

Differentiation of potato samples using a modified High Identity Traits (HITS) method is greater
with trained panels than untrained

by

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Abstract

Descriptive Sensory Analysis uses a highly trained panel of assessors to develop detailed profiles of products based on their appearance, aroma, flavor, and/or texture. These comprehensive product profiles can be important to product development and quality control processes, but long lists of attributes may not be necessary for preliminary research and development decision-making. An alternative method previously was developed to create simplified product profiles centered on no more than five High Identity Traits (HITS), or characteristics that are most important to the identity of a sample. This research examined two different applications of a modified HITS method. The goal of the first study was to determine which of five cooking methods best facilitates the differentiation of potato varieties by descriptive analysis. Five potato varieties were each prepared using boiling, mashing, baking, deep frying, and air frying methods. Six, highly trained panelists evaluated the aroma, flavor, and texture of each sample to develop a list of up to five HITS. Additionally, panelists scored each sample for Degree of Difference (DOD) from a control. Based on the HITS profiles and DOD scores, mashing, baking, and air frying methods were all effective in differentiating the samples, while frying and boiling methods introduced too much variation and are not recommended for future descriptive studies. The objective of the second study was to find out if an untrained consumer panel could provide similar sensory profiles to a highly trained panel using the modified HITS method. Based on the results from the first study, an untrained panel of six consumers evaluated five potato varieties cooked by mashing, baking, and air frying. The consumers developed HITS profiles and rated each sample for DOD. The results of this panel were compared to the mashed, baked, and air fried results from the first study. The consumer panel was able to identify differences and some of the same traits as the trained assessors, but did

not develop similar sensory profiles overall. While the highly trained assessors were able to identify complex aroma and flavor traits, the consumers focused mainly on texture, which prevented them from finding more subtle product differences. The results of these studies show that a highly trained descriptive panel can use HITS profiles to differentiate products, which can help cut time and costs when making preliminary decision regarding sensory characteristics.

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Chapter 1 - Literature Review

Descriptive Sensory Analysis

Trained vs. Untrained Panelists

Descriptive Sensory Analysis has been defined as a class of methods that identify and “quantify the perceived intensities of the sensory characteristics of a product” (Lawless and Heymann, 2010). These methods use highly trained panels of assessors to develop comprehensive product profiles based on appearance, aroma, flavor, and/or texture attributes. However, highly trained panelists can be costly to obtain and time-consuming to properly train. Previous studies have been conducted to explore the possibility of using untrained or semi-trained panels to carry out sensory analysis methods to cut costs and save time on training. Chambers, *et al.* (2004) looked at how different amounts of training time (4 h, 60 h, and 120 h) affected the discrimination abilities of a descriptive panel. The study found that panelists can detect product differences with limited training, but that the differentiation was mainly limited to texture attributes and some flavor attributes for the pasta sauces evaluated. The research concluded that higher levels of training would increase panelists’ discrimination abilities and decrease variability among the assessors, but that more training may not be necessary if minimal information about product differences is needed. Similar conclusions were made by Chambers, *et al.* (1981), which tested the effects of different experimental designs on highly trained and semi-trained panelists. The study found that while the semi-trained panel was able to find sample differences, the highly trained panelists were more consistent in their attribute scoring, especially for flavor characteristics. Both previously mentioned studies found that texture attributes were easier for panelists with lower levels of training to identify and differentiate than more complex flavor attributes.

The discrimination efficiency of untrained panelists was also studied by Chollet (2001), who looked at the effect of training on assessors' abilities to perform various tasks related to the differentiation of beer samples. The study found that the effect of training largely depended on the type of task performed. Untrained panelists were able to match beer sensory profile descriptions to samples just as well as trained panelists. During a descriptive communication task, the untrained panelists were able to describe differences somewhat effectively but used far less complex and precise language than the trained assessors. These results imply that certain methods can be developed that cater to the abilities of untrained or semi-trained panelists to generate relevant research outcomes. Guerrero, *et al.* (1997) compared the descriptive sensory profiles of toasted almonds developed by highly trained and semi-trained panelists. In this case, the trained panelists each had six years of experience in descriptive analysis methods, while the semi-trained panelists only received a total of forty-eight hours of training. Again, the results indicated that panelists with less training develop "less specific, and, sometimes, ambiguous and redundant" attributes, but the researchers also concluded that the resulting profiles were more or less the same between the two panels.

Instead of allowing the panelists to develop their own attributes, a 1994 study by Roberts and Vickers provided three panels with different experience levels with a pre-existing list of cheese attributes and compared the attribute intensity scores. The study found that the attribute intensities were different between trained and untrained panelists, with both trained descriptive panelists and trained dairy judges rating cheese attributes as less intense than an untrained panel. Despite the differences in intensity, Roberts and Vickers concluded that the sizes of intensity differences among samples found by the trained and untrained panels were not very different.

Overall, most of the studies comparing trained and untrained or semi-trained panels found that the terms or descriptions provided by assessors with less training were less precise and complex than their highly trained counterparts, but that the assessors with less training were still able to identify differences among samples.

Alternative Descriptive Methods

In an attempt to overcome the cost and time limitations of conducting a descriptive panel, several alternative methodologies have been developed that provide more rapid results and can be completed by panelists with little to no training. Some novel methods that can help categorize products more rapidly include sorting, flash profiling, projective mapping, and check-all-that-apply, or CATA, questioning (Varela and Ares, 2012). Varela and Ares looked at applications of the listed methods and compared advantages and limitations for each. Ultimately, the review stated that alternative methods are most effective for gathering general sensory information as a preliminary step in a research process.

