weak/strong" category, especially for the samples which do not have any respondent percentage in this category. For example, Masquerade cultivar had no respondent in 'much too strong' category and eventually it ended up with having more "weak" flavor percentages compared to "strong", thus laying it appear far from the JAR anchor.

Fig. 4.4 Deviation of potato samples on FLAVOR LIKING from JAR anchor of JAR scale



Segmentation of potato consumers

Consumers were segmented into three clusters based upon their overall liking score (Fig. 4.5 and 4.6). First cluster had almost 50% of total respondents while second and third clusters had 16 and 36% of respondents, respectively. Comparing cluster one and three, cluster one contained respondents who scored lowest overall liking for Russian Banana, POR12PG28-3, Purple Majesty, Vermillion, Valery and Rio Colorado cultivars, which could be a reason for the origin of this cluster. Color of the flesh of these cultivars could be a reason for this lower overall liking in cluster one. Cluster one showed very narrow choice with respect to taste/overall liking, such as highest liking was reported towards Masquerade cultivar. Contrarily, cluster two and three showed a range of favorite potato cultivars, such as highest overall liking was reported towards Rio Colorado (7.13) and CO05068-1RU (7.13) in cluster two whereas Valery (6.06), Purple Majesty (5.97) and Rio Colorado (5.97) in cluster three, respectively. Overall, cluster two respondents were found liking all test samples compared to other clusters. Russian Banana cultivar was found least liked irrespective of obtained clusters.

Fig. 4.5 Dendrogram of consumers clustered into three segments by individual OVERALL LIKING of potato samples (N = 96)

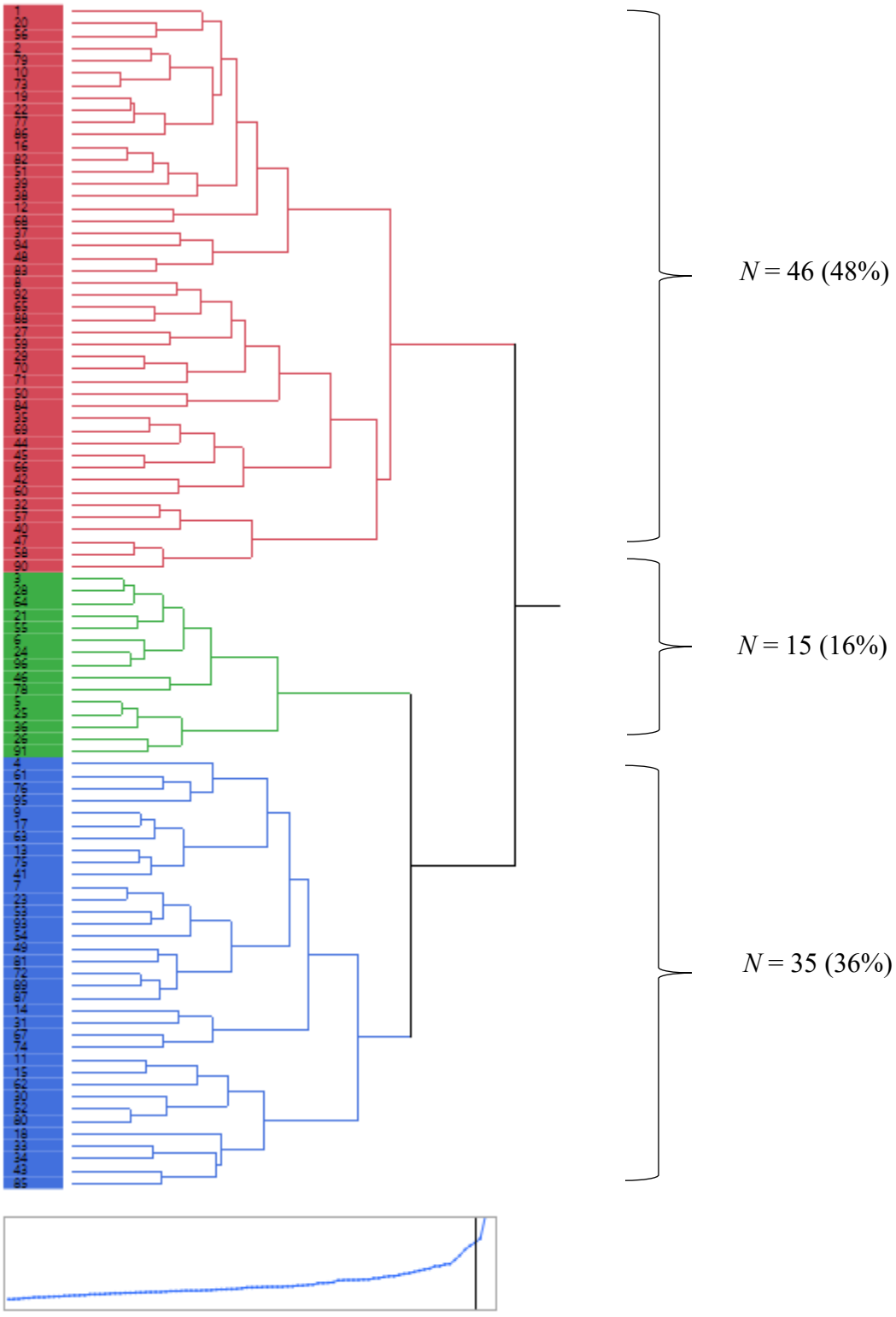
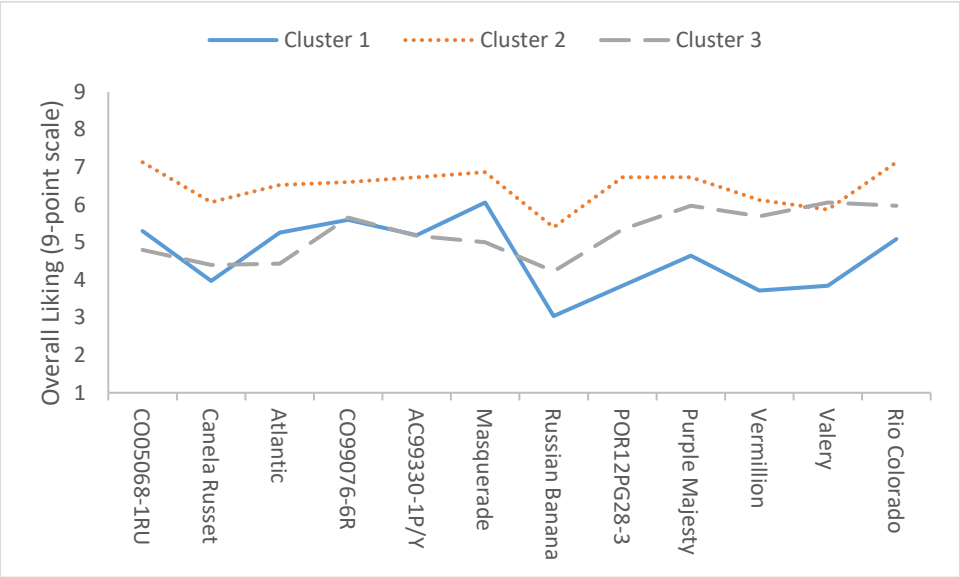


Fig. 4.6 Plot of clusters with respect to overall liking score



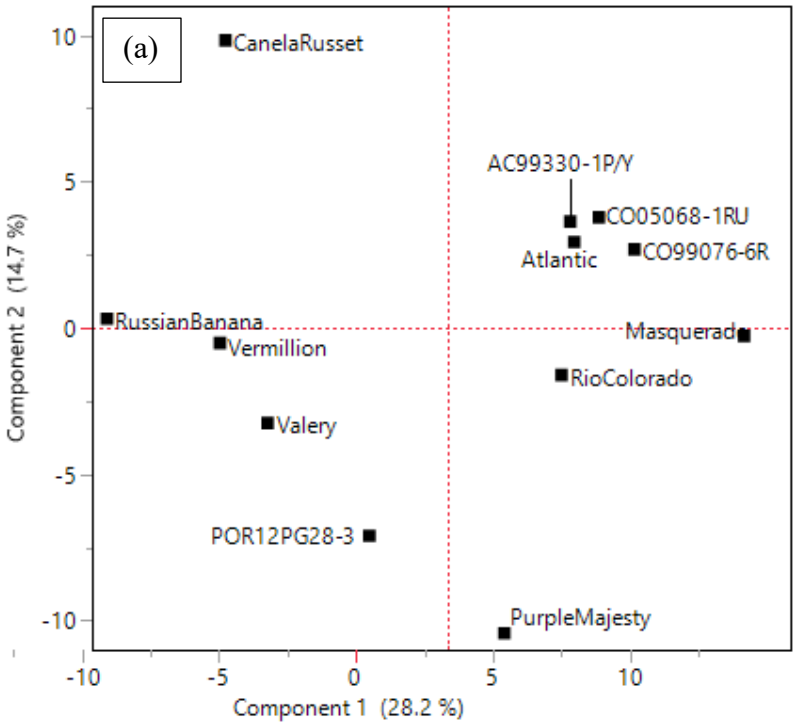
Preference mapping for obtained clusters

Internal Preference Mapping – Cluster one

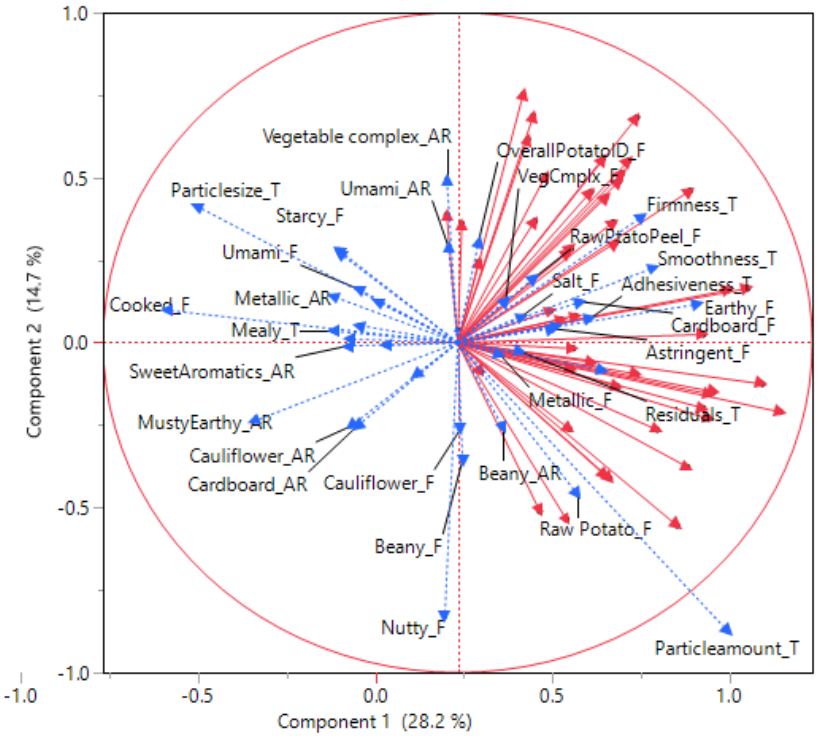
The first thing towards interpreting IPM was to assess whether or not a given principal component (PC) can be adequately approximated by fewer than p (original number) variables or not. About 65% of total variation in samples could be described by using first four principal components (PCs) (Fig. 4.7). The low accountability of total variation might be due to subtle differences among samples, poor linear relation among variables (consumers), nature of the consumers or other unknown reasons. Vegetable complex, beany, raw potato, raw potato peel, metallic, astringent, cardboard, earthy, salty, overall potato ID, smooth, firm and adhesive texture seem to be the major drivers of liking for the first cluster of respondents, while dominance of cooked, sweet aromatics, cauliflower, musty earthy, grainy, mealy, and texture do not trigger high hedonic ratings (Fig. 4.7). PCs are often interpreted by looking at the loadings for each variable (Cadima and Jollifee, 1995) and for this reason, sensory description of the samples could be useful in IPM interpretation. From the size of the coefficients, the first component dominated by musty-

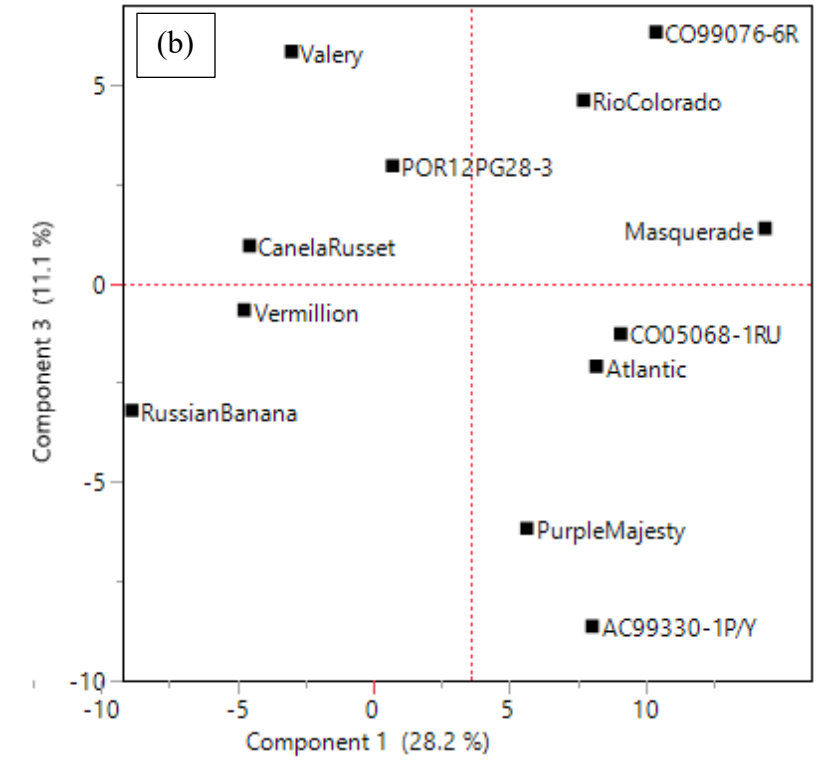
earthy, cooked, earthy, particle size and particle amount, while second component by nutty and particle amount. Third component was dominated by overall potato ID, particle amount and lumpiness while fourth component by cauliflower aroma and earthy aroma. Russian banana, Vermillion and Valery were found having strong intensity of negative drivers of liking.

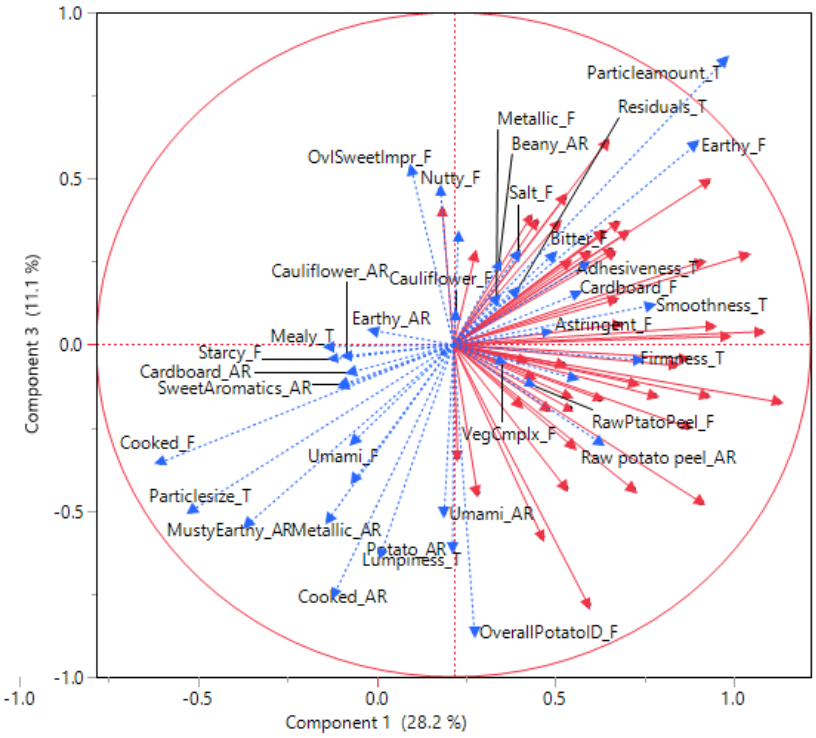
Fig. 4.7 Internal preference mapping (IPM) for the first cluster of respondents for (a) components 1-2 and (b) components 1-3♣



♣ IPM plots were obtained by using PCA technique on covariance. All descriptors were added as supplementary variable. Homogeneous respondents were pre-identified by using Hierarchical clustering method in JMP Pro.


Component 2 (14.7 %)
Component 1 (28.2 %)
Vegetable complex_AR
OverallPotatoID_F
VegCmplx_F
Particlesize_T
Umami_AR
Starcy_F
Firmness_T
RawPratoPeel_F
Umami_F
Smoothness_T
Salt_F
Adhesiveness_T
Cooked_F
Metallic_AR
Earthy_F
Mealy_T
Cardboard_F
Astringent_F
SweetAromatics_AR
Metallic_F
Residuals_T
MustyEarthy_AR
Cauliflower_AR
Cardboard_AR
Cauliflower_F
Beany_AR
Raw Potato_F
Beany_F
Nutty_F
Particleamount_T


(b)
Component 3 (11.1 %)
Component 1 (28.2 %)
Valery
CO99076-6R
RioColorado
POR12PG28-3
Masquerade
CanelaRusset
Vermillion
CO05068-1RU
Atlantic
RussianBanana
PurpleMajesty
AC99330-1P/Y



Simple linear regression was performed to complement the obtained results of the IPM. Average liking score for overall liking was used in function of each attribute, to visualize the positive and negative drivers of liking. Linear and quadratic relationship of attributes were observed with mean liking. From polynomial equation, r^2 was obtained and plotted as bar graph in Fig. 4.8. Saturation point phenomenon (pattern where liking starts increasing/decreasing after minimum/maximum point observed) was observed with some attributes such as, potato, earthy, cooked, cardboard and umami. Cardboard flavor has been used extensively in publications in relation to potato taste and could qualify as major character impact compound of potato (McGorrin, 2007). Interestingly, a certain level of bitterness was appreciated by consumers, showing quadratic relation (Fig. 4.9). Similarly, metallic flavor Beany and vegetable complex aroma appeared to have quadratic relation with overall liking (Fig. 4.9).

Fig. 4.8 Coefficient of determination (r^2) for the relationship between overall liking and sensory attributes (polynomial equation used for r^2; red bars shows negative drivers of liking)

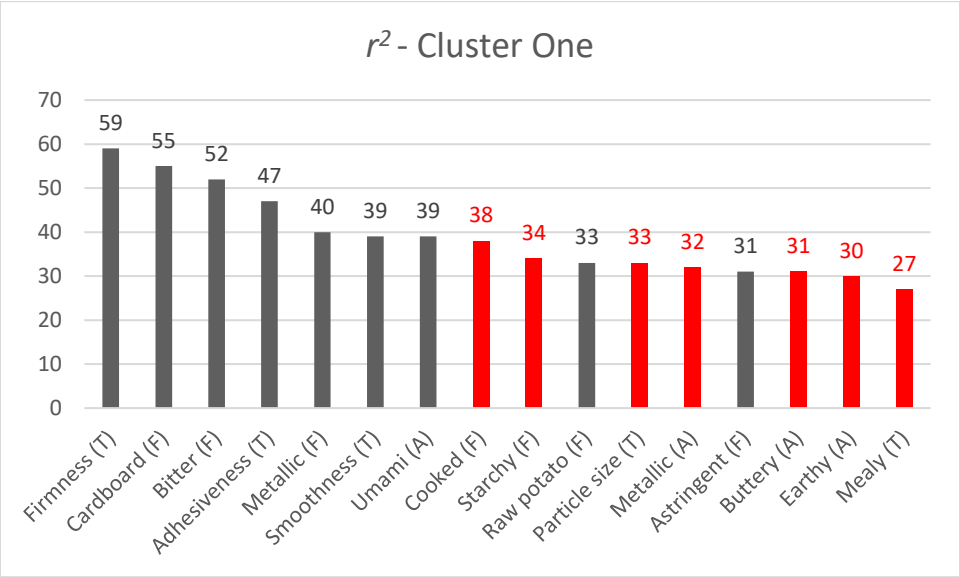
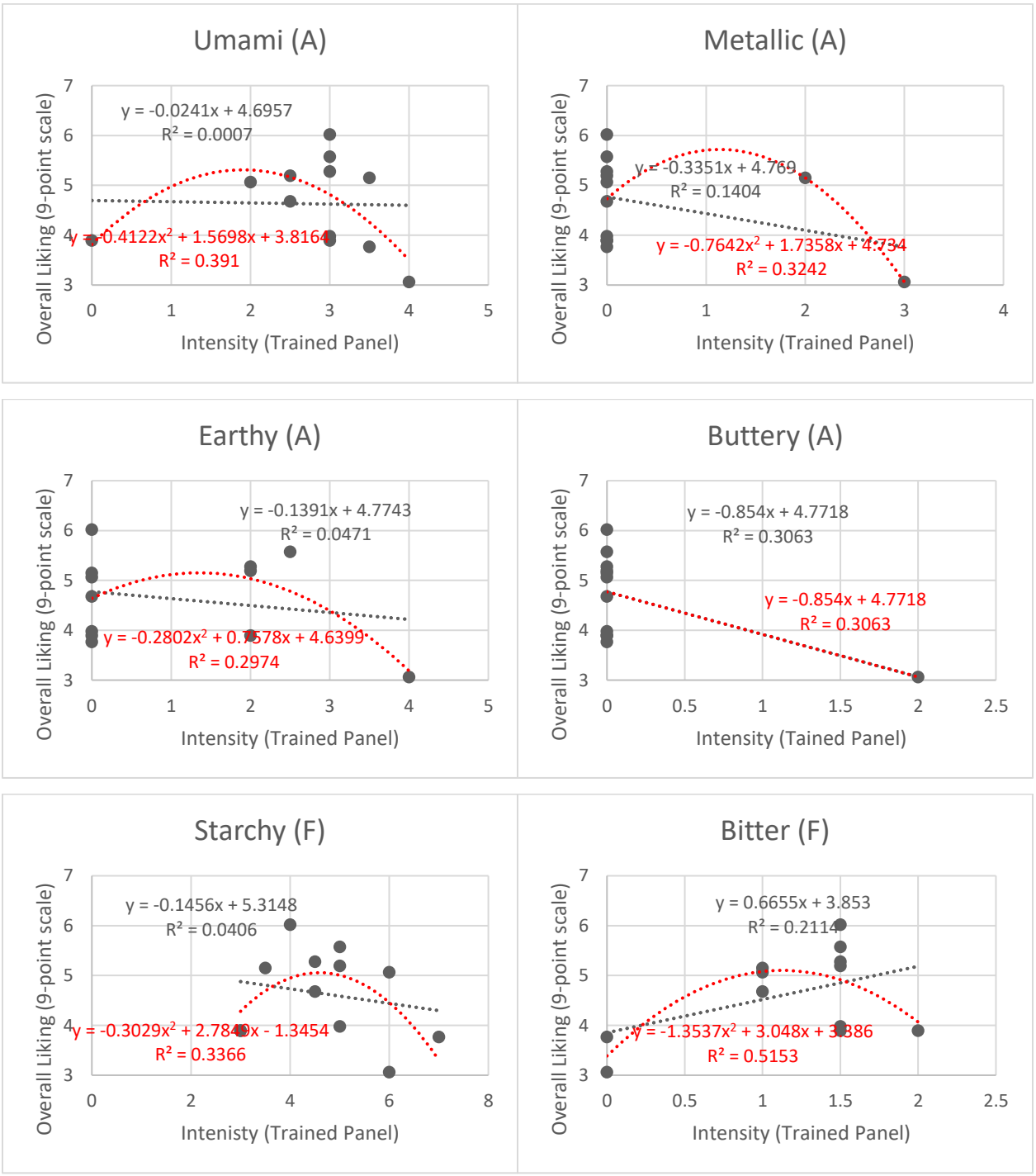
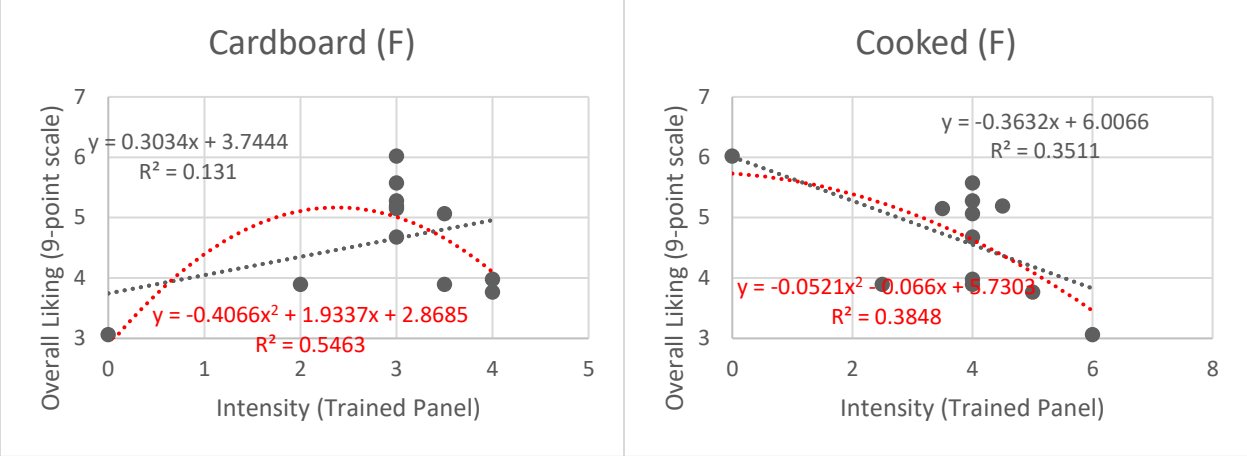
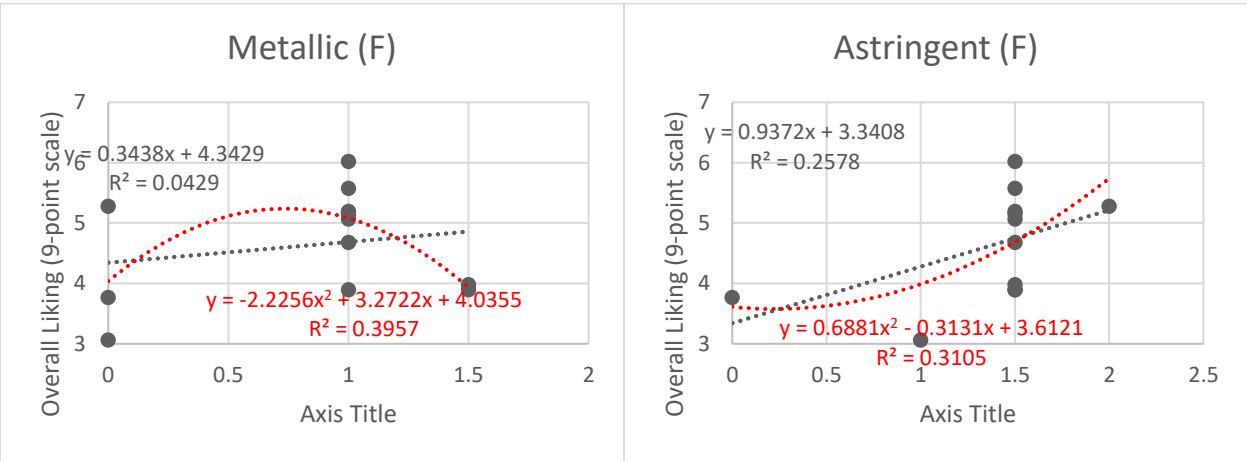
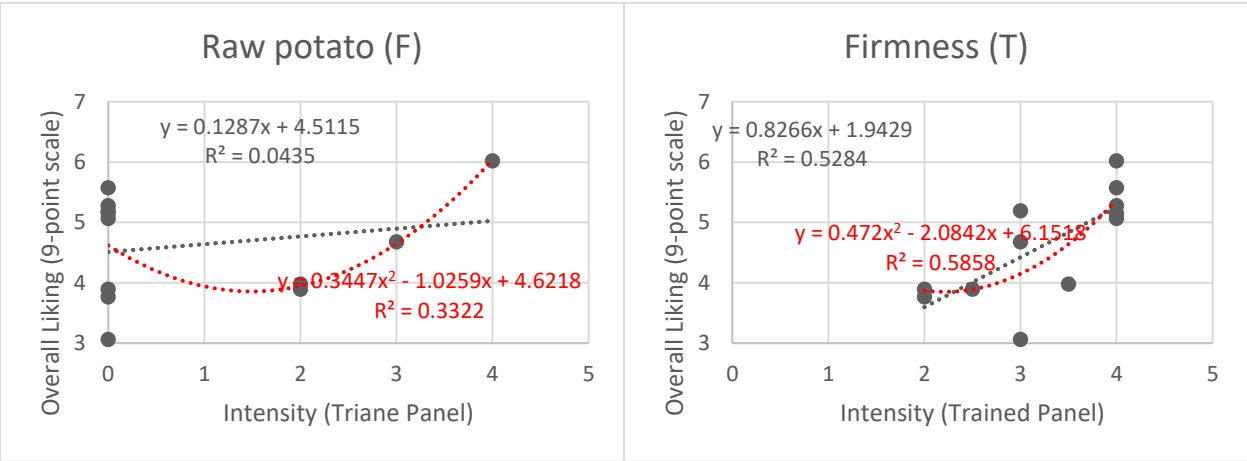


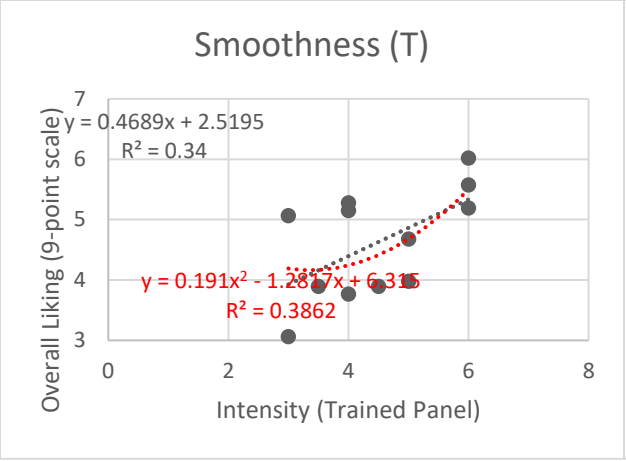
Fig. 4.9 IPM trace plots of each attribute with respect to consumers in cluster 1 OVERALL LIKING for potato samples; grey dotted line – Linear equation, red dotted line – Polynomial equation

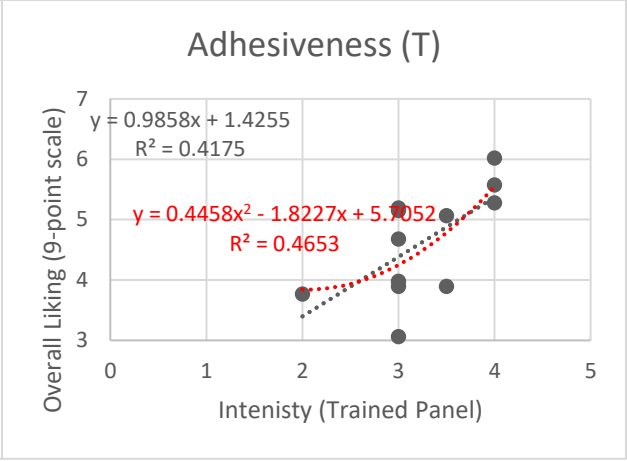


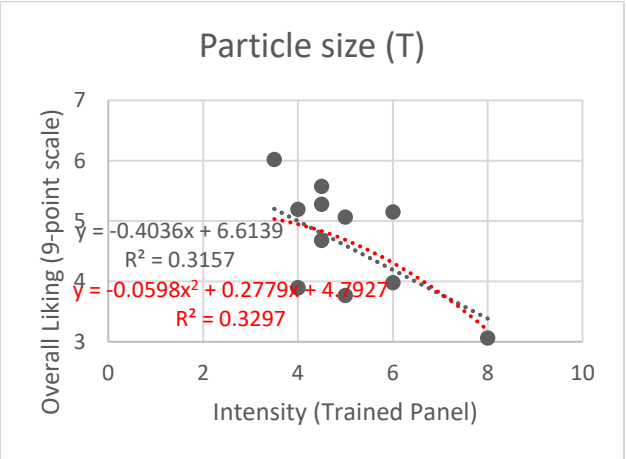

Cardboard (F)
y = 0.3034x + 3.7444
R² = 0.131
y = -0.4066x² + 1.9337x + 2.8685
R² = 0.5463
Overall Liking (9-point scale)
Intensity (Trained Panel)
Cooked (F)
y = -0.3632x + 6.0066
R² = 0.3511
y = -0.0521x² - 0.066x + 5.7302
R² = 0.3848
Overall Liking (9-point scale)
Intensity (Trained Panel)


Metallic (F)
y = 0.3438x + 4.3429
R² = 0.0429
y = -2.2256x² + 3.2722x + 4.0355
R² = 0.3957
Overall Liking (9-point scale)
Axis Title
Astringent (F)
y = 0.9372x + 3.3408
R² = 0.2578
y = 0.6881x² - 0.3131x + 3.6121
R² = 0.3105
Overall Liking (9-point scale)
Axis Title


Raw potato (F)
y = 0.1287x + 4.5115
R² = 0.0435
y = 0.3447x² - 1.0259x + 4.6218
R² = 0.3322
Overall Liking (9-point scale)
Intensity (Triane Panel)
Firmness (T)
y = 0.8266x + 1.9429
R² = 0.5284
y = 0.472x² - 2.0842x + 6.1518
R² = 0.5858
Overall Liking (9-point scale)
Intensity (Trained Panel)


Smoothness (T)
Overall Liking (9-point scale)
y = 0.4689x + 2.5195
R² = 0.34
y = 0.191x² - 1.2817x + 6.315
R² = 0.3862
Intensity (Trained Panel)

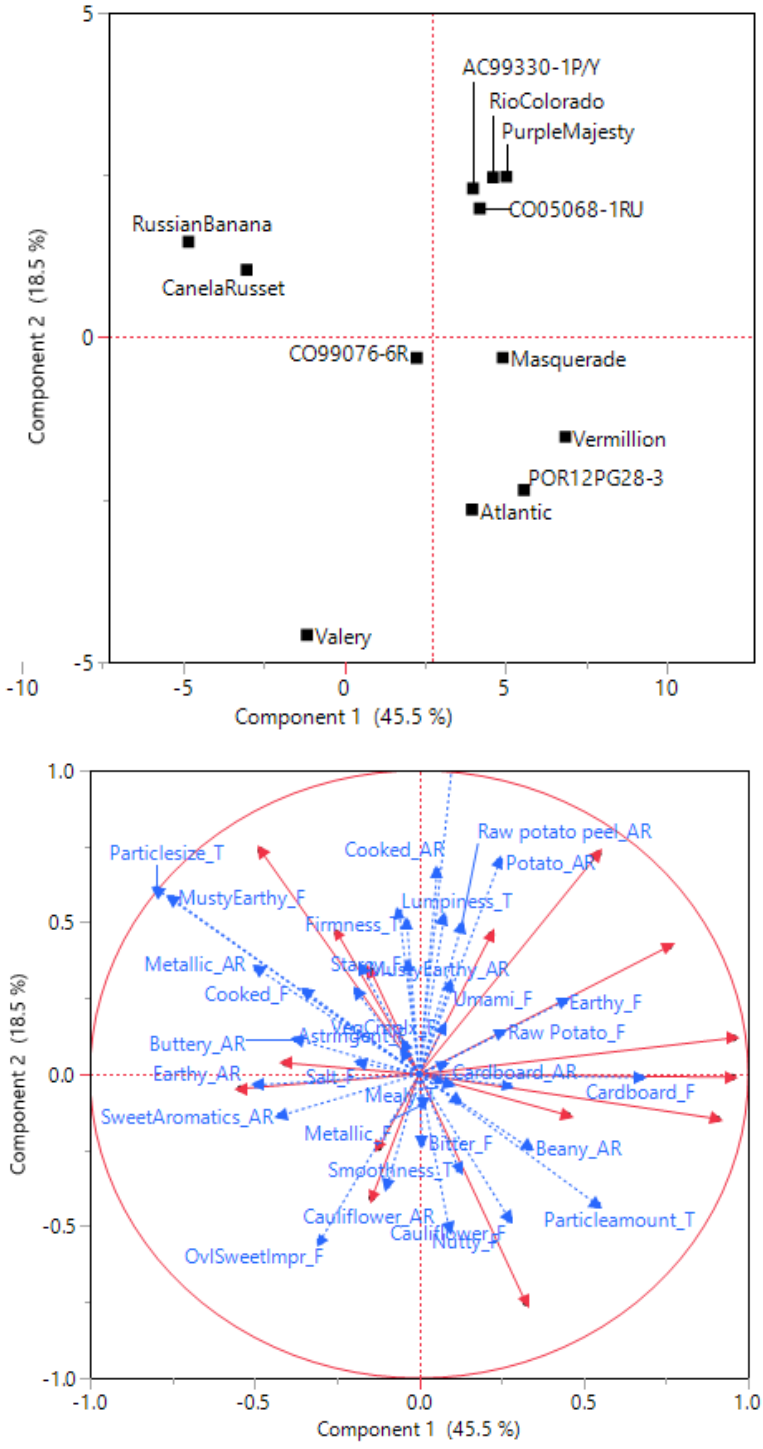

Adhesiveness (T)
Overall Liking (9-point scale)
y = 0.9858x + 1.4255
R² = 0.4175
y = 0.4458x² - 1.8227x + 5.7052
R² = 0.4653
Intenisty (Trained Panel)


Particle size (T)
Overall Liking (9-point scale)
y = -0.4036x + 6.6139
R² = 0.3157
y = -0.0598x² + 0.2779x + 4.7927
R² = 0.3297
Intensity (Trained Panel)

Internal Preference Mapping – Cluster two

PCA technique explained higher variability for second group of respondents (Fig. 4.10) but the group of respondents in itself looked heterogeneous as vectors were found in all directions therefore drivers of liking could not be generalized for this group. This group of respondents was found liking all potato types with no particular reason, which could be another reason for non-aligned vectors direction.

Fig. 4.10 Internal Preference Mapping (IPM) for second cluster of respondents♣



Internal Preference Mapping – Cluster three

Group three respondents looked quite homogeneous (Fig. 4.11) with respect to their response, thus making generalization of the drivers more robust for this group. The first three components explained around 60% of total variation. Overall sweet impression, sweet aromatics, beany and nutty flavor, cardboard flavor, bitter flavor, raw potato flavor and a hint of cauliflower flavor appeared to trigger hedonic liking for this group of respondents (Fig. 4.11). From texture standpoint, particle amount and residuals seemed to prompt hedonic liking. Compared to cluster one, this group of respondents had higher liking for toasted, nutty, and sweet impression. The first component was found dominated by earthy aroma, overall potato ID, starchy flavor, umami flavor, cooked flavor, and nutty flavor while second component was found dominated by cauliflower aroma, starchy flavor, and lumpy texture. Third component was found dominated by musty-earthy aroma, cooked aroma, raw potato peel aroma, raw potato flavor, cooked flavor, earthy flavor and musty-earthy flavor, while fourth component by musty-earthy aroma. About 40% of variation in overall liking can be explained by nutty flavor (Fig. 4.12). A number of quadratic relations were observed with attributes, presented in regression plots in Fig. 4.13.