Flash profiling is a commonly used method and its ability to differentiate products based on panelist-generated profiles in combination with product ranking has been widely studied, with several studies comparing the method to both traditional descriptive analysis and other alternative methods. A recent study by Liu, *et al.* (2018) compared a Flash Profile method to Modified Flash Profiling, Free Choice Profiling, and a conventional descriptive panel for evaluating red wines. The researchers concluded that all three alternative methods provided similar results to the descriptive panel. It is worth noting, though, that the conventional descriptive panelists received less than twelve total hours of training prior to evaluation, so the results may not provide a fair comparison for drawing conclusions. Albert, *et al.* (2011) compared Flash Profiling to Quantitative Descriptive Analysis (QDA) and projective mapping to

compare the profiles of fish nuggets. Again, the study concluded that the profiles from all three methods were well correlated with each other and that Flash Profiling is a viable, rapid alternative to traditional descriptive methods, such as QDA. Flash Profile methods were compared to conventional descriptive analysis in two other studies: Delarue and Sieffermann, 2004 and He and Chung, 2019. Delarue and Sieffermann found the comparison of methods to depend on the product category evaluated. For yogurts, the sensory spaces were almost identical between the two methods but were slightly different for apricot cheeses. The study by He and Chung concluded that the Flash Profile method could be a suitable, rapid alternative, but also cautioned that QDA still resulted in more detailed profiles that could be easier to replicate due to the highly trained panel.

Another frequently studied rapid methodology is Temporal Dominance of Sensations, or TDS. TDS involves having assessors identify and quantify dominant sensations as they appear throughout the evaluation of a product. Multiple studies have compared the results of TDS methods with untrained consumers to more conventional descriptive profiling methods with highly trained panelists. Albert, *et al.* (2012) used fish stick samples to compare TDS to key-attribute profiling and found that both methods produced similar sensory profiles. Given the similarities, the researchers recommend using a TDS method because it allows documentation of how the sensory profile may change over time, while not requiring any additional training. A 2009 study by Labbe, *et al.* made similar conclusions to the Albert, *et al.* study based on comparisons between TDS and sensory profiling. By comparing TDS to QDA, Oliver, *et al.* (2018) made a case for conventional descriptive analysis over the rapid method. The study still found that both methods provided similar profiles, but also concluded that the highly trained

QDA panel was able to more accurately describe complex flavor attributes while covering the entire product profile instead of just dominant attributes.

While recent studies have found that flash profiling and TDS procedures provide similar profiles to traditional descriptive methods, these alternative methods still present limitations. Flash profiling allows assessors to develop their own individual attribute lists, so the sample descriptions can vary widely and be difficult to interpret (Varela and Ares). Additionally, the samples must be evaluated simultaneously to allow ranking based on the developed attribute list, so the entire procedure would need to be repeated for additional samples (Delarue and Sieffermann). Despite alternative methods becoming more rapid, they can still involve a long list of complex sensory attributes. Pineau, *et al.* (2012) looked at how many attributes are actually selected by assessors during a TDS evaluation and found that they, on average, only use four different attributes to describe the dominant sensations of a product over time. Overall, there are advantages and limitations for any sensory method and researchers should always consider their project objectives carefully before choosing a method.

High Identity Traits

High Identity Traits (HITS) profiling was developed by Talavera-Bianchi, *et al.* (2010) to help differentiate products using more simplified lists of attributes, with no more than five traits to describe each sample. Talavera-Bianchi, *et al.* compared the HITS profiles developed by a trained panel to the results of a detailed descriptive analysis and found that while the sensitivity of the HITS method is reduced, the panel was still able to find differences and classify products effectively. These results are similar to those from studies with other alternative methods, but most other rapid methods use an untrained or semi-trained panel. Since this previous application of the HITS method was performed with a highly trained panel, it would be worth exploring if

similar results can be obtained using an untrained consumer panel to help save time and money on training sessions and compete with other alternative methods.

Sample Preparation

When evaluating the sensory profiles of different varieties of a product, it is important to keep all other factors the same, so that any differences found in sensory properties can be attributed to true differences among the samples. Controlling the preparation of samples for sensory evaluation can be key in reducing bias (Lawless and Heymann, 2010). Therefore, it is often necessary to choose only one preparation method for all samples that will provide the best opportunity to find significant differences. The decision about which preparation method to use may need to be facilitated by previous research or a preliminary study to test the options. Examples of preliminary studies have been carried out using products such as coffee and green tea (Sanchez and Chambers 2015; Lee and Chambers 2009). Sanchez and Chambers tested four different coffee preparation methods to determine which one would provide the best differentiation among coffee varieties. While a drip brewing method was found to discriminate the samples the most, the researchers ultimately concluded that the preparation method chosen should rely on the project objectives. There were no previous studies found to test the best cooking method for differentiation of potatoes.

Potatoes

U.S. Production and Consumption

Potatoes are the most consumed vegetable in the United States, with a per capita value in 2016 of about 46 lbs and almost half of the consumption coming in the form of fresh potatoes. This is 16 lbs more than the per capita consumption of the second vegetable on the list, tomatoes (USDA ERS, 2018). Additionally, according to the National Potato Council (2018), the United

States ranks as one of the world's top five producers of potatoes, coming in at just under 20 million tons in 2016. With both high rates of production and consumption, potatoes are likely to remain a staple of American diets for many years to come, so it is worth understanding their sensory profiles to help inform decisions about production, processing, marketing, and usage.