Fig. 4.11 Internal Preference Mapping (IPM) for third cluster of respondents♣

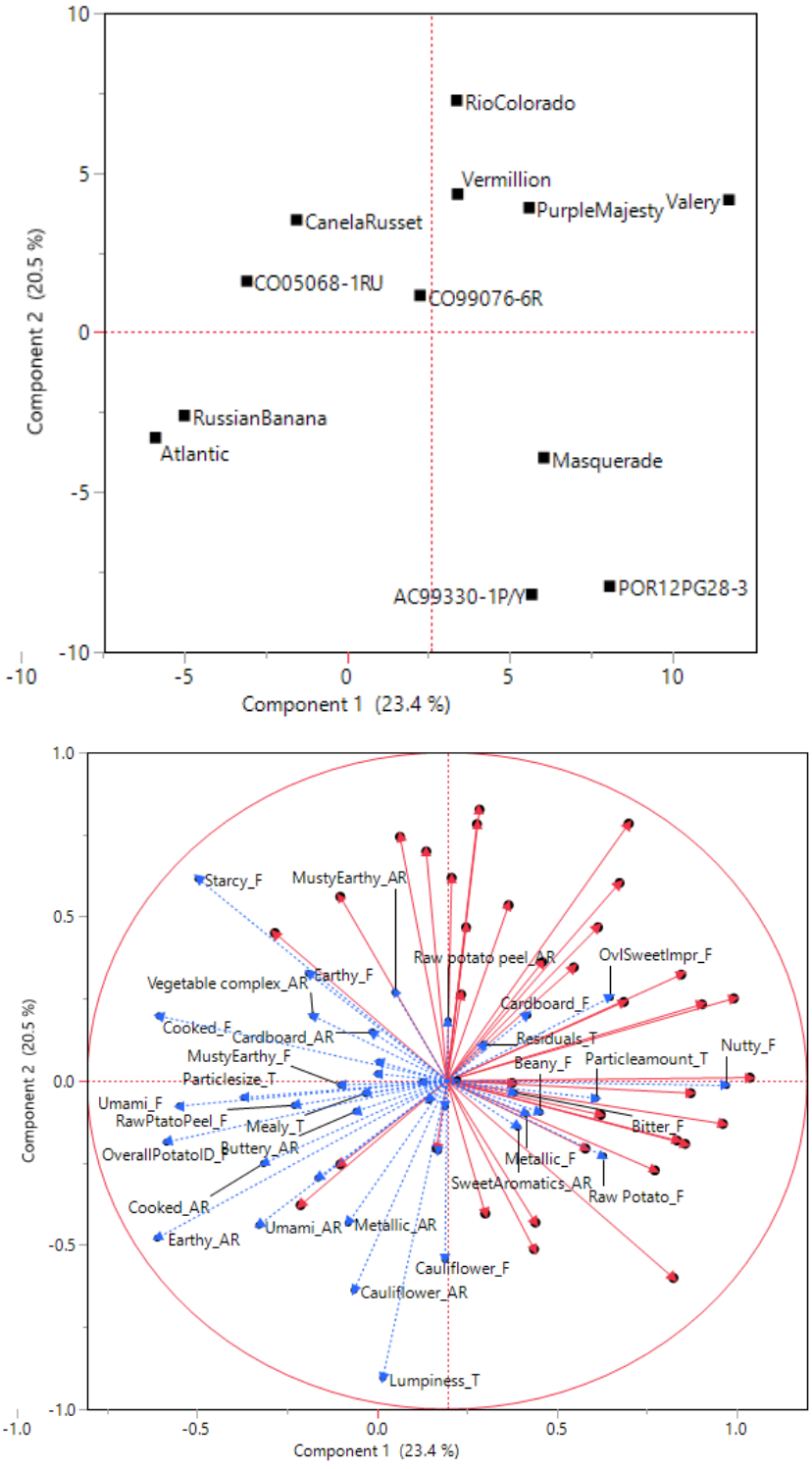


Fig. 4.12 Coefficient of determination (r^2) for the relationship between overall liking and sensory attributes (polynomial equation used for r^2; red bars shows negative drivers of liking)

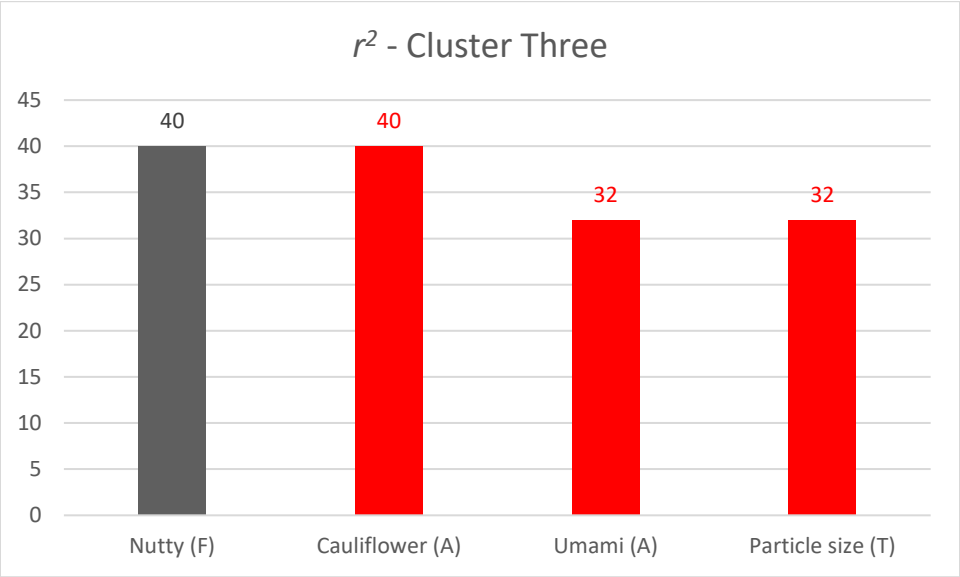
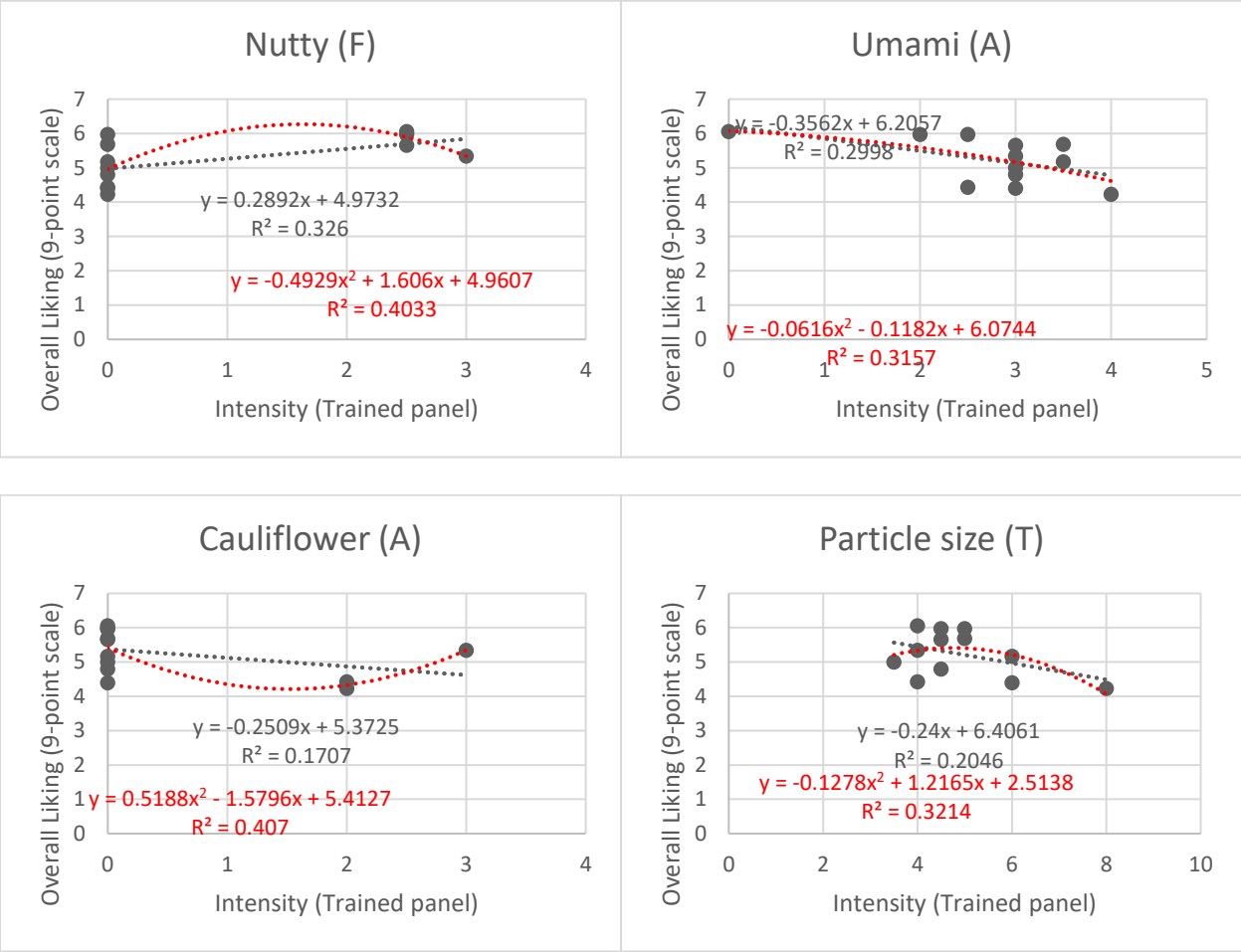


Fig. 4.13 IPM trace plots of each attribute with respect to consumers in cluster 3 OVERALL LIKING for potato samples; grey dotted line – Linear equation, red dotted line – Polynomial equation



Factors impact purchase decisions

Overall, price was found being the most important factor (25%) during purchase, followed by cultivar (16%), color of peel and size (15%), locally produced (11%), nutritional information (9%), shape (5%) and packaging and organic (2%). Organic was found a less important factor for consumers (31%), followed by packaging (26%), nutritional information (18%), locally produced (6%), cultivar, color of peel and size (4%), price and shape (3%). Compared to proportions, median value was calculated to find the central tendency for ranked data and no difference was found

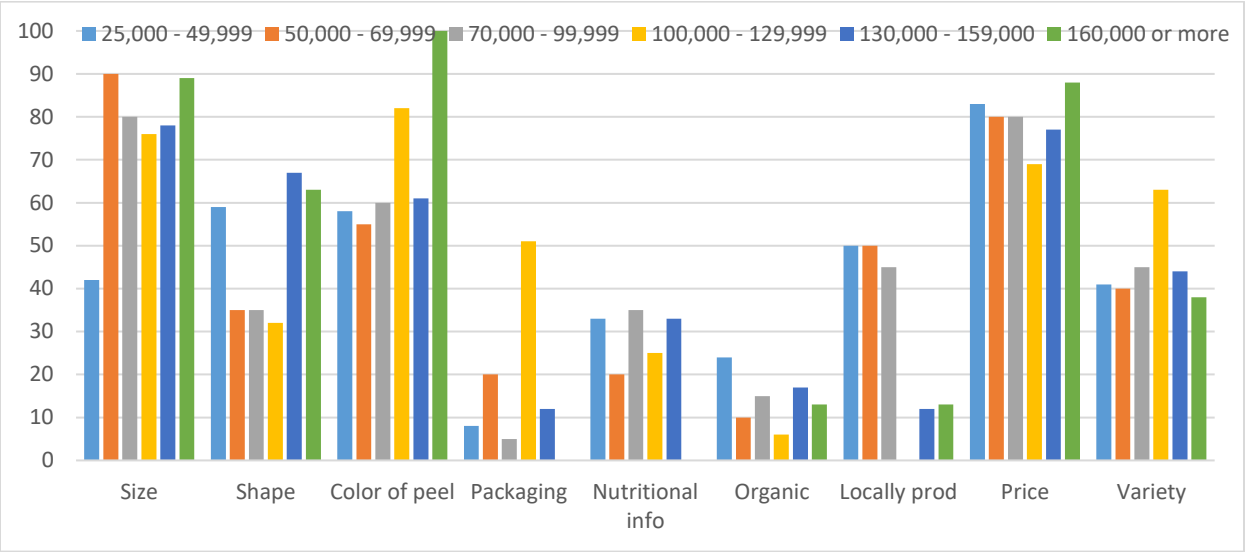
between size and price rank (Table 4.6). Similarly, shape and cultivar were found sharing rank five for high to least important factor score. Gender differences were observed with some factors such as male were found rating shape (54 versus 36%), organic (20 versus 6%) and locally produced (34 versus 24%) higher compared to female consumers, whereas price was rated higher by female consumers (88 versus 70%). Similarly, a difference in least important factors among males and females was found, such as shape and price found as least important factors for males compared to females (20 versus 6% and 16 versus 6%, respectively). Nutritional information (67 versus 60%), organic (85 versus 72%) and locally produced (65 versus 58%) were found least important for female consumers compared to male consumers. Choice of important factors also found affected with household income groups (Fig. 4.14), such as size of potato and color of peel were not an important factor for low household income groups compared to high household income groups. Locally produced was found not an important factor for high household income groups. Importance of locally produced and color of peel factors found depleting with the increasing education level (Fig. 4.15).

Table 4.6 Factors influencing purchase decision ($N = 95$)

Factors influencing purchase decision	Median	Importance
Size	3	Highly important
Price	3	
Color of Peel	4	
Shape	5	
Cultivar	5	
Locally produced	6	
Packaging	7	
Nutritional Information	7	
Organic	8	Least important

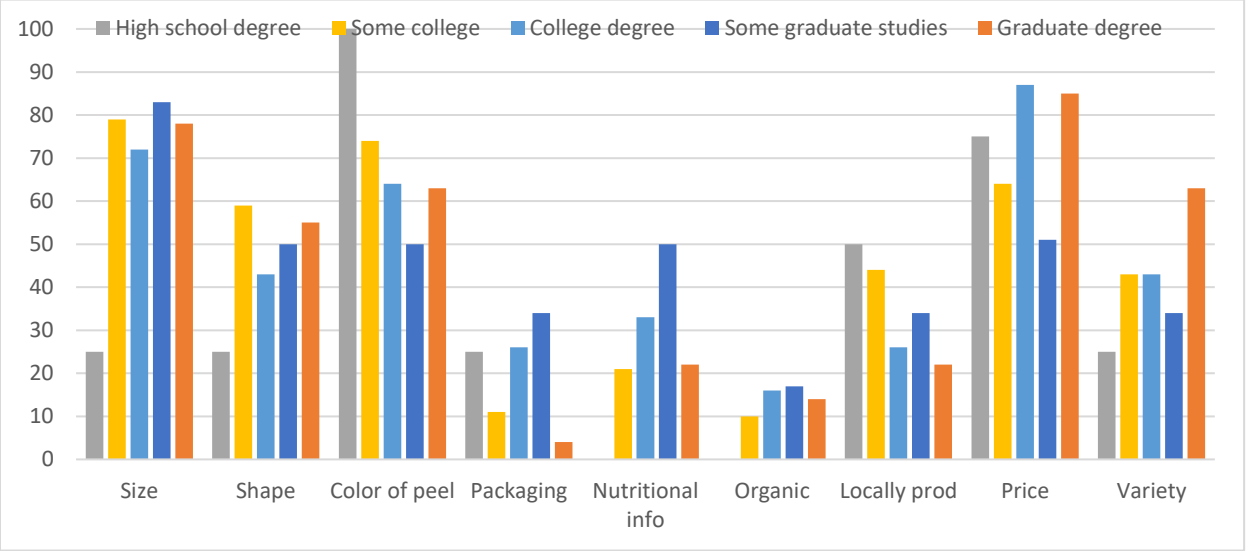
Note: Please rank the items in order from most important to least important to you when purchasing potatoes. *Click and drag the MOST IMPORTANT FACTOR for you into the 1st box. Click and drag the LEAST IMPORTANT FACTOR for you into the 9th box.*

Table 4.7 Importance of factors with respect to household income (in %)



Question – Please rank the items in order from most important to least important to you when purchasing potatoes.

Fig. 4.14 Importance of factors with respect to level of education



Question – Please rank the items in order from most important to least important to you when purchasing potatoes

Consumer choice of cooking methods

Baked and mashed potato cooking methods were ranked as the most liked potato preparation methods followed by fried, boiled, microwaved and other (Table 4.7). From proportion data, mashed method of potato preparation was cited as most liked (44%), followed by baked (28%). Microwaved method was least liked method (19%) of cooking potatoes, followed by boiling (11%). With respect to question asked, obtained results indicate the most liked potato preparation method, excluding convenience and time restrictions.

Table 4.8 Favorite potato preparation method

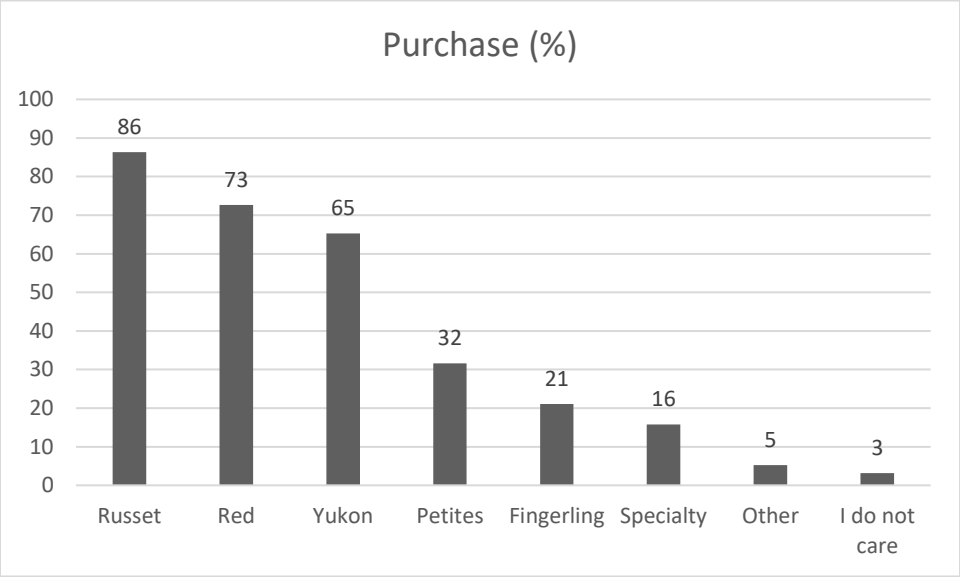
Potato preparation method	Median	Importance
Baked	2	Highly important
Mashed	2	↓
Fried	3	↓
Boiled	4	↓
Microwaved	5	↓
Other	6	Least important

Note: Rank in order the potato cooking method you like most (to least) that you, yourself like to eat. *Click and drag the name of the method you LIKED THE MOST into the 1st box. Click and drag the name of the method you LIKED THE LEAST into the 6th box.*

Potato cultivar preference

Russets, red and Yukon were found the most frequently checked cultivars by the consumers (Fig. 4.16). Only 3% of consumers stated that they do not care about cultivars when making a purchase, indicated the growing importance of cultivar name on the package. Most recipes specify certain types of potato cultivars and consumers following these recipes and cooking shows are looking for the prescribed cultivar.

Fig. 4.15 Consumer's purchase percentage for different cultivars ($N = 95$)

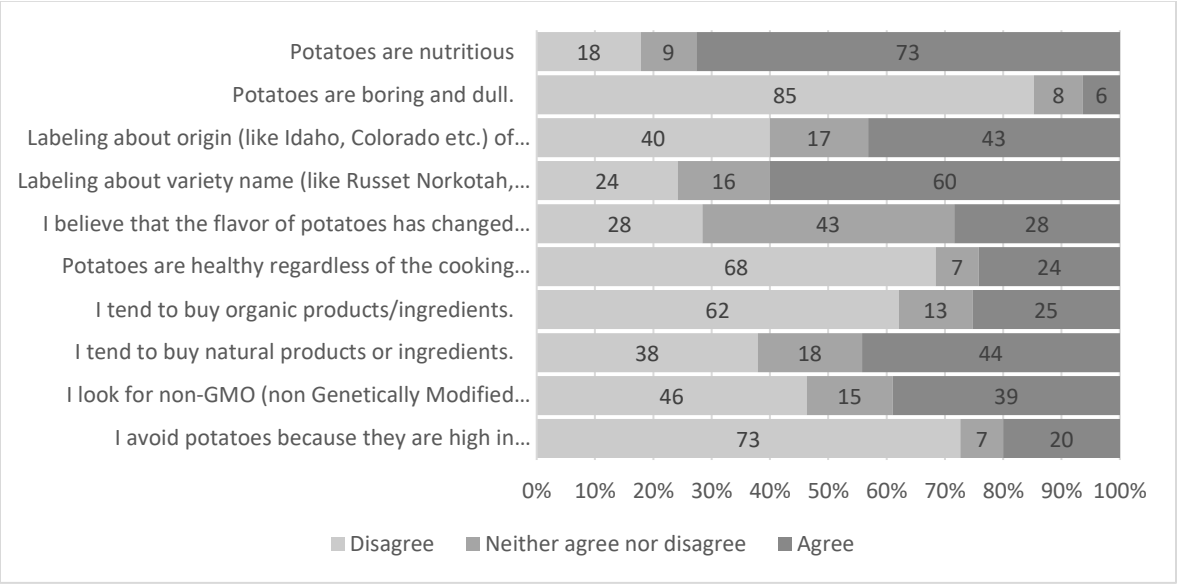


Question – Which potato cultivars do you normally purchase? Please check all that apply.

Attitudes, Opinions and Perceptions

Consumers were asked to indicate the extent to which they were in agreement or disagreement with a number of statements about potatoes. Agree/Disagree questions were treated as ordinal data, and because the assumptions of independence were violated twice (each respondent answered each question, and categories were related), Friedman's two-way analysis of variance test was used (Fig. 4.17).

Fig. 17 Belief and attitudes inquiring of Kansas City respondents ($N = 95$)



- ***Potatoes are nutritious*** (N = 95). Potatoes were found nutritious by 73% of total consumers, whereas 18% of consumers were found to have disagreement with this statement.
- ***Potatoes are boring and dull (N = 95).*** Only 5% of consumers agreed with this statement.
- ***Labeling about origin (like Idaho, Colorado etc.) of potatoes influence my purchase decision (N = 95).*** Two distinct groups were observed with respect to this statement, as 44% respondents agreed whereas 40% disagreed.
- ***Labeling about cultivar name (like Russet Norkotah, Snowden etc.) on the package influences my purchase decision (N = 95).*** A significant effect of cultivar name was observed on purchase decision, as 61% of respondents agreed with this statement while 24% disagreed.
- ***I believe that the flavor of potatoes has changed historically (N = 95).*** Respondents were found having no clear trend about this statement, as 29% were agreed whereas 28% were disagreed. Highest percentage of 'neither agree nor disagree' option was chosen by the respondents (43%) for the abovementioned statement implying the lack of belief or relevance (understanding) of this statement.
- ***Potatoes are healthy regardless of the cooking method (N =95).*** Overall, 68% of respondents disagreed with this statement while 24% agreed.
- ***I tend to buy organic products/ingredients (N = 95).*** Organic produce fetches price premiums and to inquire respondents' attitude around organic produce was explored by this statement. Overall, 62% respondents disagreed with this statement while 23% agreed. Gender's attitude differences with respect to food safety and environmental contamination

could be considered by this statement, as female respondents were found less attentive towards these issues (67% were disagreed) compared to male respondents (58% disagreed).