With over 200 varieties sold in the U.S., there is a wide range of textures, flavors, and aromas that exist among potatoes (Potatoes USA). However, a much narrower range is generally available to consumers in food markets and grocery stores, allowing many Americans the opportunity to develop preferences for one variety over another. A 2010 study by Greenway, *et al.* looked at the preferences for common potato varieties across nine U.S. census regions. Demand for Yukon Gold potatoes was highest in the New England region, Russet potatoes were most preferred in the East South Central region by states such as Alabama and Tennessee, and states such as Kansas, Nebraska, and Minnesota prefer Red potatoes.

Effects on Sensory Characteristics

Since so many varieties of potatoes exist with a wide range of sensory characteristics, it is important to understand how factors such as growing location, storage conditions, or cooking method can affect the overall sensory profile. Descriptive sensory analysis can be utilized to help measure the individual texture, flavor, and aroma attributes of each of the potato varieties to create complete sensory profiles. This allows for the categorization of varieties into groups with similar characteristics, which can provide a lot of valuable information to both producers and consumers. Previous research has been done to determine what factors affect the sensory properties of potatoes, but much of the research focuses on defects or off-flavors that can potentially affect potato quality or consumer health. Blanda, *et al.* (2010) used QDA, along with analytical methods, to identify sensory attributes and volatile compounds commonly categorized

as off-aromas and flavors in boiled potatoes. Potato samples were subjected to a variety of treatment conditions and evaluated for attributes such as ‘Cardboard-like off-odour’, ‘Hardness’, and ‘Mealiness.’ A study by Mestdagh, *et al.* (2008) was one of many that investigated the acrylamide formation in potatoes during frying. This study looked at how chemical pre-treatments used to decrease acrylamide formation can affect the sensory properties of fried potato chips. The QDA-trained panel found significant differences among the sensory attributes for some of the pre-treatment methods, so potato profiles can be affected by outside sources during preparation or cooking.

Another category of potato sensory study involves relating sensory data to analytical measurements such as moisture content or hardness. Alvarez, *et al.* (2011) looked at the effect of adding olive oil to mashed potatoes on the texture. A texture analyzer was used for the analytical measurements, and a four-person, highly trained descriptive panel evaluated the sensory properties. Since the focus was on moisture, the panelists evaluated attributes such as ‘Stickiness’, ‘Denseness’, and ‘Firmness’ and found that the addition of olive oil resulted in the decrease in intensity of most of the texture characteristics.

The sensory properties of potatoes can be greatly affected by growing locations and growing conditions. Jansky (2008) compared the sensory properties of baked potatoes for thirteen different cultivars grown in four different locations in Wisconsin. Among the thirteen varieties were two Russet samples, which can help validate the discrimination abilities of the sensory method used. The panel found that the Russet Burbank sample was mealier than the Russet Norkotah and that the Russet Norkotah had relatively high potato flavor across all growing locations. The researcher concluded that potato flavor was affected by growing location within the same cultivar, so even potatoes labeled as the same variety could vary in sensory

profile if they were not grown in the same location. A study by Seefeldt, *et al.* (2011) investigated the effect of potato variety, growing location, and cooking preparation on sensory properties. The panel evaluated twenty-six appearance, texture, and flavor attributes across boiling, oven-frying, and mashing methods. The results showed similarities by variety across the cooking methods, but differences by growing location, thus reinforcing the results from Jansky that sensory characteristics can be affected by environmental factors associated with production. The Seefeldt, *et al.* study also suggested that a small set of attributes ('yellow', 'moist', 'adhesiveness', and 'hardness') could be used to produce simplified sensory profiles that are still reliable because they are where most of the differences were found.

Effects Related to Cooking Methods

Depending on whether potatoes are prepared using moist heat cooking methods such as boiling and mashing or dry heat methods such as frying and baking, the sensory profiles can change drastically. For example, a study by Oruna-Concha, *et al.* (2002) found that different cooking methods affected the volatile compounds of potato samples. Potatoes cooked by boiling were higher in lipid-derived compounds, while the baked samples were higher in volatiles associated with Maillard browning and sugar degradation. Since different cooking methods can lead to different sensory profiles, it is important to consider multiple cooking methods when evaluating potato samples by descriptive methods.

There have been previous studies that looked at the effect of different cooking methods for potatoes on sensory properties. Some of the studies choose to stay within a single sample form such as French fries or chips. For example, Giovanelli, *et al.* (2017) compared appearance, aroma, flavor, and texture attributes for two brands of frozen French fries using deep-fat frying, air frying, baking, and microwaving. In addition to some analytical measurements, a nine-person

panel with minimal training evaluated attributes such as ‘Potato’ and ‘Fried’ aromas, ‘Potato’, ‘Oil’, and ‘Defects’ flavors, and ‘Crust Crunchiness’ and ‘Flesh Softness’ textures. The results showed significant effects for French fry type and cooking method, with higher oil flavor for the conventionally deep-fried fries than the other methods. Also, the deep-fried and baked methods resulted in higher oiliness and potato aroma and flavor than the air-fried and microwaved samples. Another study (Teruel, *et al.* 2015) also evaluated full sensory profiles for deep fried French fries versus air fried French fries, comparing the results to several analytical tests. A trained panel found significant differences between the methods for over two-thirds of the attributes, primarily in regards to aroma and mouthfeel as the deep fried potatoes provided higher oily mouth coating.