- ***I tend to buy natural products or ingredients (N = 95).*** Overall, 38% respondents disagreed with this statement while 44% agreed. Higher percentage of female respondents compared to male respondents (22 versus 14%) were found to have uncertainty about if being natural will affect their purchase decision or not, as they selected neither agree nor disagree'. Male respondents agreed with the statement significantly higher compared to female respondents (50% versus 38%).
- ***I look for non-GMO (Genetically Modified Organisms) ingredients in the food I eat (N = 95).*** Higher proportion of respondents (46%) disagreed with the statement that they look for non-GMO ingredients in their food compared to those who agreed (38%). Male respondents disagreed with this statement significantly more than female respondents (52 versus 40%, respectively).
- ***I avoid potatoes because they are high in carbohydrates (N = 95).*** Overall, 73% respondents disagreed while 20% agreed with the statement. Most of the respondents irrespective of gender differences were found to disagree (73% Female, 72% Male) with this statement.

Discussion

Hedonic Liking of cultivars

Colored cultivars, such as purple and red colored, were found less liked for appearance in this study, followed by bright yellow. Yellow and red cultivars had been previously found more acceptable over purple colored cultivars (Wechsler, 2011). Unique color appearance of purple and red potatoes has been cited as a reason for slow acceptance of the colored cultivars (Wechsler, 2011). Masquerade (light yellow flesh color) cultivar has been previously cited for highest overall acceptability irrespective of preparation methods (steamed and microwaved) (Larson, 2014)

Segmentation of potato consumers

Obtained clusters were looked for relationship with the household income and level of education, but no sharp differentiation observed with those demographic parameters. The reason of this could be that potatoes are not as such a premium product, but a more common product enjoyed by all segments of population, regardless of income and educational differences. Attitudinal dissimilarities between clusters were investigated by agree disagree questions (Table 4.8). Varietal information on potato pack affects cluster one respondents purchase decisions. Compared to varietal information, origin of potato was not as important for cluster one respondents as it was for cluster three respondents. An almost equal proportion of respondents who agree and disagree with the statement that 'flavor of potatoes has changed historically' found for cluster one respondents. Cluster one respondents were less interested about natural, organic or non-GMO and carbohydrates content. More options in the potato aisle might confuse these respondents. Cluster two respondents significantly disagreed (33%) with the statement that potatoes are nutritious compared to other two clusters. Building on this, it was expected that cluster two would have lower agreement (since they eat for pleasure) with the statement that 'potatoes are boring and dull' and

indeed no single respondent in cluster two agreed with this statement. For cluster two respondents, which had previous opinion of potatoes being “not so nutritional”, any kind of information on the package might not be as instrumental for them in making purchase decisions since this information will not change the nutritional value of the potatoes. However, labeling about origin seemed to have some influence on cluster two purchase making decision. Cluster two, who reported that origin was more instrumental over cultivar, seemed to have some idea about flavor of potatoes, as they reported highest agreement with the statement that ‘flavor of potatoes has changed historically’. Belief about origin may share some cognitive concept with flavor, which could lead respondents to believe that flavor of potatoes has changed historically. Organic ingredients seem more liked by cluster two respondents, strengthening the construct where origin, historical flavor, organic have higher importance. Similar kinds of response by cluster two respondents were reported with natural products though proportion of uncertainty (neither agree nor disagree) was higher (27%) compared to organic products (20%). Cluster two respondents were found having highest agreement (53%) with the statement that ‘I look for non-GMO ingredients’, which further strengthen the belief carrying by second cluster. Potatoes are blamed for their high carbohydrates content and consumers who have previous opinion of potatoes being not so nutritional, would certainly agree with this statement. This was obvious with second cluster and they found highest agreement with the statement that they avoid potatoes because of high carbohydrate content. Second cluster appears to have construct of being natural, organic, non-GMO, geographical origin importance and nutritionally informed. With respect to package and label requirements, cluster three was found highly agreed with the statement that labeling about origin influence purchase decision. It was assumed that for this cluster labeling about cultivar name on the package would certainly influence their purchase decision and expected results were found. Thus, third cluster

pays more importance to package and package information. Third segment of consumers seems to want more informed package with cultivar name and origin on it, more natural than organic and least agree with the statement that flavor has changed historically. Overall, word 'natural' was more influencing than 'organic' irrespective of segments.

Table 4.9 Relation of obtained clusters with sensory and attitudinal aspects

	Cluster one	**Cluster two**	**Cluster three**
Sensory/Hedonic aspects	overall, lowest liking for some samples	overall, all of the tested samples were highly liked	intermediate liking
	very narrow choice	broad choice	broad choice
	highest liking (6.06) was reported for *Masquerade*	highest liking (7.13) was reported for *CO05068-1RU* and *Rio Colorado*	highest liking (6.06 and 5.97) was reported for *Valery* and *Purple Majesty, Rio Colorado*
	Russian Banana was least liked	*Russian Banana* was least liked	*Russian Banana* was least liked
	lower hedonic score to colored cultivars	seems not much impact of color	higher hedonic score for colored cultivars
Attitudinal aspects	nutritional information matters	nutritional information does not matter as much	nutritional information matters
	hint of boredom associated with potatoes	no boredom	hint of boredom associated with potatoes
	does not matter from where potato is coming	origin does matter	origin highly matter's
	cultivar name matters a lot	cultivar name does not matter as much	cultivar name matters a lot

	package information important	no impact of package information	package information highly important
	not as much believe that potato flavor changed	believes that potato flavor has changed historically	not as much believe that potato flavor changed
	cooking method affects nutrition	cooking method does not impact potato nutrition	cooking method affects nutrition
	organic, natural is least important	organic, natural is important	organic, natural is important
	not as much opponent of GMO or supportive to GMO	non-GMO supporter	not as much opponent of GMO or supportive to GMO
Consumer Segments	**Price-oriented, conventional potato user group**	**Blind potato lovers' group**	**Health-oriented, acceptor of new color varieties group**

Price and health-oriented potato consumer segments were identified previously (Yue, Grebitus, Bruhn, & Jensen, 2008) in a survey conducted in Germany. These participants do not care much about price and carry a belief that cheap food has equal quality to expensive food and increased price does not ensure better taste. Health oriented consumers were found in almost all categories, and results were not different in potatoes.

Internal Preference Mapping for obtained clusters

Visual trace plots were used for determining positive and negative drivers of liking (Fig. 4.9 and 4.13). Only raw potato peel, vegetable complex and beany aroma were found as positive drivers of liking by linear regression equation, but several attributes were found having saddle or off-saddle relation with overall liking by polynomial regression equation. Aroma attributes such as earthy, cooked, umami, metallic and potato were found having an optimal saturation level after

which liking dropped. Similarly, several flavor attributes were found having a quadratic relation with overall liking, where liking dropped after saturation point. Cardboard, beany, earthy, metallic, bitter, astringent, nutty, vegetable complex, overall sweet impression, raw potato and peel flavor were identified as positive drivers of liking by linear regression equation. Among texture modality, particle size, mealiness and lumpiness were found as negative drivers of liking whereas particle amount, smoothness, firmness, residuals and adhesiveness were identified as positive drivers of liking.

Factors important in making purchase decision

Contrary to Jemison et al (2008) findings of lower importance of price by Maine respondents, price was found highly important in our study [conducted in the Kansas City (KC) area]. Being a cash crop (produced for its commercial value rather than for use by the grower), potato size has huge economic importance and even size potato packs have been documented previously as an important factor (Cheng, Peavey, & Kezis, 2001). Appearance (79%), flavor (72%), size (59%), nutrition (57%), texture (55%) and price (48%) were found most important attributes for Colorado consumers whereas cultivar and organic certification were least important (Hine, Loureiro, & Meyer, 2001). Massachusetts consumers found favorable towards “Maine” label whereas North Carolina consumers towards “Idaho” label (Cheng et al., 2001). Brand label affect was found missing in most studies (Cheng et al., 2001). Locally produced, firmness and transparent package were found most influential factors in making the fresh potato purchase decision (Dukeshire et al., 2016).

Potato cooking method and convenience

Baking and mashing were reported as most liked potato preparation methods in this study, excluding convenience and time constraints, which could otherwise affect these results. Demand for processed potatoes found increasing in both domestic and international markets. Boiling has been previously cited as the most common method of potato preparation worldwide, but the demand of instant mashed potatoes has been cited increasingly (Hine et al., 2001). In 1990s, baked method (47%) of potato preparation was found favorite among Washington state consumers, followed by mashed (30%) and french fries (16%) (McCracken & Marotz, 1989). Similarly, baked method (69%) was found preferred method of fresh potato preparation in Maine consumers followed by mashed (59%) and roasted methods (41%) (Jemison Jr, Sexton, & Camire, 2008). Women expressed a slightly higher interest in baked potatoes while men expressed a greater interest in roasted potatoes. Mashed potatoes were the preferred choice for respondents of 20 to 50 years of age while baked potatoes were preferred for respondents older than 50 years of age (Jemison Jr et al., 2008).

Potato cultivar preference

Cultivars consumers normally purchase around KC area were found russets, followed by red's and Yukon's. Yukon Gold has been previously stated as the most important cultivar by Colorado consumers followed by Russet Burbank and Russet Nugget (Hine et al., 2001). Hine et al (2001) reported no cultivar preference for about 55% of the Colorado consumers and Yukon Gold was the most frequently stated cultivar followed by Russet Burbank. Compared to Colorado consumers, russets were the most popular (55%) among Washington state consumers, followed by white (18%) and red (9%) potatoes (McCracken & Marotz, 1989). Higher percentage of no preference consumers (18%) was also observed at that time, in 1990s. About 50% of consumers

were found having no favorite cultivar in Delaware region whereas 27% selected the red cultivar, followed by russets (13.6%), white (4.3%), Yukon Gold (3.1%) and yellow (1.5%) (Cook, Toensmeyer, German, & Bacon, 2000). Dukeshire et al (2016) found cultivar of potato factor not significant in purchase making decisions. Type of question asked could possibly have some influence on the obtained results, as in some cases respondents must write the name of the cultivar whereas in other cases they must select the cultivar from existing list.

Beliefs, Attitudes, Opinions and Perceptions

Over 96% of Maine respondents considered potatoes as a healthy food compared to 73% of Kansas City respondents. Maine, as a potato growing state could have healthy perception of potatoes due to the long history of potato in the state and better marketing strategies. Healthy perception of potatoes align with previous findings (Dukeshire et al., 2016; Fernqvist et al., 2015; Jemison Jr et al., 2008). The perception of "potatoes are boring" was found higher (<20% agreed) in British consumers (Fearne, 1992) compared to US consumers (<10% agreed). Perception of being boring and/or old fashioned has been found not an issue to most of potato consumers (Wood, Carragher, & Davis, 2017). Consumer's positive perception about origin or source stamp on package has been documented extensively (Cheng et al., 2001; Cook et al., 2000; Hine et al., 2001; Jemison Jr et al., 2008). Low positive perception of potato source label among Kansas City respondents could be explained by the fact that Kansas is a non-potato growing state and respondents usually favor local produce (Denver & Jensen, 2014) which in the case of potatoes it is not. Gender and having a college degree were previously found having little impact on a shopper's decision to buy organic produce (Thompson & Kidwell, 1998). Consumers perception and opinion about "what constitutes natural" was questioned previously and found that chemical sounding names and the age of the consumers influence whether an ingredient or food would

consider natural or not (Chambers V, Chambers IV, & Castro, 2018). The impact of 'organic' in purchase was found not important for most consumers in our study. Jemison et al (2008) reported "organic" as less important factor in purchase decisions. Demand for organic found to differ geographically, as consumers from California and East coast were found more open to organics than traditional Midwest and south (Greenway, Guenthner, Makus, & Pavek, 2011). Consumer understanding of GMOs was found low among US consumers, with just 48% knowing that GMOs were available in market and indeed 16% knew nothing at all (Wunderlich & Gatto, 2015). Perceptions about potatoes such as "High in carbohydrates" and "Starchy vegetables are not healthy" have been previously found a reason for decline in potato consumption (Wood et al., 2017). Nutritional value and flavor appeared most important driving force for future potato clone's improvement (Hine et al., 2001).

Limitations of this study

Only a single indicator was used to capture consumer's attitude to an issue in Agree/Disagree questions, which could be limitation of this study because more indicators (to scrape attitudinal construct, nutritional and health awareness, price, etc.) produce better differentiation and breadth of the concept. Some other limitations were of logistics, time constraint and feasibility nature, such as two-day study, one preparation method (mashed), consumer fatigue, etc., which could have some impact on the obtained results.

Conclusion

Potatoes were considered healthy by most respondents; thus, marketing of potatoes should be built around this opinion. Three segments of potato consumers were found in this study, characterized by price-oriented group, potato lovers' group and health-oriented group. Vegetable complex, beany, raw potato, raw potato peel, metallic, astringent, cardboard, earthy, salty, overall

potato ID, smooth, firm and adhesive texture seem to be the major drivers of liking for the first cluster of respondents. Cluster two respondents were small in number and their drivers were not aligned to one direction. Overall sweet impression, sweet aromatics, beany and nutty flavor, cardboard flavor, bitter flavor, raw potato flavor and a hint of cauliflower flavor appeared triggers hedonic liking for the third group of respondents. Mashed method of fresh potato preparation was liked by most KC consumers as a potato cooking method. Gender also was found to affect opinions and attitudes. The practical implications of this study will be important to breeders, growers, sensory science, marketers and consumers.

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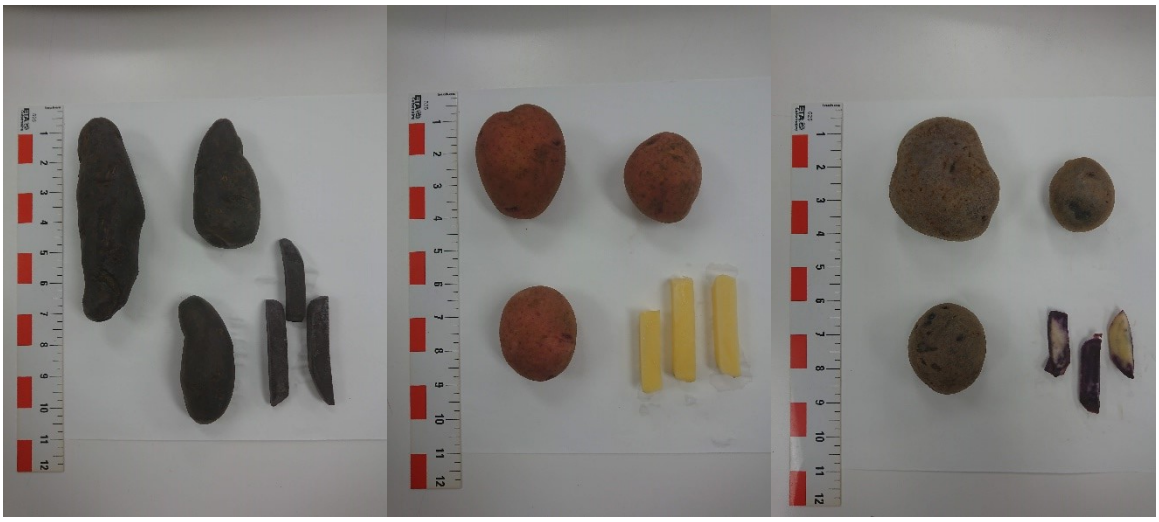
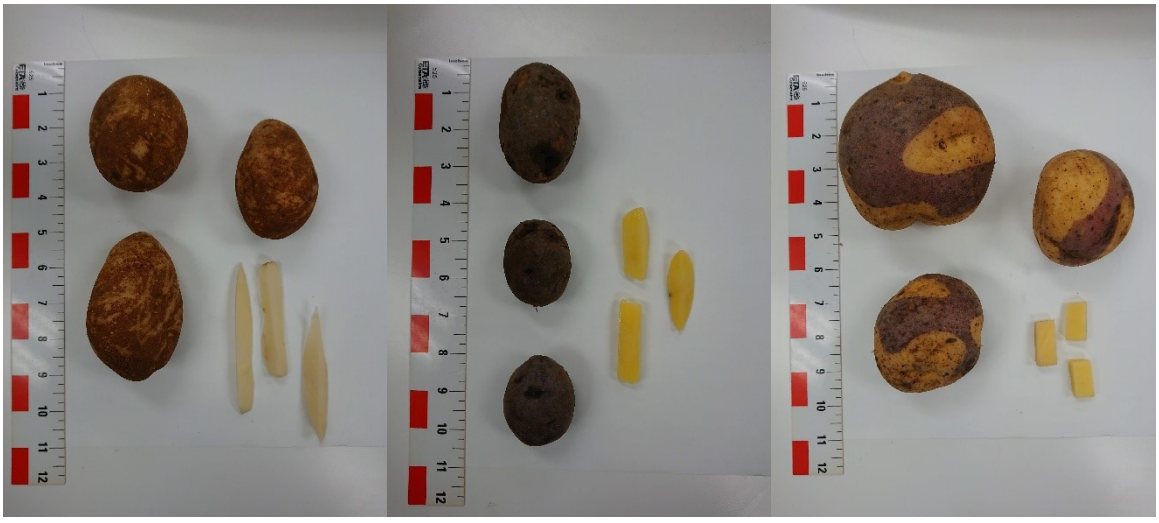
Appendix A - **Pictures of Potatoes used in this study:**



CO08062-3PF/P CO97232-2R/Y CO05028-4P/PY

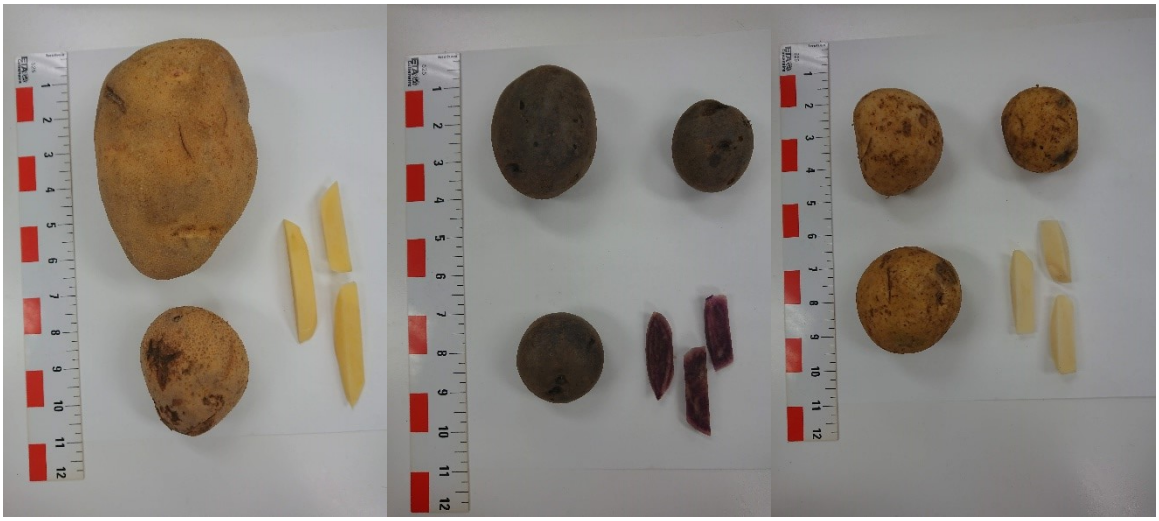
Amarosa Chipeat Crimson King

Jester Lamoka Vermillion



AC05039-2RU AC99330-1P/Y Masquerade

CO00277-2R CO08029-1RF/R Russet Nugget



Jelly POR11PG7-1 Winterset

Rio Colorado Colorado Rose Sangre

AO06191-1 Atlantic Purple Pelisse

Castle Russet POR11PG62-3 Russet Norkotah

CO00405-1RF CO05068-1RU CO12117-4RF/R

Canela Russet CO98012-5R Rio Grande Russet

AllBlue POR12PG28-3 Purple Majesty

CO08155-2RU/Y Valery Yellow Fin

Magic Molly No 390 CO12125-3PF/P

CO05037-2R/Y CO05037-3W/Y CO99076-6R

Ranger Russet Russet Burbank Snowden

Cheshire Pike Purple Majesty Colorado

CO07131-1W/Y

Appendix B - **Codes used in the third chapter**

R-Codes used

```
#read data
mydata <-read.table(file.choose(), header = T, sep = ",")

#MDS for CATA code
mds <- cmdscale(1-cor(mydata[, -c(1:2,20)], use = "complete.obs"))
plot(mds, xlab = "Component 1", ylab = "Component 2", type="p", asp=1.2)
text(mds, col = "blue", cex = 0.75, rownames(mds))

#effective sample size determination for Cochran's Q test
eff.sample.size <- apply(bookdata[,3:16], 2, function(x) ave(x, bookdata[,1], FUN=function(y)
mean(y, na.rm=TRUE)))
eff.sample.size <- apply(eff.sample.size, 2, function(x) length(unique(bookdata[! x %in%
c(0,1),1])))
eff.sample.size
#data read for MFACT analysis
df1 <-read.table(file.choose(), header = T, sep = ",",row.names = 1)
df1
library(FactoMineR)
res<-MFA(df1,group = c(6,45), type = c("f","f"),name.group = c("CATA","OpenEnd"))
plot(MFA(res, axes = c(1,2), choix="freq",habillage="group", invisible=ind)
  plot.MFA(res,choix = "group")
```