Comparing the sensory characteristics between deep fried and air fried samples was a common research theme as a third study looked at the effects of the two methods on the acceptability of sweet potato chips (Caetano, *et al.*, 2017). While the study did not use any descriptive sensory methodologies, it is still worth noting that the cooking methods had an effect on consumer liking, with the highest acceptability for the deep fried chips. The largest acceptability differences between deep fried and air fried samples were found for aroma and flavor. Another study that looked at different cooking methods in relation to consumer opinions was carried out by Seefeldt, *et al.* (2011). Recognizing that different potato varieties may be more suitable for different cooking methods, the study compared consumers’ “appropriateness” ratings to descriptive sensory profiles for eleven varieties cooked by boiling, oven frying, and mashing. The results found several varieties that were rated as appropriate for all three cooking methods and determined that the appropriateness was based primarily on the variety being rated highly for attributes such as ‘creamy’, ‘moist’, and ‘sweet.’

The descriptive analysis portion of the previously mentioned study by Seefeldt, *et al.* was further explored in its own paper, also by Seefeldt, *et al.* (2011). Again, this study compared the sensory profiles of eleven potato varieties prepared by three different cooking methods: boiling, oven frying, and mashing. The panel profiled a total of twenty-six appearance, texture, and flavor attributes across the three cooking methods, with some attributes only applying to one cooking method. For example, ‘Hardness’ and ‘Fracturability’ were only rated for boiled samples. While other studies found clear differences in the sensory profiles based on the cooking method, this study found many characteristics to be intrinsic to the potato variety, meaning that they were similarly rated across all three methods. This study was the only one found that discussed the differentiation abilities of the cooking methods, concluding that mashing resulted in less variation than boiling or oven frying and attributing the low variation to the homogenization of the samples’ texture. However, it is worth noting that panelists only participated in three sessions of training before completing the evaluation, so they were not considered highly trained which could decrease the precision of the attribute intensity ratings.

Research Objectives

When characterizing the sensory profiles of foods, like potatoes, it is important to choose a preparation or cooking method that will help highlight the product’s intrinsic properties to maximize differentiation among a set of samples. Therefore, the first objective of this research was to apply a modified High Identity Traits method to determine which cooking method results in the most differences in sensory properties of potato varieties. The results of the first study can then be used to recommend a cooking method for use in future descriptive analysis studies that seek to evaluate differences among potato samples based on variety, growing conditions, or growing location.

The second objective of this research was to determine if a consumer panel with no previous experience in descriptive sensory analysis could develop similar product profiles and differentiation patterns to a highly trained panel using a modified HITS method. Companies are always looking to save time and money by using rapid methods with consumer panels instead of conventional descriptive methods with highly trained panelists. While the HITS method is faster and simpler than traditional tests, the use of a highly trained panel can still be costly and time-consuming. This research can help establish the best way to apply a modified HITS method for maximum differentiation of samples.

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Chapter 2 - Determining which cooking method provides the best sensory differentiation of potatoes

Abstract

There are many different ways to prepare potatoes that each provide a unique set of sensory properties, including aroma, flavor, and texture. However, when a descriptive sensory study is conducted, it is important to utilize a cooking method that will highlight, and not distract, from the sensory differences among potato samples due to factors such as variety or growing conditions. This study aimed to determine which of five cooking methods results in the best differentiation among potato varieties to recommend a single method for use in future descriptive sensory analysis studies. Five different potato varieties were each prepared using boiling, mashing, baking, frying, and air frying methods. The samples were provided to six highly-trained descriptive panelists and evaluated by consensus using a modified High Identity Traits (HITS) method. Panelists evaluated the aroma, flavor, and texture to develop a list of up to five total HITS per sample. Additionally, panelists scored each sample for Degree of Difference (DOD) from control. The intensity of each HIT and DOD were scored on a scale from 0-15 with 0.5 increments. Based on the HITS profiles and DOD scores, mashing, baking, and air frying methods were all effective in differentiating the samples. Frying and boiling methods introduced too much variation and are not recommended for sample differentiation. Ultimately, the method chosen for future research would depend on the study objectives.

Introduction

Potatoes are the most consumed vegetable in the United States, with a per capita value in 2016 of about 46 lbs and almost half of the consumption coming in the form of fresh potatoes.

This is 16 lbs more than the per capita consumption of the second vegetable on the list, tomatoes (USDA ERS, 2018). Additionally, according to the National Potato Council (2018), the United States ranks as one of the world's top five producers of potatoes, coming in at just under 20 million tons in 2016. With both high rates of production and consumption, potatoes are likely to remain a staple of American diets for many years to come.

With over 200 varieties sold in the U.S., there is a wide range of textures, flavors, and aromas that exist among potatoes (Potatoes USA). Descriptive sensory analysis can be utilized to help measure the individual texture, flavor, and aroma attributes of each of the potato varieties to create complete sensory profiles. This allows for the categorization of varieties into groups with similar characteristics, which can provide a lot of valuable information to both producers and consumers. Previous research has been done to determine what factors affect the sensory properties of potatoes, but much of the research focuses on defects or off-flavors that can potentially affect potato quality or consumer health (Blanda, *et al.* 2010; Mestdagh, *et al.* 2008). Another large category of potato sensory studies involves relating sensory data to analytical measurements such as moisture content or hardness (Alvarez, *et al.* 2011; Caetano, *et al.* 2017; Seefeldt, *et al.* 2011). There are fewer studies that explore differences in sensory properties across varieties, but Jansky (2008) compared the sensory properties of baked potatoes for thirteen different cultivars.