Trend of responses to Open-ended questions

Table Comment 1 trend of asked Open-ended question

Modality and frequency of use	Terms under modality
Appearance = 201	Yellow (47), White (42), Purple (36), Color (27), Colorful (8), Golden (5), good color (5), Appearance (4), real potato color (3), odd color (3), potato color (3), Bright (3), Look (3), Pink (2), Gold (2), Red (1), visually (1), yellowish (1), Pale (1), Looked (1), Looking (1), Violet (1), Visually (1)
Aroma = 8	Smell (3), Lavender (2), Smelling (1), Smells (1), Pungent (1)
Flavor = 107	Bland (39), Flavor (7), Taste (7), Flavorful (6), Tasteless (4), Tasty (4), Buttery (4), Aftertaste (3), Earthy (3), Tastes (3), Butter (2), Buttered (2), Chalky (2), Starchy (2), good flavor (2), good taste (2), tastes like (2), weird taste (2), Old (2), Bitter (1), Cooked (1), Flavored (1), Flavorless (1), Stale (1), Sweet (1), Tangy (1), Tasteful (1), Urine (1),
Texture = 151	Dry (20), Creamy (19), Thick (11), Smooth (10), Soft (9), Moist (7), Grainy (6), Lumpy (6), Dense (5), Gritty (5), Texture (5), Hot (5), Buttery (4), Fluffy (3), Hard (3), good texture (2), little dry (2), Warm (2), Firm (2), Mashed (2), Mushy (2), Runny (2), Stiff (2), Chunky (1), Cohesive (1), Compact (1), Consistency (1), Cream (1), Crumbly (1), Damply (1), Dough (1), Doughy (1), Flaky (1), Gummy (1), Heavy (1), Mealy (1), Textured (1), Water (1), Wet (1), Paste (1)
Hedonic = 282	Good (31), Real (9), Potato (8), Like (7), Bad (6), Nice (6), Weird (6), Instant (5), natural (5), Okay (5), Slightly (5), Fake (4), Fresh (4), Gross (4), Odd (4), Ugly (4), Real potato (4), Baby (3), Boring (3), Delicious (3), Fine (3), Light (3), Little (3), Nasty (3), Pleasant (3), Putting (3), Right (3), Traditional (3), Baby food (2), Like potato (2) etc.

Table Comment 2 trend of asked Open-ended question

Modality and frequency of use	Terms under modality
Appearance = 72	White (14), Color (10), Yellow (9), Purple (6), Looks (5), Looking (4), Looks like (4), Bright (3), Appearance (2), Dull (2), Golden (2), Yellowish (2), Good color (2), Colored (1), Colorful (1), Colorless (1), Grey (1), Opaque (1), Pale (1), Shiny (1)
Aroma = 17	Aroma (6), Smells (6), Earthy aroma (2), Smells good (2), Lemon (1)
Flavor = 148	Bland (29), Flavor (18), Taste (16), Tasty (11), Flavorful (8), Earthy (7), Tasteless (5), Flavorless (3), Salt (3), Taste (3), Tasting (3), Artificial (2), Chemical (2), Stale (2), Starchy (2), Sweet (2), Tasteful (2), Woody (2), Aftertaste (1), Artificial (1), Bitter (1), Butter (2), Chalky (1), Fiber (1), Fishy (1), Flavored (1), Lingers (1), Plastic (1), Salty (1), Salt less (1), Squash (1), Turnip (1), Unsalted (1), Ice-cream (1), Old (1)
Texture = 225	Smooth (24), Thick (19), Creamy (18), Moist (18), Dry (17), Lumpy (14), Texture (14), Chunky (12), Firm (7), Grainy (7), Dense (5), Good texture (5), Hot (4), Gritty (4), Stiff (4), Thin (4), Fluffy (3), Gummy (3), Pasty (3), Soft (3), Solid (3), Chewy (2), Watery (2), Coarse (2), Mealy (2), Mushy (2), Pasty (2), Texture okay (2), Runny (2), Starchy (2), Slightly lumpy (2), Textured (2), Watery (2), Wet (2), Clumpy (1), Cohesive (1), Compact (1), Fibrous (1), Flakey (1), Hard (1), Mashed (1), Waxy (1)
Hedonic = 260	Good (27), Natural (11), Like (10), Plain (8), Fake (5), Nice (5), Ok (5), Slightly (5), Strong (5), Mild (4), Needs (4), Potato (8), Weak (4), Average (3), Instant (3), Interesting (3), Nasty (3), Non (3), Odd (3), Pleasant (3), Unappetizing (3), Appealing (2), etc.

Table Comment 3 trend of asked Open-ended question

Modality and frequency of use	Terms under modality
Appearance = 54	Color (9), Looking (6), White (6), Yellow (5), Good color (4), Appearance (4), Purple (4), Look (3), Looks (2), Pink (2), Translucent (2), Slight translucent (2), Bright (1), Colorful (1), Coppery (1), Gold (1), Golden (1)
Aroma = 17	Aroma (5), Smells (5), Smell (4), Smells like (2), Odorless (1)
Flavor = 177	Bland (34), Flavor (21), Taste (14), Flavorful (13), Tasty (11), Salt (8), Earthy (7), Aftertaste (6), Tasting (5), Tasteless (4), Tastes (4), Cooked (3), Sweet (3), Butter (2), Chemical (2), Salty (2), Bitter (1), Buttery (2), Artificial (1), Fiber (1), Flavored (1), Flavorable (1), Flavor (1), Flavorful (2), Flavorless (1), Metallic (1), Old (1), Plastic (1), Pungent (1), Starchy (1), Tasted (1), Tasteful (1), Needs salt (6), bad aftertaste (4), Lacking flavor (2), natural flavor (2), needs Butter (2), Potato flavor (2), tastes like (2)
Texture = 220	Smooth (30), Dry (20), Creamy (19), Thick (18), Lumpy (14), Texture (14), Chunky (11), Moist (10), Consistency (5), Mashed (5), Warm (5), Firm (4), Good texture (4), Grainy (4), Gritty (4), Pastey (4), Mushy (3), Solid (3), Cohesive (2), Real potato texture (2), Good consistency (2), Potato texture (2), Crumbly (2), Dense (2), Pasty (2), Rubbery (2), Thin (2), Velvety (2), Watery (2), Chewy (1), Compact (1), Dough (1), Fluffy (1), Heavy (1), Hot (1), Lumps (1), Oily (1), Mouthfeel (1), Paste (1), Sandy (1), Smooth (1), Soft (1), Sticky (1), Stringy (1), Tacky (1), Tender (1), Textured (1), Texture less (1), Watered (1), Wet (1)
Hedonic = 360	Good (32), Real (12), Needs (11), Potato (11), Tasty (11), Slightly (10), Natural (9), Like (8), Nice (7), Weak (7), Fake (6), Ok (6), Plain (6), Pleasant (6), Bad (5), Little (5), Okay (5), Potatoes (5), Weird (5), Boring (4), Cafeteria (4), Fine (4), Mild (4), Strong (4), Unappetizing (4), Appealing (3), Non (3), Strange (3), Like real (3), Real potato (3), Taste ok (3), Like real potatoes (2), tastes like real (2) etc.

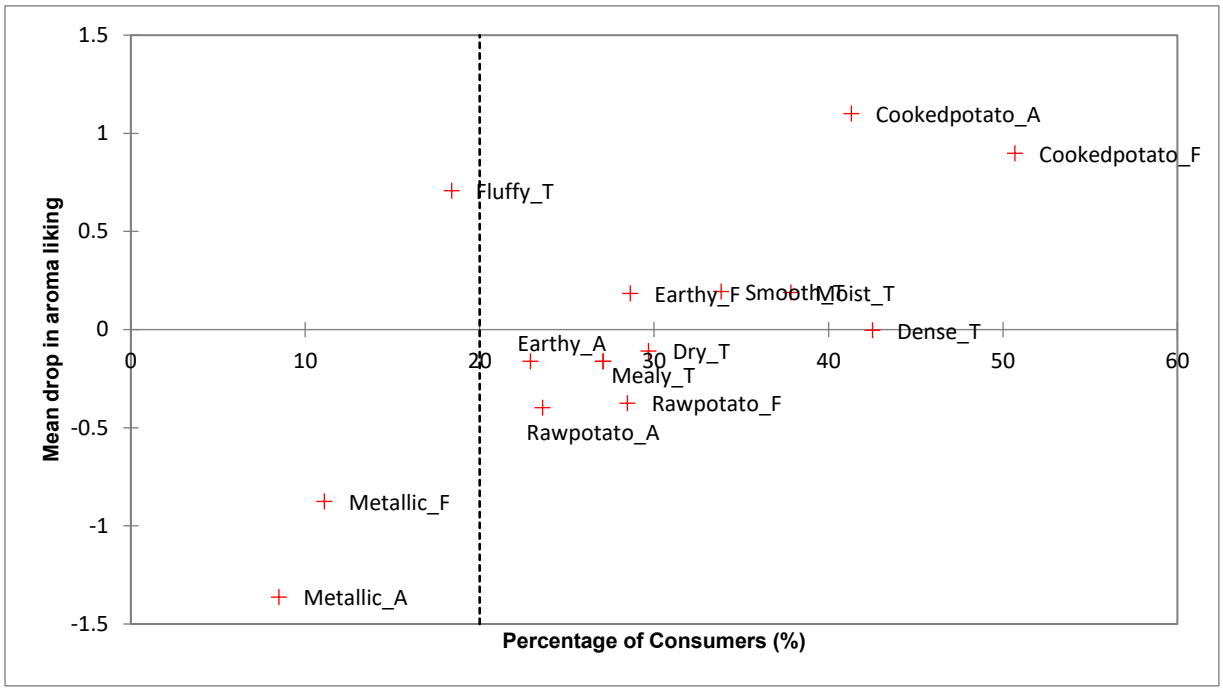
Table Comment 4 trend of asked Open-ended question

Modality and frequency of use	Terms under modality
Appearance = 46	Color (9), Yellow (8), White (6), Look (6), Opaque (2), Natural color (2), Odd color (2), Purple (2), Appear (1), Appearance (1), Colorful (1), Colorless (1), Discolored (1), Dull (1), Pink (1), Red (1), Yellowish (1)
Aroma = 24	Aroma (6), Smell (5), Smells (4), Smelled (1), Smelling (1), Smells like (3), Bad smell (2), Nice aroma (2)
Flavor = 168	Bland (23), Flavor (19), Taste (16), Tastes (11), Earthy (9), Tasty (9), Flavorful (8), Tasteless (8), Tastes like (8), Starchy (5), Bitter (4), Buttery (4), Tasting (4), Aftertaste (3), Flavorless (3), Salt (3), Good flavor (3), Potato taste (2), Tastes real (2), Butter (2), Cooked (2), Sweet (2), Artificial (2), Buttered (1), Cardboard (1), Chalky (1), Chemical (1), Earthy (1), Flavorful (2), Flavored (1), Good flavor (1), Milk (1), Old (1), Salty (1), Squash (1), Unflavored (1), Unsalted (1), Woody (1)
Texture = 198	Smooth (23), Creamy (18), Texture (18), Chunky (13), Dry (12), Lumpy (11), Good texture (8), Thick (6), Warm (6), Mashed (5), Clumpy (4), Firm (4), Grainy (4), Gritty (4), Lumps (4), Dense (3), Heavy (3), Hot (3), Moist (3), Soft (3), Pasty (3), Sticky (3), Chewy (2), Runny (2), Crumbly (2), Paste (2), Thin (2), Watery (2), Wet (2), Airy (1), Cohesive (1), Coarse (1), Doughy (1), Dryish (1), Flakey (2), Gooey (1), Luke warm (1), Mealy (1), Mouthfeel (1), Sand (1), Silky (1), Sticks (1), Stiff (1), Textured (1), Velvety (1), Way (1)
Hedonic = 356	Good (28), Real (16), Natural (15), Like (13), Nice (9), Potato (9), Odd (8), Ok (7), Fake (6), Pleasant (6), Potatoes (6), Slight (6), Real potatoes (6), Bad (5), Needs (5), Okay (5), Boring (4), Plain (4), Poor (4), Processed (4), Strong (4), Weak (4), Weird (4), Blah (3), Bold (3), Different (3), Fine (3), Great (3), Little (3), Mild (3), Slightly (3), Like real (3), Strange (3), Alright (2), Appealing (2) etc.

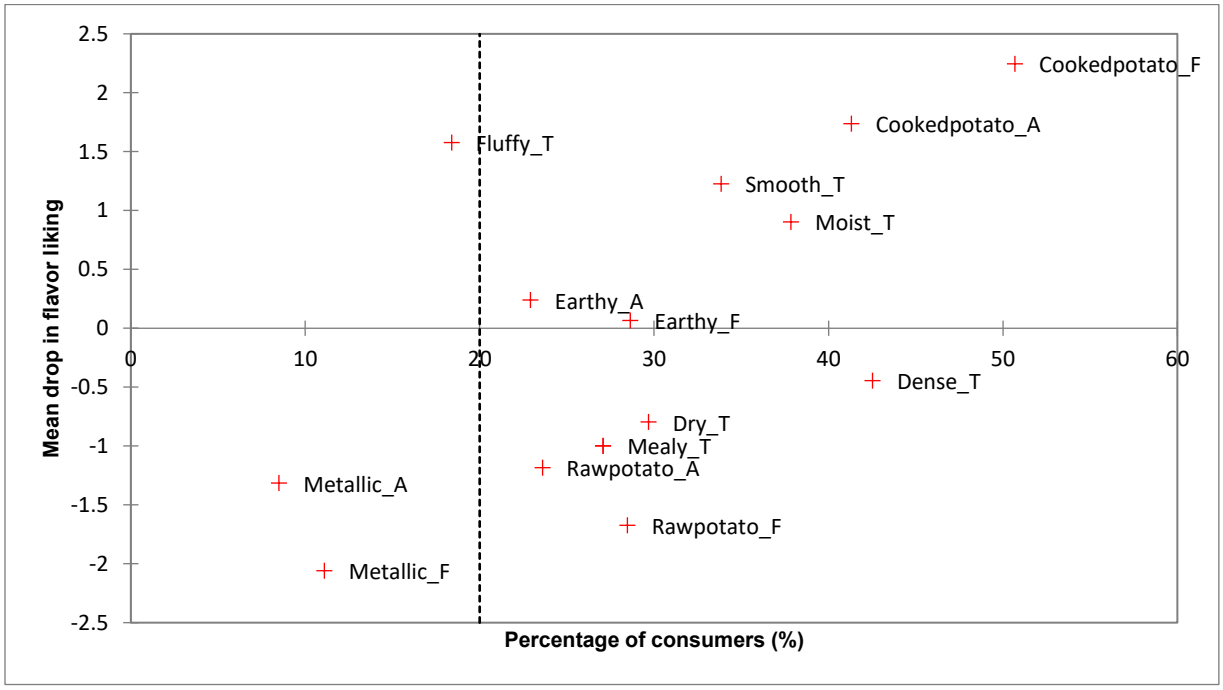
Table Comment 5 trend of asked Open-ended question

Modality and frequency of use	Terms under modality
Appearance = 39	Color (11), Dull (5), Looks (5), White (5), Looking (3), Yellow (3), Weird color (2), Colored (1), eye (1), Look (1), Miscolored (1), Yellowish (1)
Aroma = 13	Aroma (6), Smell (3), Odorless (1), Smells (1), Smelly (1), Stinks (1)
Flavor = 122	Bland (33), Taste (11), Flavor (10), Tasty (9), Aftertaste (6), Flavorless (5), Salt (5), Butter (4), Starchy (4), Earthy (3), Flavorful (3), Tasteless (3), Cooked (2), tasteful (2), Tastes (2), Tasting (2), Bad aftertaste (2), Mild flavor (2), Needs butter (2), Slight bland (2), Bitter (1), Chalky (1), Chemical (1), Fiber (1), Flavored (1), Flavoring (1), Milk (1), Salt less (1), Sweet (1), Stale (1), Tastey (1), Needs salt (1)
Texture = 150	Smooth (14), Dry (10), Warm (10), Chunky (10), Creamy (8), Lumpy (8), Grainy (7), Gritty (6), Texture (6), Soft (5), Moist (4), Fluffy (3), Heavy (3), Mashed (3), Pastey (3), Sticky (3), Consistency (2), Crumbly (2), Dense (2), Hot (2), Solid (2), Textured (2), Watery (2), Wet (2), Good texture (2), Compact (2), Clumpy (1), Coarse (1), Consistent (1), Firm (1), Flaky (1), Gummy (1), Hard (1), Lumps (1), Mash (1), Moist (1), Moisture (1), Pasty (1), Sandy (1), Slimy (1), Stiff (1), Tender (1), Velvety (1)
Hedonic = 402	Good (33), Ok (12), Okay (12), Needs (11), Bad (10), Just (8), Real (8), Boring (7), Fine (7), Slightly (7), Like (6), Mild (6), Plain (6), Pleasant (6), Unpleasant (6), Appetizing (5), Enjoyable (5), Great (5), Homemade (5), Little (5), Nasty (5), Odd (5), Strong (5), Week (5), Weird (5), Somewhat (4), Appealing (3), Better (3), Cafeteria (3), Fake (3), Gross (3), Instant (3), Natural (3), Pleasing (3), Potato (3), Unappealing (3), Average (2), Blah (2), Cafeteria (2) etc.