While the highlighted research provides valuable insight into the sensory properties of potatoes, most of these studies focused on preparing the samples with only one cooking method. Potatoes are an extremely versatile food and can be prepared in a number of different ways, making the sensory characterization of potatoes much more complex because the sensory properties can be reliant on the cooking method. Cooked potato preparations can include dry heat

transfer methods such as baking, roasting, deep frying, or air frying. These methods are generally accompanied by reactions such as Maillard browning and caramelization, which can affect the exterior texture by making it crisp or affect the flavor by imparting toasted, bitter, or sweet attributes. Additionally, some of these methods involve the use of oil, such as olive or canola, which can draw attention away from the natural flavors or aromas of the potato. Methods such as boiling, mashing, and steaming are moist heat cooking preparations and the use of water can add moistness but may also create an accumulation of starch which can affect the sensory properties.

Since different cooking methods can lead to different sensory profiles, it is important to consider multiple cooking methods when evaluating potato samples. There have been previous studies that looked at the effect of different cooking methods of potatoes on sensory properties but stayed within a single sample form. For example, Giovanelli, *et al.* (2017) compared appearance, aroma, flavor, and texture attributes for French fries using deep-fat frying, air frying, baking, and microwaving. Another study (Teruel, *et al.* 2015) also evaluated full sensory profiles for deep fried French fries versus air fried French fries. Seefeldt, *et al.* (2011) compared twenty-six different attributes across three different cooking methods and forms: boiled, mashed, and oven fried.

When evaluating the sensory profiles of different varieties of a product, it is important to keep all other factors the same, so that any differences found in sensory properties can be attributed to true differences among the samples. Therefore, it is necessary to choose only one preparation method for all samples that will provide the best opportunity to find significant differences. The decision about which preparation method to use may need to be facilitated by previous research or a preliminary study to test the options. Examples of preliminary studies have been carried out using products such as coffee and green tea (Sanchez and Chambers 2015;

Lee and Chambers 2009). There have not been any previous studies conducted to determine the best cooking method for differentiation of potatoes.

The objectives of this study were to determine which cooking method would result in the most differences in sensory properties of potato varieties and to recommend a cooking method for use in future studies comparing the properties of different potato samples.

Materials and Methods

Potato Samples

For this study, five varieties of raw potatoes were purchased from a local grocery store in Manhattan, Kansas. The five varieties were Red, Gold, Petite White, Russet Norkotah, and Russet Burbank. These varieties were chosen for their commercial availability, consumption popularity, and range of sensory properties. Two varieties of Russet potatoes were included to test the sensory method's ability to differentiate between similar samples. After purchase, samples were kept in a cool, dark room in their original packaging. All samples were used within ten days of purchase.

Sample Preparation

Five cooking methods were chosen to represent common commercial and home preparation methods for potatoes. The methods cover both moist and dry heat preparations. The following procedures were followed as written for the Red, Gold, Russet Norkotah, and Russet Burbank varieties. Due to the size of the Petite White potatoes, the skin was not removed prior to cutting the potatoes into slices for the boiled, mashed, fried, and air-fried methods. The skin was removed by hand with a knife as the Petite White slices were reduced to their final form. Boiled, mashed, and baked samples were done cooking when a fork could be easily inserted through the center of the sample, meaning the potato is tender all the way through. A similar method for

determining doneness was also used by Tian, *et al.* (2016). Deionized water was used to rinse and cook samples as needed. The use of ultra-purified water was suggested by Trong, *et al.* (2011) to help prevent additional substances present in water from affecting the properties of the final samples.

Boiled

The skin of each potato was removed using a vegetable peeler, then each potato was rinsed under deionized water to remove any remaining dirt. Each potato was cut into slices using a Vollrath Redco® InstaCut™5.0 countertop food slicer (The Vollrath Company, LLC, Sheboygan, Wisconsin, USA) fit with a ½” stainless steel dicing blade, then the slices were cut down to ½” cubes using a knife. In a large saucepan, 225g of ½” cubes were covered with 600mL of deionized water. The saucepan was covered with a lid and brought to a boil on a gas stovetop. Once boiling, the heat was reduced to a medium simmer and the potato cubes were cooked until a fork could be easily inserted into the center. The pan was then removed from the heat and the water was drained from the cooked cubes. The boiling method was slightly adapted from the procedure followed by Oruna-Concha, *et al.* (2002).

Mashed

The potatoes were prepared and diced into ½” cubes according to the method used for the boiled potato samples. In a large saucepan, 450g of ½” cubes were covered with 800mL of deionized water. The saucepan was covered with a lid and brought to a boil on a gas stovetop. Once boiling, the heat was reduced to a medium simmer and the potato cubes were cooked until a fork could be easily inserted into the center. The pan was then removed from the heat and the cooked cubes were drained, reserving the cooking water. The cooked potatoes were pressed through a potato ricer (OXO, New York City, New York, USA) into a bowl. 35mL of the

reserved cooking water was added and the potatoes were stirred with a fork until smooth and consistent in texture.

Baked

Potatoes of similar size were chosen for each variety. The outside of each potato was scrubbed with a sponge to remove dirt from the skin, then each potato was thoroughly dried with a clean cloth. Two opposite sides of each potato were punctured ½” deep to allow for steam to escape. Next, the potatoes were individually wrapped in foil. All potatoes of the same variety were placed on a single baking sheet and baked at 425F (218C) until a fork could be easily inserted into the center. The potatoes were removed from the oven, left to cool slightly, and then unwrapped. The flesh of each potato was scooped out of the skin using a spoon and cut into ½” cubes.