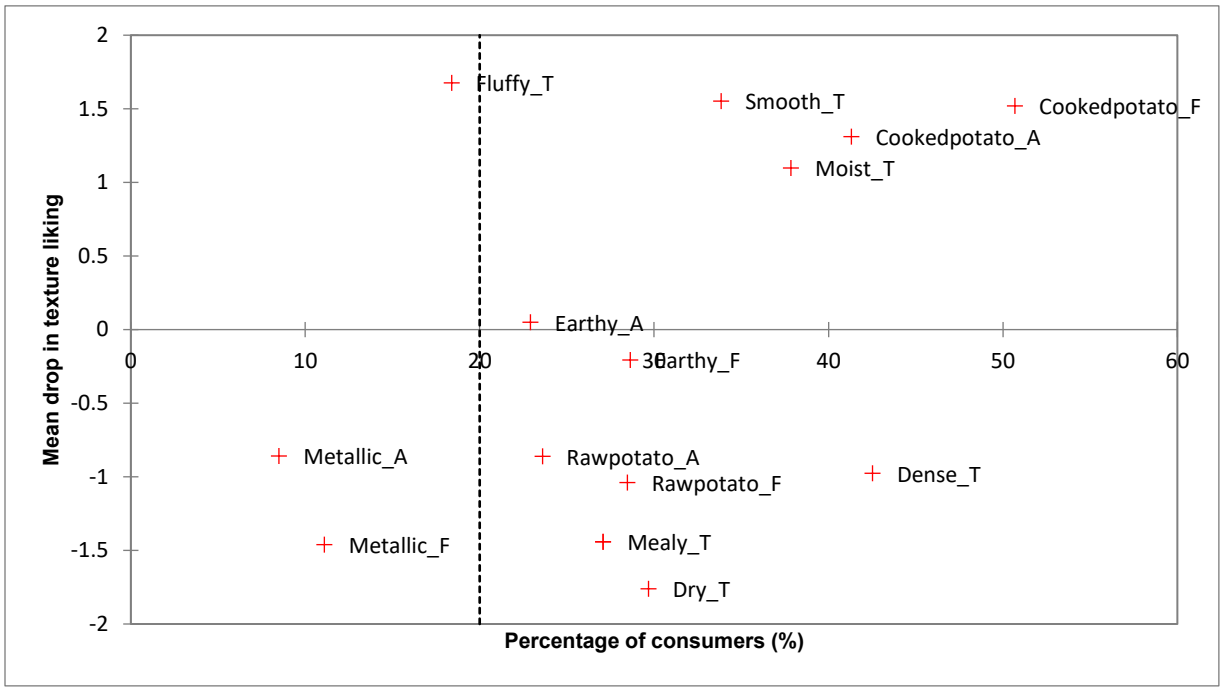
Mean drop in aroma liking



Mean drop in flavor liking



Mean drop in texture liking

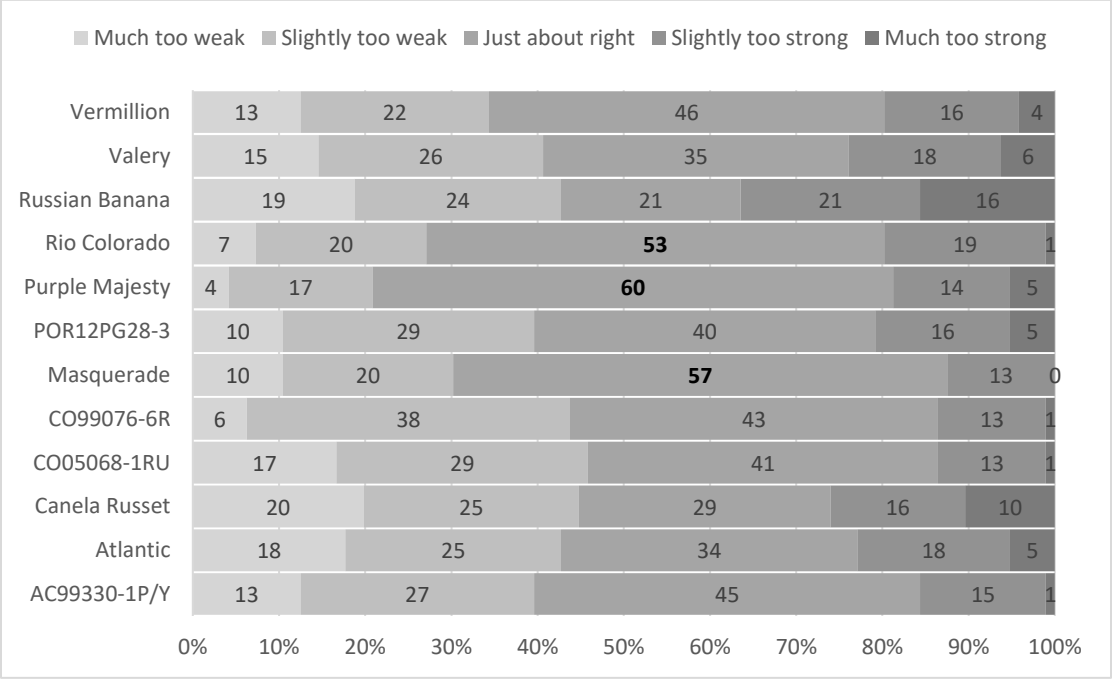


Appendix C - **Supplementary files for the fourth chapter**

Segmentation of consumers into three clusters and their properties

Clusters	*N*	Samples											
		CO05068-1RU	**Canela Russet**	**Atlantic**	**CO99076-6R**	**AC99330-1P/Y**	**Masquerade**	**Russian Banana**	**POR12PG28-3**	**Purple Majesty**	**Vermillion**	**Valery**	**Rio Colorado**
Cluster 1	46	5.30	3.97	5.26	5.60	5.19	6.06	3.04	3.85	4.65	3.72	3.85	5.09
Cluster 2	15	7.13	6.07	6.53	6.60	6.73	6.87	5.40	6.73	6.73	6.13	5.87	7.13
Cluster 3	35	4.80	4.40	4.43	5.66	5.17	5.00	4.23	5.34	5.97	5.69	6.06	5.97
Total	96	5.41	4.46	5.16	5.78	5.43	5.80	3.84	4.84	5.46	4.81	4.97	5.73

Just-about-right (JAR) on 5-point choice



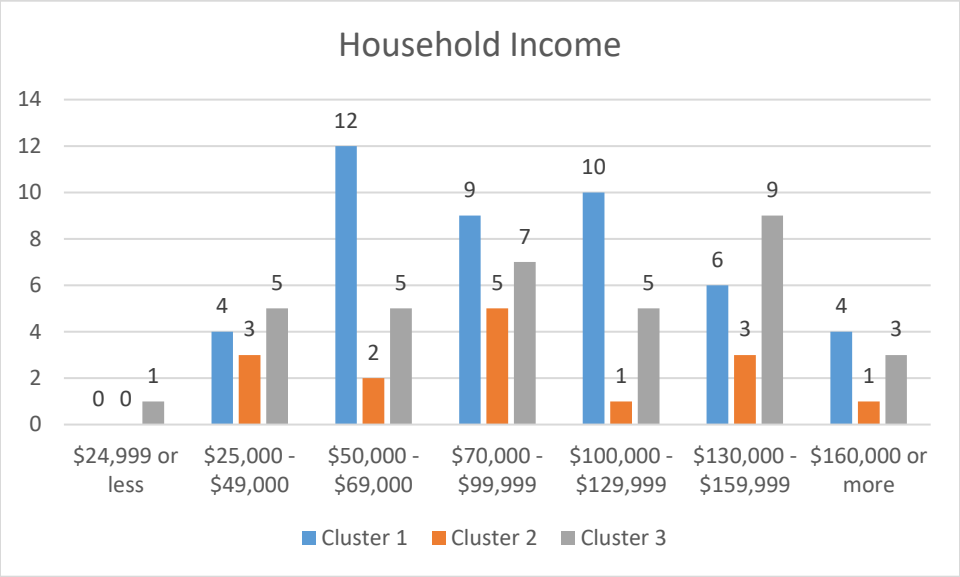
SAS code used for statistical analysis

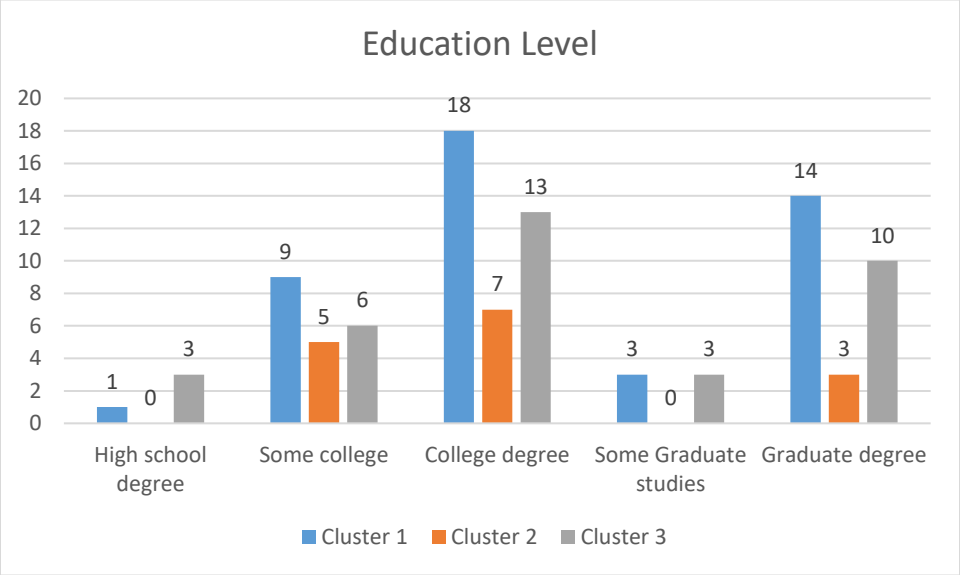
```
PROC IMPORT DATAFILE="/folders/myfolders/OpenEndLiking.xlsx"
                    OUT=WORK.Mean
                    DBMS=XLSX
                    REPLACE;
                    Getnames=Yes;
                    Datarow=2;
run;

/** Print the results. **/

PROC PRINT DATA=WORK.Mean; run;

data Mean;set Mean;
if Trt=1 then Potato='A';
else if Trt=2 then Potato='B';
else if Trt=3 then Potato='C';
else if Trt=4 then Potato='D';
else if Trt=5 then Potato='E';
else if Trt=6 then Potato='F';
else if Trt=7 then Potato='G';
else if Trt=8 then Potato='H';
else if Trt=9 then Potato='I';
else if Trt=10 then Potato='J';
else if Trt=11 then Potato='K';
else if Trt=12 then Potato='L';
run;

proc sort data=Mean;
by subject_id period;
proc transpose data=mean out=mean2 prefix=T;by subject_id;
```

```
var potato;
run;

data mean2; set mean2;
sequence= t1 || t2 || t3 || t4 || t5 || t6 || t7 || t8 || t9 || t10 || t11 || t12;
run;

proc freq data=mean2;
table sequence/norow nocol nopercent;
run;
proc freq data=mean;
table period*Potato/norow nocol nopercent;
run;

proc mixed data=mean;
class period potato subject_id;
model Appearance_Liking=period potato;
lsmeans potato/pdiff adjust=tukey;
random subject_id;
run;
proc mixed data=mean;
class period potato subject_id;
model Aroma_Liking=period potato;
lsmeans potato/pdiff adjust=tukey;
random subject_id;
run;
proc mixed data=mean;
class period potato subject_id;
model Overall_Liking=period potato;
lsmeans potato/pdiff adjust=tukey;
random subject_id;
```

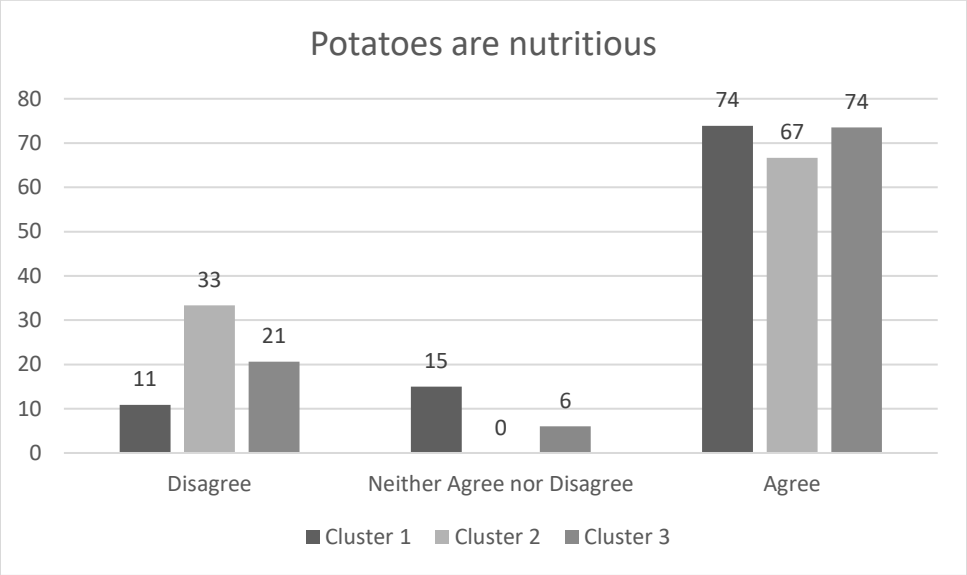
```
run;
proc mixed data=mean;
class period potato subject_id;
model Flavor_Liking=period potato;
lsmeans potato/pdiff adjust=tukey;
random subject_id;
run;
proc mixed data=mean;
class period potato subject_id;
model Texture_Liking=period potato;
lsmeans potato/pdiff adjust=tukey;
random subject_id;
run;
proc mixed data=mean;
class period potato subject_id;
model Aftertaste_Liking=period potato;
lsmeans potato/pdiff adjust=tukey;
random subject_id;
run;
```

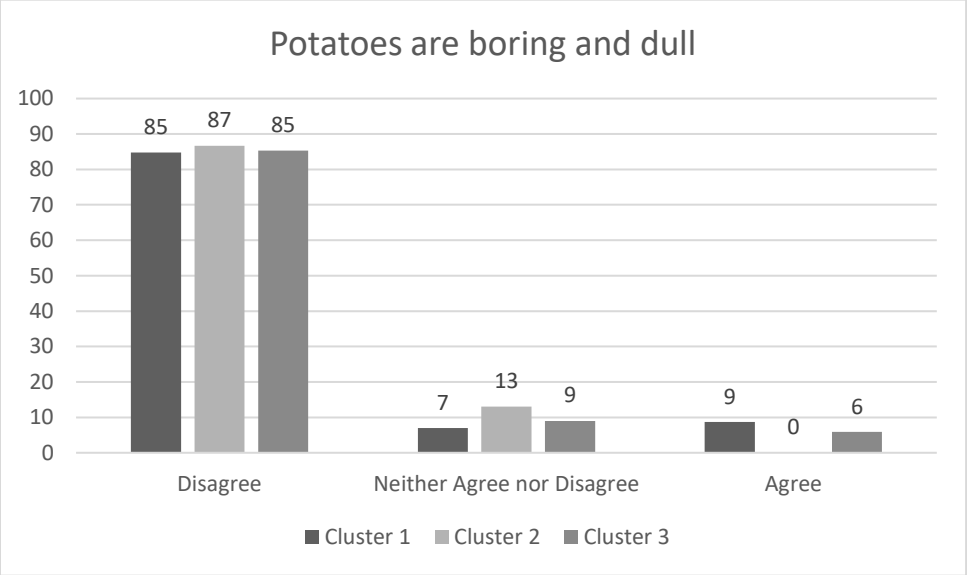
Relation of household income and education level to obtained potato consumer segments

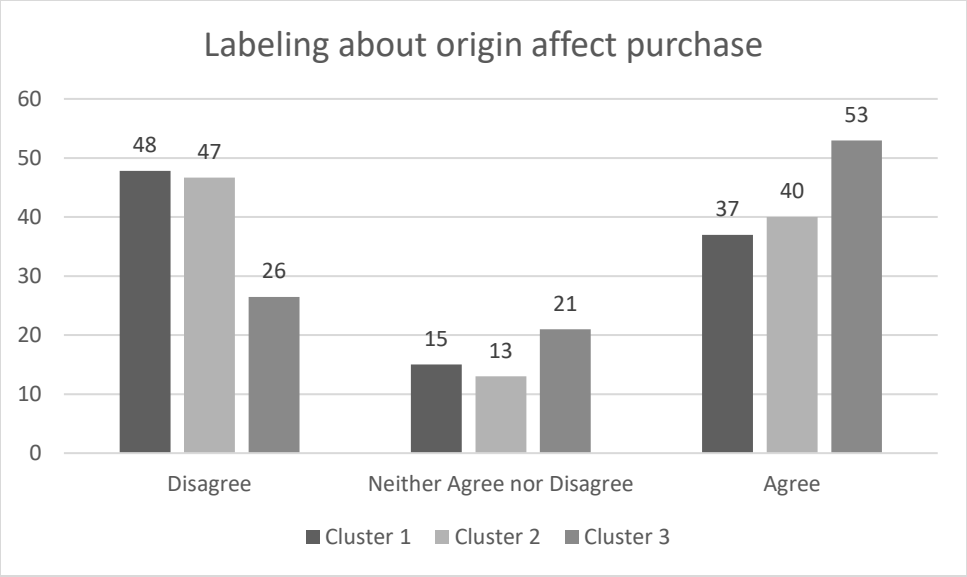


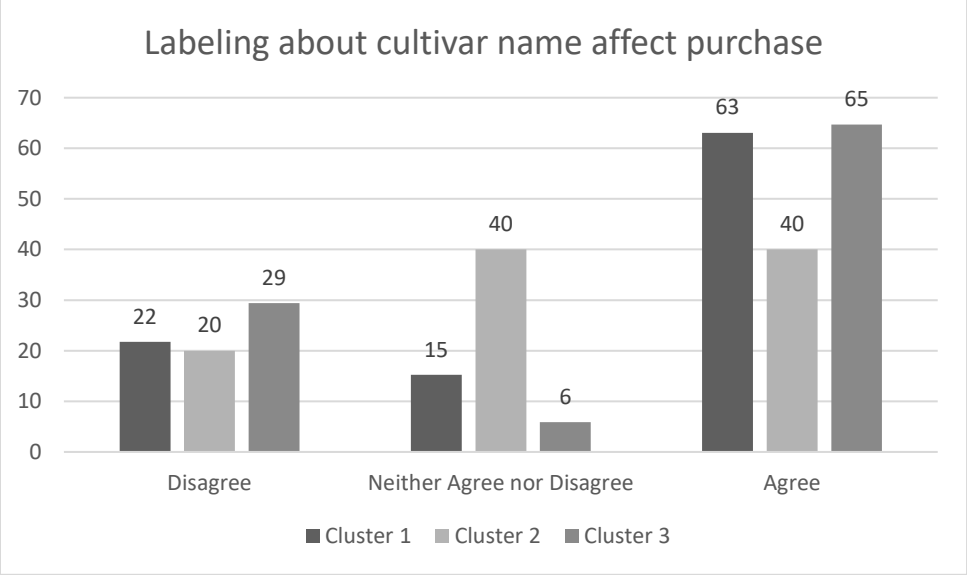


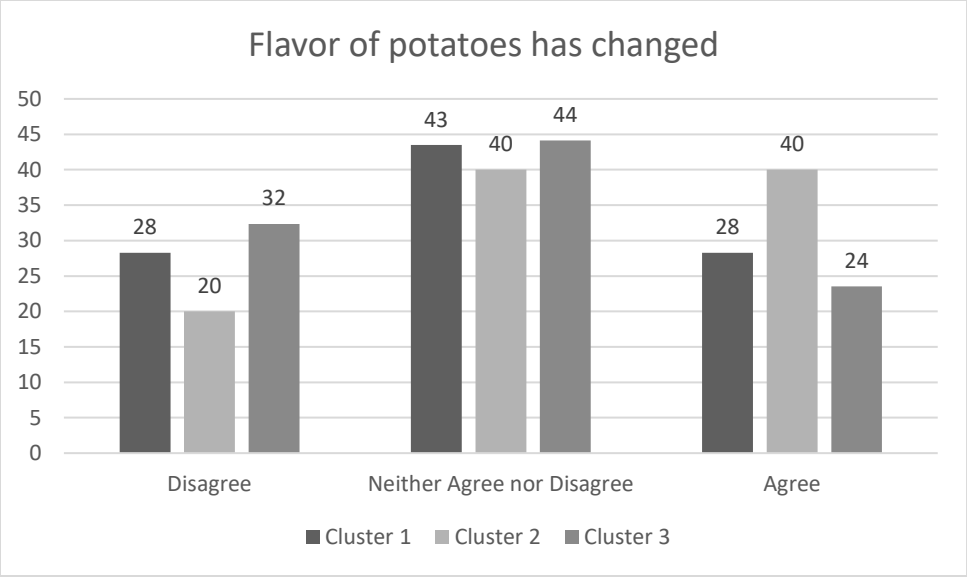
Relation of attitude and beliefs to obtained potato consumer segments

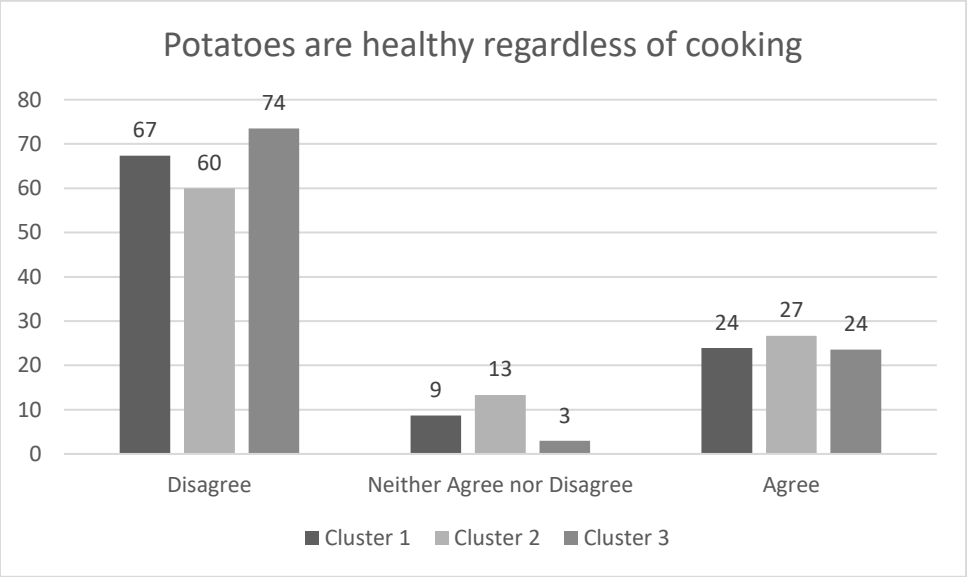


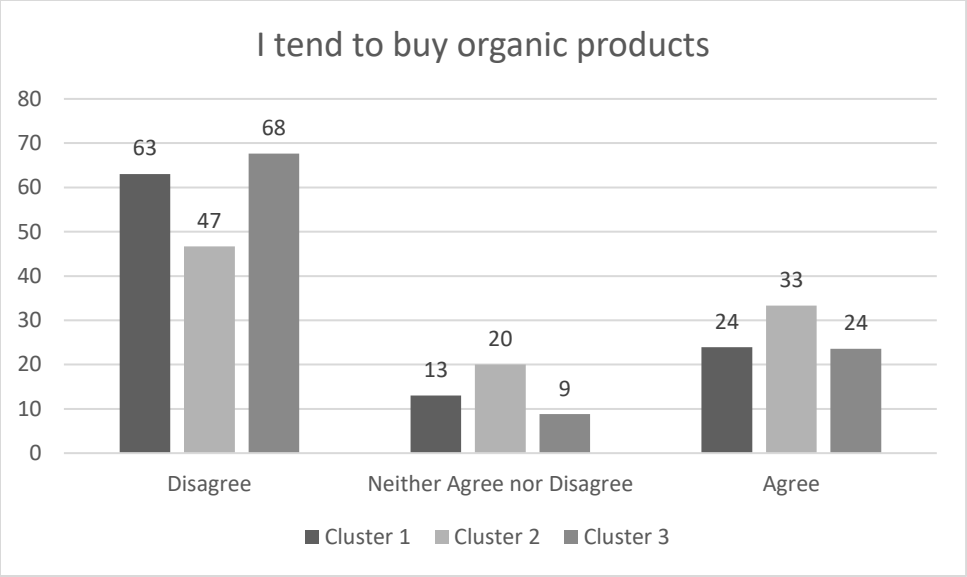


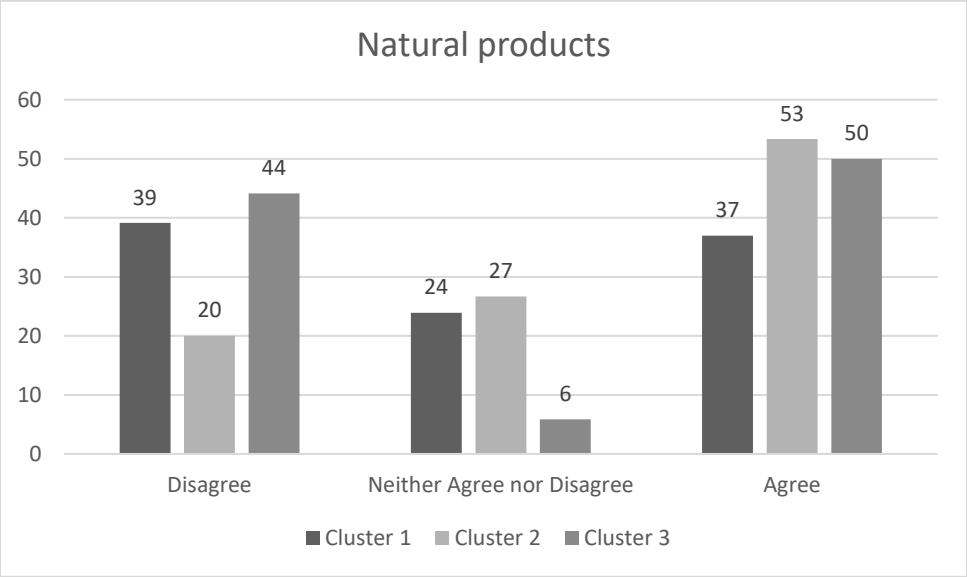

Labeling about origin affect purchase
60
50
40
30
20
10
0
48
47
26
15
13
21
37
40
53
Disagree
Neither Agree nor Disagree
Agree
Cluster 1
Cluster 2
Cluster 3

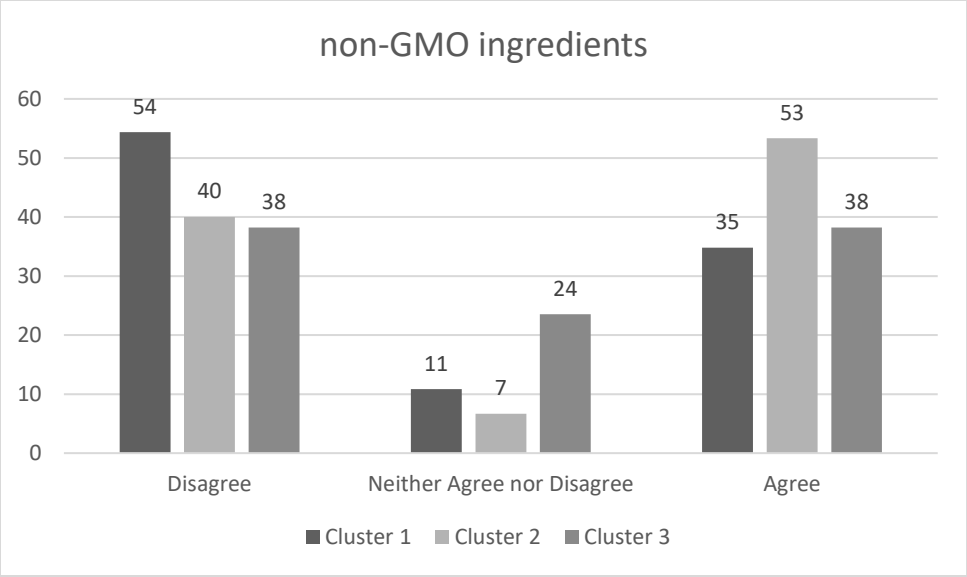

Labeling about cultivar name affect purchase
70
60
50
40
30
20
10
0
22
20
29
15
40
6
63
40
65
Disagree
Neither Agree nor Disagree
Agree
Cluster 1
Cluster 2
Cluster 3

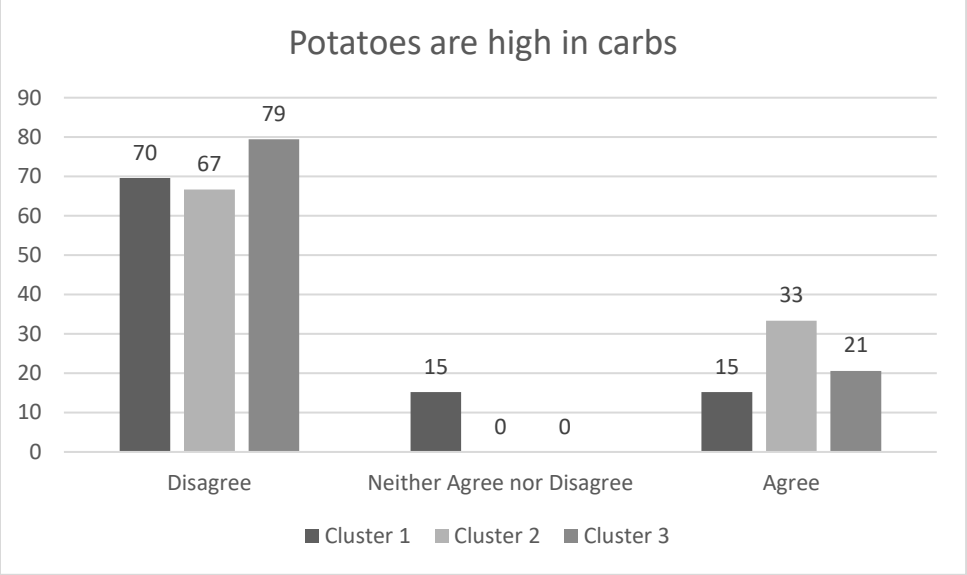

Flavor of potatoes has changed
50
45
40
35
30
25
20
15
10
5
0
28
20
32
43
40
44
28
40
24
Disagree
Neither Agree nor Disagree
Agree
Cluster 1
Cluster 2
Cluster 3


Potatoes are healthy regardless of cooking
80
70
60
50
40
30
20
10
0
67
60
74
9
13
3
24
27
24
Disagree
Neither Agree nor Disagree
Agree
Cluster 1
Cluster 2
Cluster 3


I tend to buy organic products
80
70
60
50
40
30
20
10
0
63
47
68
13
20
9
24
33
24
Disagree
Neither Agree nor Disagree
Agree
Cluster 1
Cluster 2
Cluster 3

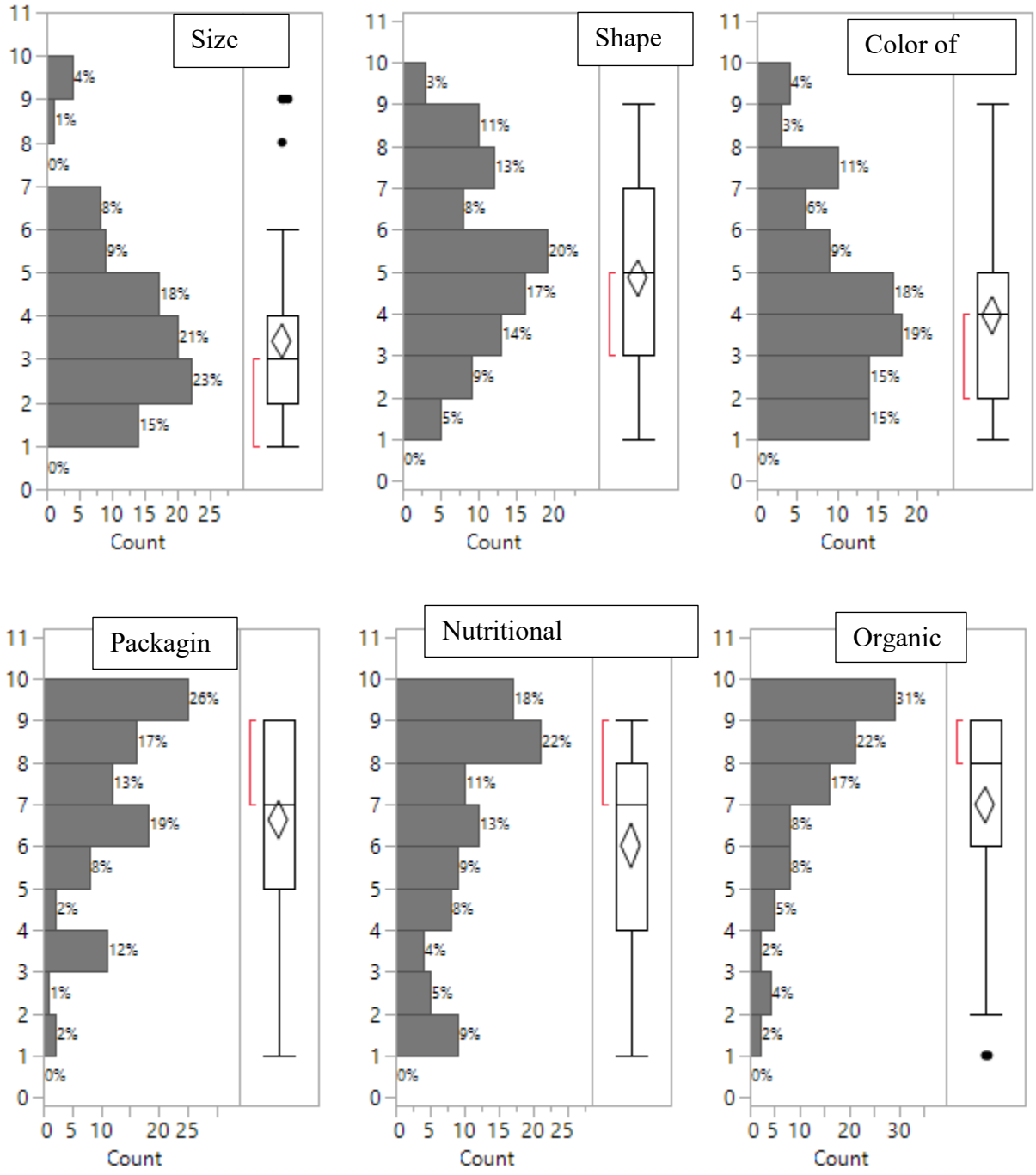

Natural products
60
50
40
30
20
10
0
39
20
44
24
27
6
37
53
50
Disagree
Neither Agree nor Disagree
Agree
Cluster 1
Cluster 2
Cluster 3

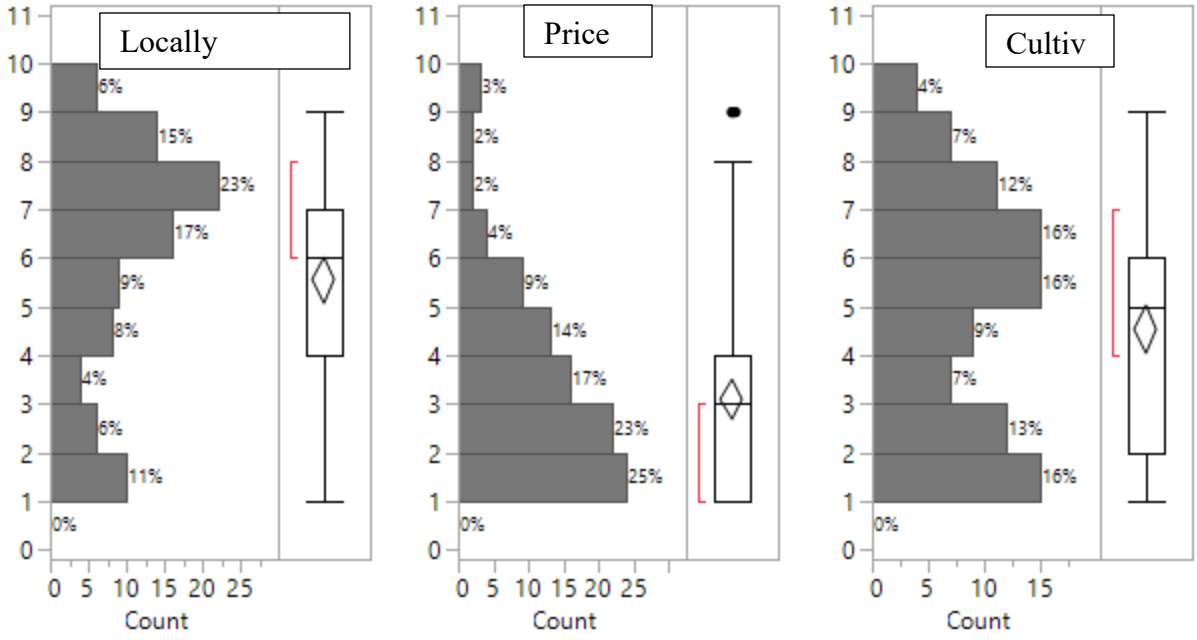

non-GMO ingredients
60
50
40
30
20
10
0
54
40
38
11
7
24
35
53
38
Disagree
Neither Agree nor Disagree
Agree
Cluster 1
Cluster 2
Cluster 3


Potatoes are high in carbs
90
80
70
60
50
40
30
20
10
0
70
67
79
15
0
0
15
33
21
Disagree
Neither Agree nor Disagree
Agree
Cluster 1
Cluster 2
Cluster 3

Factors influencing potato purchase decisions

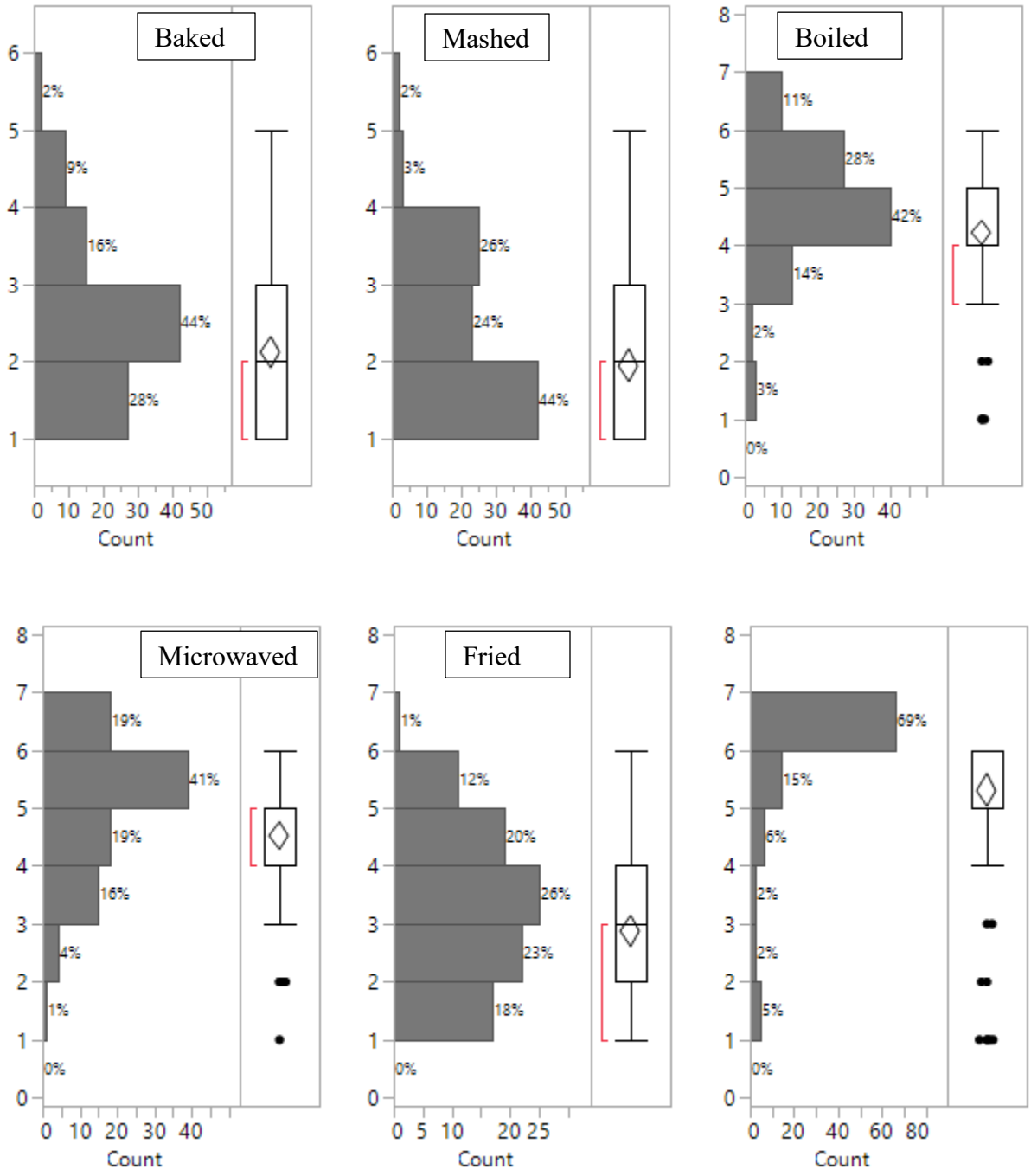
Fig. Distribution of respondents with respect to factors influencing purchase decision ($N = 96$)




Locally
6%
15%
23%
17%
9%
8%
4%
6%
11%
0%
0 5 10 15 20 25
Count
Price
3%
2%
2%
4%
9%
14%
17%
23%
25%
0%
0 5 10 15 20 25
Count
Cultiv
4%
7%
12%
16%
16%
9%
7%
13%
16%
0%
0 5 10 15
Count

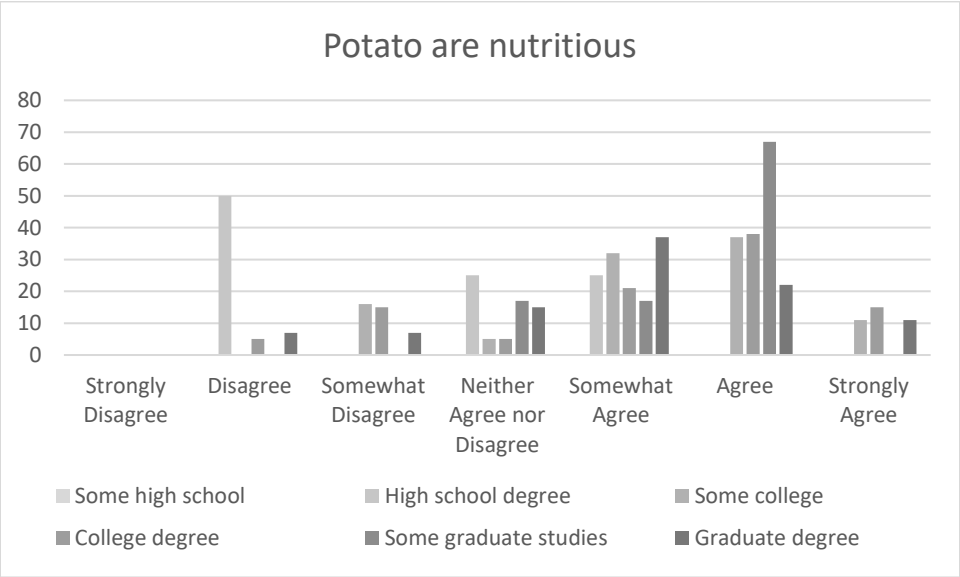
Favorite potato preparation methods

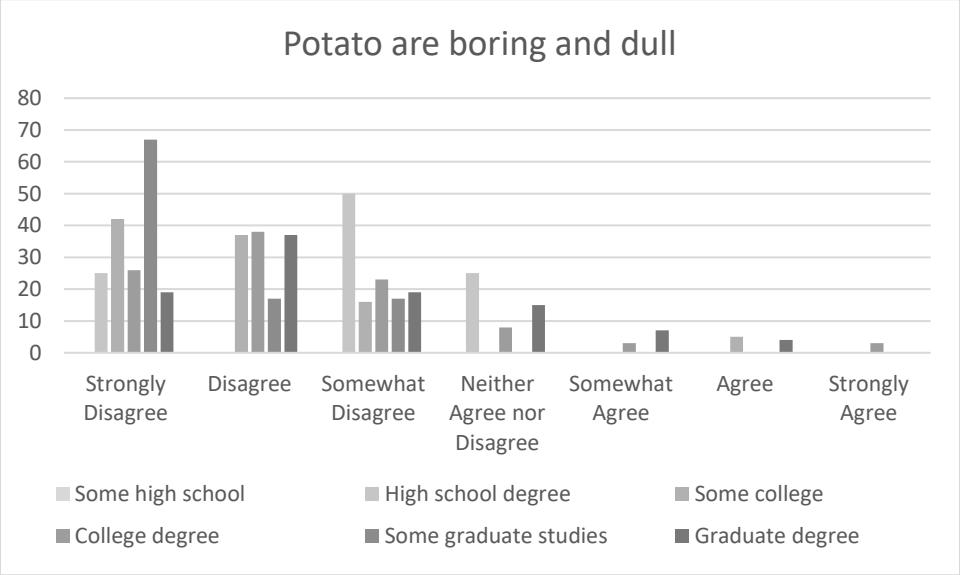
Fig. Distribution of respondents with respect to favorable potato preparation methods ($N = 96$)