Fried

The skin of each potato was removed using a vegetable peeler, then each potato was rinsed under deionized water to remove any remaining dirt. Each potato was cut into slices using a countertop food slicer fit with a ½” stainless steel dicing blade. Using only slices that were cleanly cut on all four sides, the slices were cut into 2” long pieces with squared off edges. The slices were soaked in deionized water for 30 minutes at room temperature. After soaking, the pieces were drained and the surface of each slice was dried with paper towels. Canola oil was heated in a 6-quart countertop, electric deep fryer (National Presto Industries, Inc., Eau Claire, Wisconsin, USA) to 275F (135C) and the potato slices were fried in batches of 15 pieces for 5 minutes. After the pieces were removed and drained, the temperature of the oil was increased to 350F (176C) and the slices were fried for a second time until golden brown in color. No more

than two samples were fried in a single batch of oil to prevent too much flavor transfer between samples.

Air Fried

The potatoes were prepared, cut, and soaked according to the method used for deep frying. After the slices were removed from soaking and dried, they were evenly coated with 5mL of canola oil. The coated slices were arranged with even spacing on a copper-coated crisping tray and baked in a 425F (218C) oven until golden brown in color.

Table 2.1 Approximate cooking times per method for each potato variety.

	Boiled	Baked	Fried	Mashed	Air Fried
Red	19 min	50 min	5 1/2 min	19 min	32 min
Russet Burbank	13 min	45 min	6 min	13 min	30 min
Russet Norkotah	15 min	45 min	6 1/2 min	15 min	30 min
Gold	21 min	50 min	6 min	21 min	32 min
Petite White	23 min	35 min	5 1/2 min	23 min	32 min

Sensory Evaluation

The potato samples were evaluated by six, highly trained panelists from the Center for Sensory Analysis and Consumer Behavior at Kansas State University in Manhattan, KS, USA. The panelists all received a minimum of 120 h of general descriptive sensory analysis training prior to completing this panel. The first two days of the panel consisted of 90-minute orientation sessions to introduce the method and familiarize the panelists with the types of samples they would be evaluating. Then, the panel completed five days of evaluation, with one type of cooking method being presented each day.

Samples were labeled with random, three-digit blinding codes and were served one at a time according to a Latin Square design, so that each potato variety appeared in each serving

position once over the five days. The samples were served in the following amounts: 8-10 cubes for boiled and baked methods, 65 g for the mashed method, and 3 pieces for deep fried and air fried methods. All samples were served in 4oz glass jars covered with watch glasses. The glass jars were placed on top of heated tiles in metal trays to maintain a serving temperature range of 40-45C.

High Identity Traits

The sensory profiles of the potato samples were determined using a modified High Identity Traits (HITS) method, which can be used to develop shorter, more simplified lists of terms to describe products (Talavera-Bianchi, *et al.* 2010). The simplistic nature of the profiles allows for more rapid evaluation of products. The panelists were instructed to develop a list of no more than five traits (HITS) to describe aspects of the aroma, flavor, and texture that are most important to the identity of each sample. After tasting each sample, the panelists decided on a consensus list of traits through group discussion. Then, the panelists used a consensus evaluation to rate the intensity of each HIT on a scale from 0-15 with 0.5 increments, where 0 means the trait is not present and 15 represents an extremely high intensity. This was different from the original Talavera, et al. study which only rated the intensities as slight, moderate, or strong (2010). The more complex scale used in this study potentially allows for more differentiation among samples with the same HIT. Group discussion was also used to establish a definition for each HIT identified. There were no references used during the evaluation of the samples.

Degree of Difference

Panelists also evaluated the Degree of Difference (DOD) from Control for each sample. In addition to the five varietal samples served each day, panelists were blindly served a second Red potato sample labeled as the control. After developing the HITS profiles for each sample,

Table 2.2 Definitions of HITS used for evaluation of potato samples.

	High Identity Trait	Definition
Aroma	Heated Oil	The aromatics associated with oil that has been heated.
	Metallic	An aromatic associated with tin cans or aluminum foil.
	Musty-Earthy	The musty aromatics associated with raw potatoes, decaying vegetation, and damp soil.
	Potato	The starchy and slightly metallic, cooked vegetable characteristic associated with the meat of the potato.
	Toasted	A moderately brown, baked impression.
Flavor	Bitter	A fundamental taste sensation that is characterized as being acrid, sharp, or pungent. May include a lingering flat taste over the back of the tongue.
	Cardboard	The aromatic associated with cardboard or paper packaging.
	Earthy	An aromatic that has a damp, earthy character similar to fresh mushrooms or raw potato.
	Earthy-Dirty	Dry, dirt-like aromatic associated with dry soil.
	Heated Oil	The aromatics associated with oil that has been heated.
	Metallic	An aromatic and mouth feel associated with tin cans or aluminum foil.
	Musty-Earthy	The musty aromatics associated with raw potatoes, decaying vegetation, and damp soil.
	Potato	The starchy and slightly metallic, cooked vegetable characteristic associated with the meat of the potato.
	Raw Potato	The starchy, raw vegetable-like character associated with peeled, sliced, un-cooked potatoes. May include slight green or un-ripened notes.
	Starchy	The aromatics associated with starch and starch based vegetables such as corn, potatoes, and legumes.
	Toasted	A moderately brown, baked impression.
Texture	Creamy	The rich, smooth, full feeling in the mouth which may be thick and slick.
	Crunchy	The force and noise with which the sample breaks, cracks, or ruptures.
	Firm	Requiring a moderate amount of force to bite completely through the sample.
	Gummy	A sticky, gluey impression perceived in product during mastication.
	Mealy	The perception of fine, soft, somewhat rounded smooth particles very evenly distributed within the product itself.
	Soft	The lack of resistance to the teeth when biting down on the product.
	Starchy	Degree to which the sample mixes with saliva to form a starchy, pasty slurry that coats mouth surfaces after swallowing.
	Watery	The perceived amount of moisture in the product when placed in the mouth.

the panelists rated how different the sample was from the control sample based on aroma, flavor, and texture. After group discussion, the DOD was rated by consensus on a scale from 0-15 with 0.5 increments, where 0 represents no perceived difference and 15 represents the greatest possible difference. The DOD scale was treated as product-specific, so any perceived differences are only rated against other varieties of potatoes.

Data Analysis

All data analysis was performed using Excel 2016 and XLSTAT 2018. Bar charts were used to display HITS intensity and DOD scores. Principal Component Analyses were run using the covariance matrices for each cooking method and for all samples combined. Zeros were used to fill in intensity scores for traits that were not present in samples to provide a complete matrix for analysis. Agglomerative Hierarchical Cluster Analysis was also run using this same matrix for all samples.

Results and Discussion

High Identity Traits

The panel used a total of twenty-four terms to describe the High Identity Traits (HITS) profiles of the samples across all five cooking methods. The list included five terms for aroma, eleven for flavor, and eight for texture, showing that aroma was overall least important to the identities of the potato samples. All traits and their definitions can be found in Table 2.2. Out of the twenty-four traits, only potato flavor was used to profile all samples for all cooking methods, so there were sensory differences identified among the samples despite only focusing on five traits per sample.

Some of the cooking methods produced samples with traits that were unique to that preparation. For example, starchy flavor was only used to describe the mashed and boiled

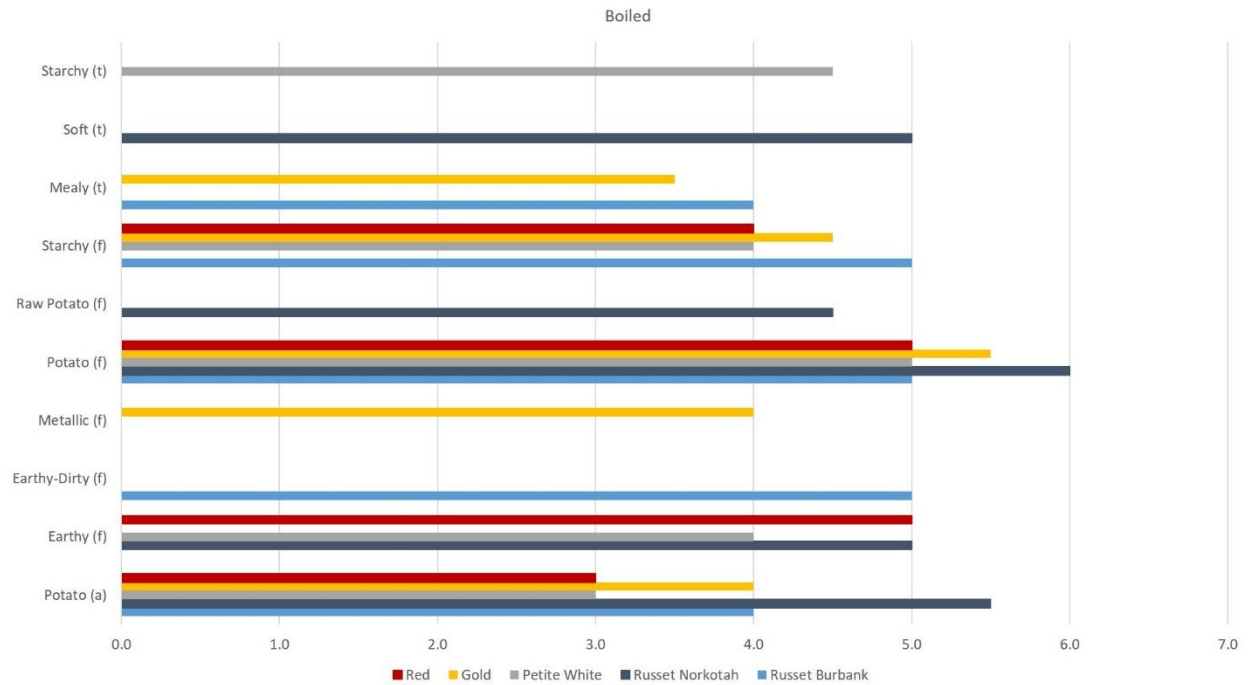


Figure 2.1 High Identity Traits (HITS) profiles of the boiled potato samples (aroma (a), flavor (f), and texture (t)).