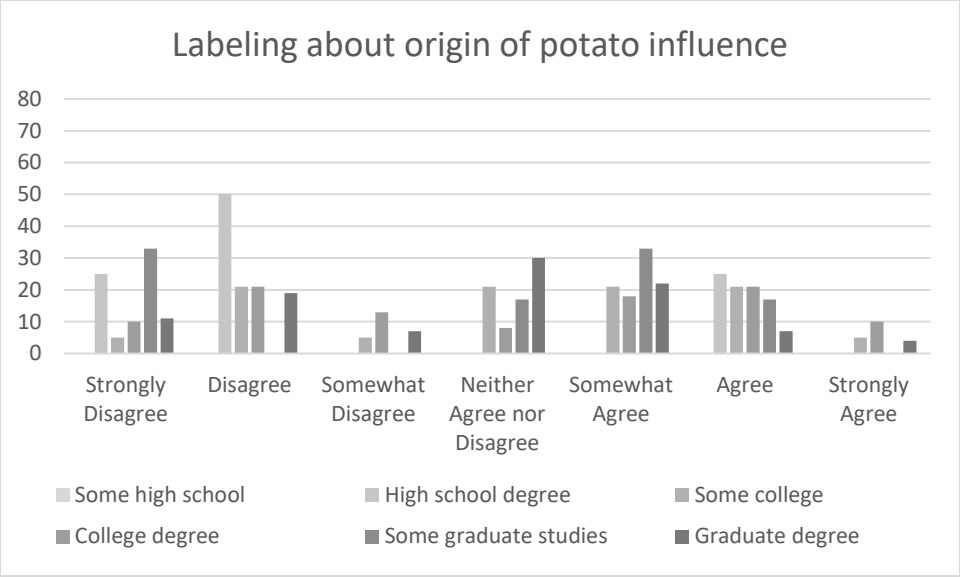


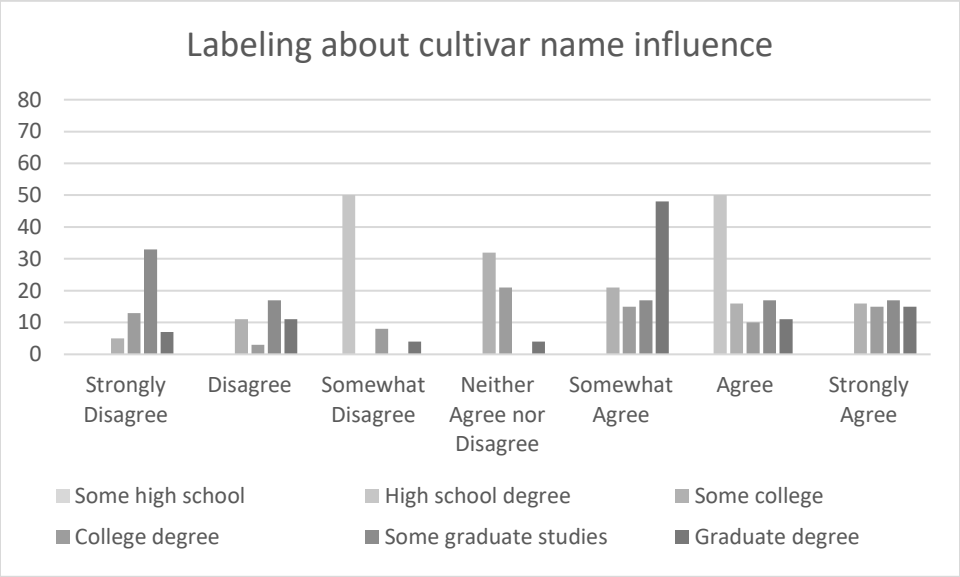
Impact of education level on potato consumer attitudes and/or opinions

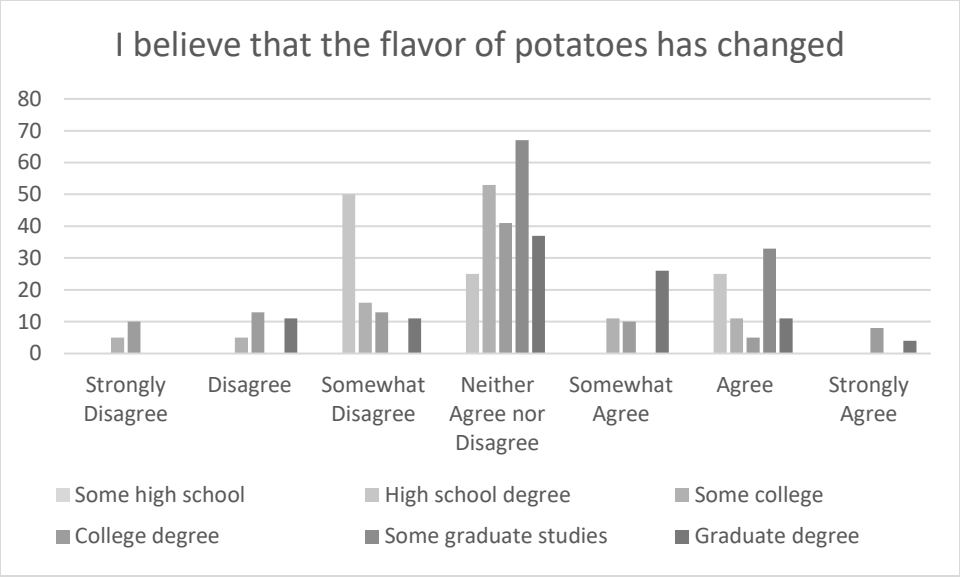
Fig. Attitudes and beliefs with respect to education level of respondents ($N = 95$)

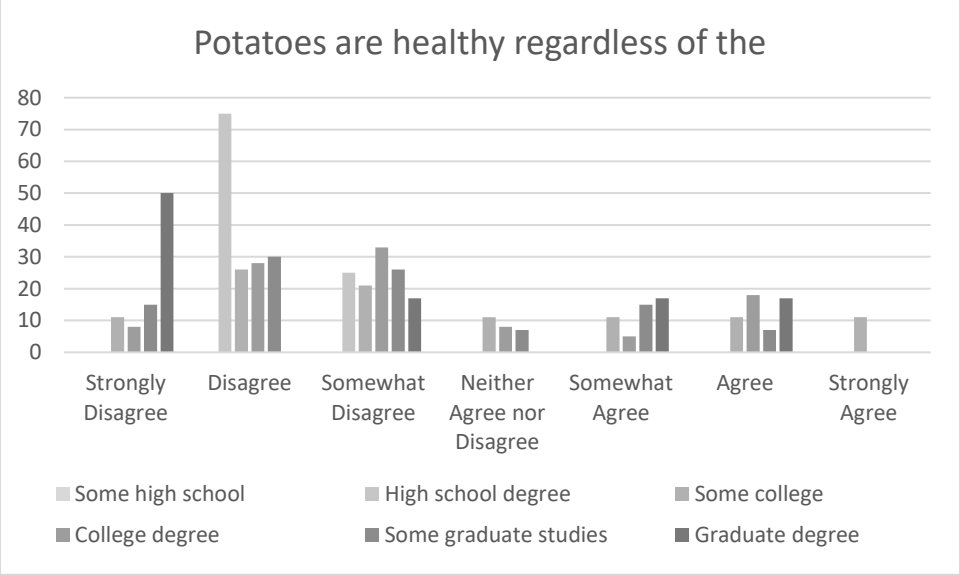


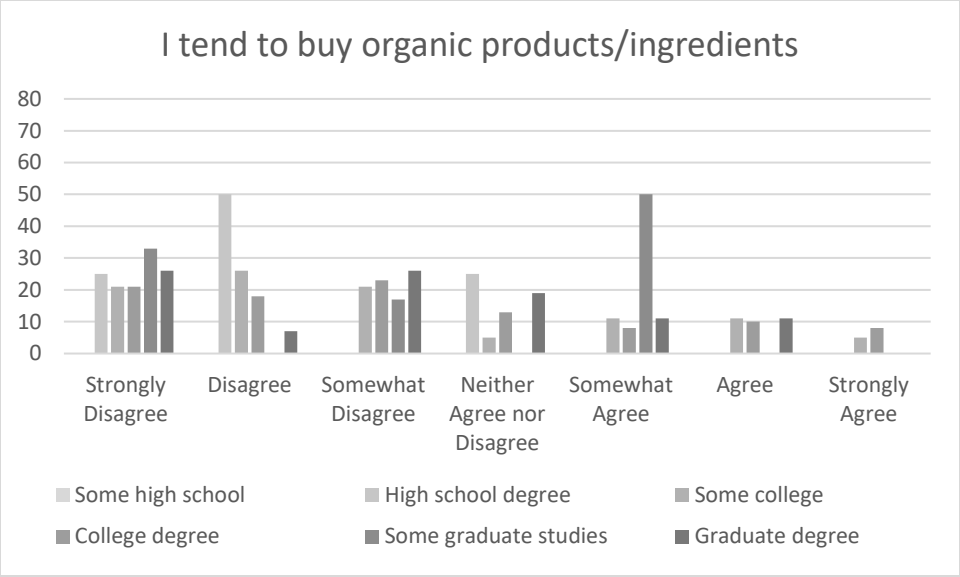


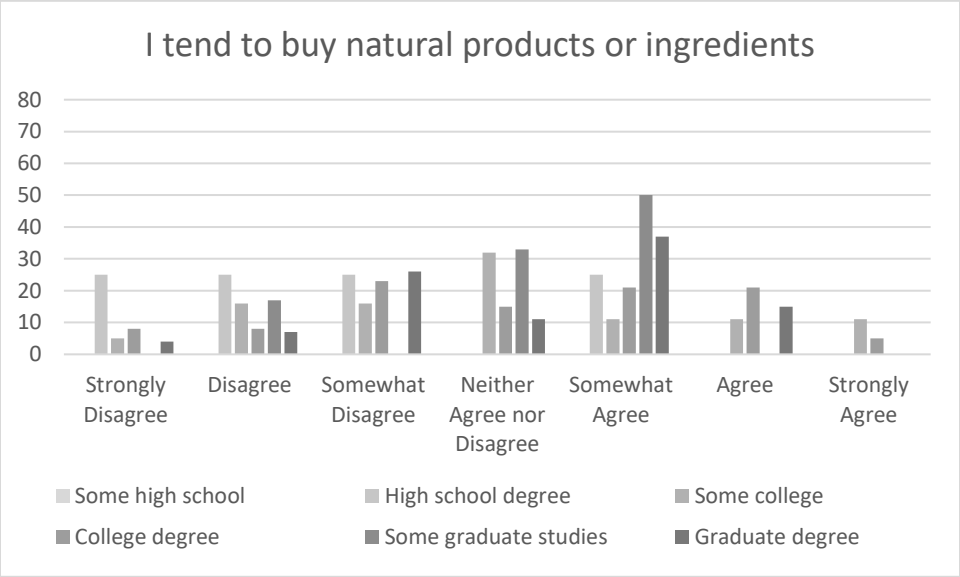

Labeling about origin of potato influence
80
70
60
50
40
30
20
10
0
Strongly Disagree
Disagree
Somewhat Disagree
Neither Agree nor Disagree
Somewhat Agree
Agree
Strongly Agree
Some high school
High school degree
Some college
College degree
Some graduate studies
Graduate degree

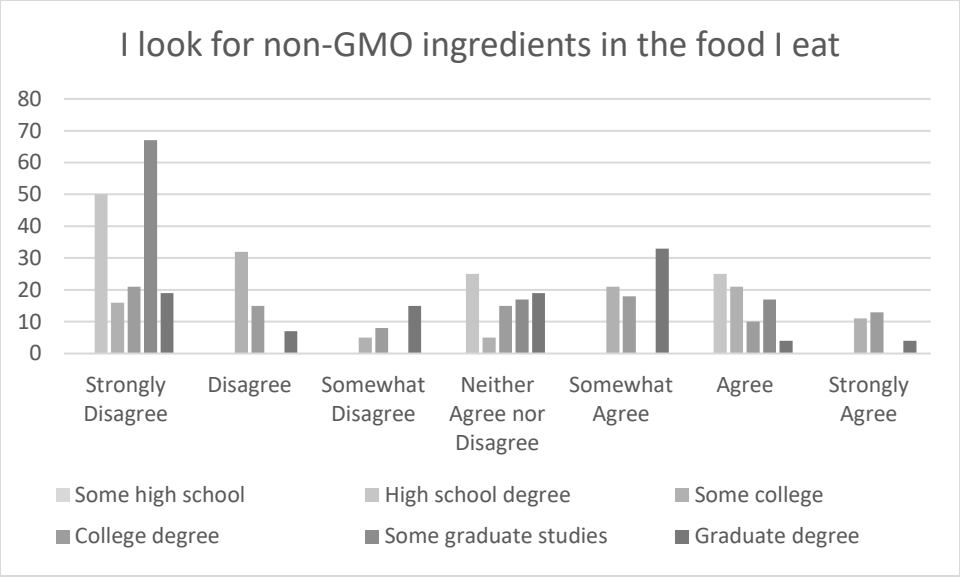

Labeling about cultivar name influence
80
70
60
50
40
30
20
10
0
Strongly Disagree
Disagree
Somewhat Disagree
Neither Agree nor Disagree
Somewhat Agree
Agree
Strongly Agree
Some high school
High school degree
Some college
College degree
Some graduate studies
Graduate degree

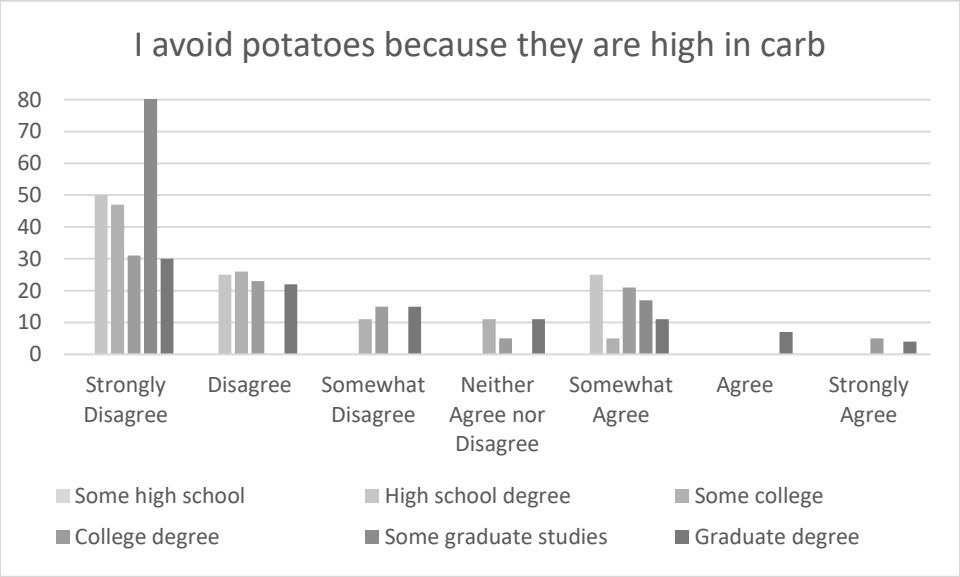

I believe that the flavor of potatoes has changed
80
70
60
50
40
30
20
10
0
Strongly Disagree
Disagree
Somewhat Disagree
Neither Agree nor Disagree
Somewhat Agree
Agree
Strongly Agree
Some high school
High school degree
Some college
College degree
Some graduate studies
Graduate degree


Potatoes are healthy regardless of the
80
70
60
50
40
30
20
10
0
Strongly Disagree
Disagree
Somewhat Disagree
Neither Agree nor Disagree
Somewhat Agree
Agree
Strongly Agree
Some high school
High school degree
Some college
College degree
Some graduate studies
Graduate degree


I tend to buy organic products/ingredients
80
70
60
50
40
30
20
10
0
Strongly Disagree
Disagree
Somewhat Disagree
Neither Agree nor Disagree
Somewhat Agree
Agree
Strongly Agree
Some high school
High school degree
Some college
College degree
Some graduate studies
Graduate degree


I tend to buy natural products or ingredients
80
70
60
50
40
30
20
10
0
Strongly Disagree
Disagree
Somewhat Disagree
Neither Agree nor Disagree
Somewhat Agree
Agree
Strongly Agree
Some high school
High school degree
Some college
College degree
Some graduate studies
Graduate degree


I look for non-GMO ingredients in the food I eat
80
70
60
50
40
30
20
10
0
Strongly Disagree
Disagree
Somewhat Disagree
Neither Agree nor Disagree
Somewhat Agree
Agree
Strongly Agree
Some high school
High school degree
Some college
College degree
Some graduate studies
Graduate degree


I avoid potatoes because they are high in carb
80
70
60
50
40
30
20
10
0
Strongly Disagree
Disagree
Somewhat Disagree
Neither Agree nor Disagree
Somewhat Agree
Agree
Strongly Agree
Some high school
High school degree
Some college
College degree
Some graduate studies
Graduate degree

Attitude of Kansas-City potato consumers towards potatoes

Table Belief and attitudes inquiring of Kansas City respondents ($N = 95$)

Statements	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
Potatoes are nutritious.	--	6.32	11.58	9.47	27.37	33.68	11.58
Potatoes are boring and dull.	29.47	34.74	21.05	8.42	3.16	2.11	1.05
Labeling about origin (like Idaho, Colorado etc.) of potatoes influence my purchase decision.	11.58	20.00	8.42	16.84	20.00	16.84	6.32
Labeling about cultivar name (like Russet Norkotah, Snowden etc.) on the package influence my purchase decision.	10.53	7.37	6.32	15.79	31.58	13.68	14.74
I believe that the flavor of potatoes has changed historically.	5.26	9.47	13.68	43.16	13.68	10.53	4.21
Potatoes are healthy regardless of the cooking method.	12.63	28.42	27.37	7.37	9.47	12.63	2.11
I tend to buy organic products/ingredients.	23.16	16.84	22.11	12.63	11.58	9.47	4.21
I tend to buy natural products or ingredients.	6.32	10.53	21.05	17.89	25.26	14.74	4.21
I look for non-GMO (Genetically Modified Organisms) ingredients in the food I eat.	23.16	14.74	8.42	14.74	21.05	9.47	8.42
I avoid potatoes because they are high in carbohydrates.	37.89	22.11	12.63	7.37	14.74	2.11	3.16

Table Belief and attitudes inquiring of Kansas City respondents ($N = 95$)

Statements	**Disagree**	**Neither Agree nor Disagree**	**Agree**
Potatoes are nutritious.	17.90	9.47	72.63
Potatoes are boring and dull.	85.26	8.42	6.32
Labeling about origin (like Idaho, Colorado etc.) of potatoes influence my purchase decision.	40.00	16.84	43.16
Labeling about cultivar name (like Russet Norkotah, Snowden etc.) on the package influence my purchase decision.	24.22	15.79	60.00
I believe that the flavor of potatoes has changed historically.	28.41	43.16	28.42
Potatoes are healthy regardless of the cooking method.	68.42	7.37	24.21
I tend to buy organic products/ingredients.	62.11	12.63	25.26
I tend to buy natural products or ingredients.	37.9	17.89	44.21
I look for non-GMO (Genetically Modified Organisms) ingredients in the food I eat.	46.32	14.74	38.94
I avoid potatoes because they are high in carbohydrates.	72.63	7.37	20.01