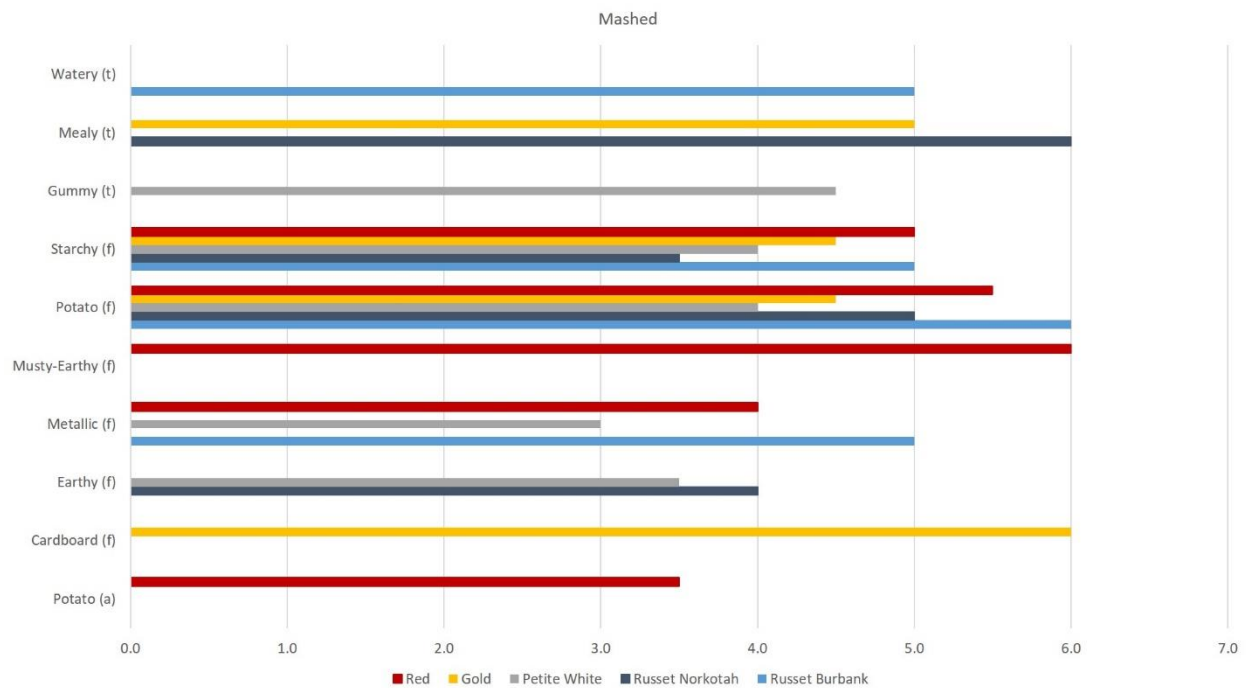


Figure 2.2 High Identity Traits (HITS) profiles of the mashed potato samples (aroma (a), flavor (f), and texture (t)).

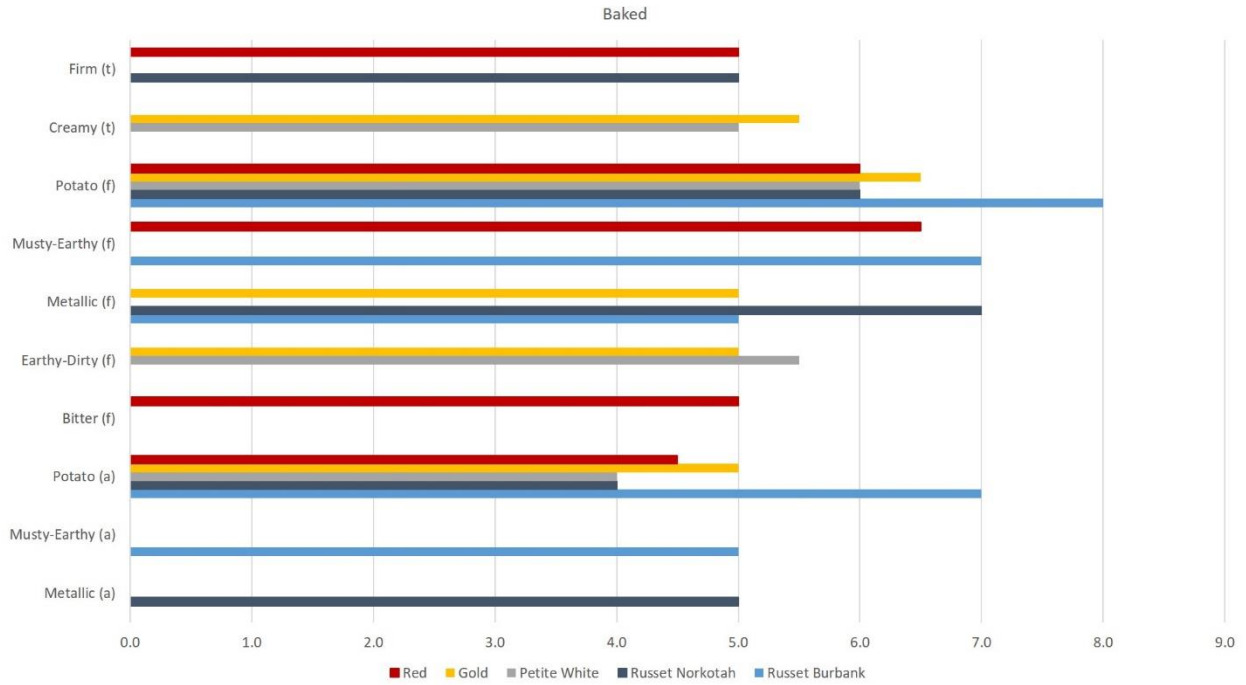


Figure 2.3 High Identity Traits (HITS) profiles of the baked potato samples (aroma (a), flavor (f), and texture (t)).

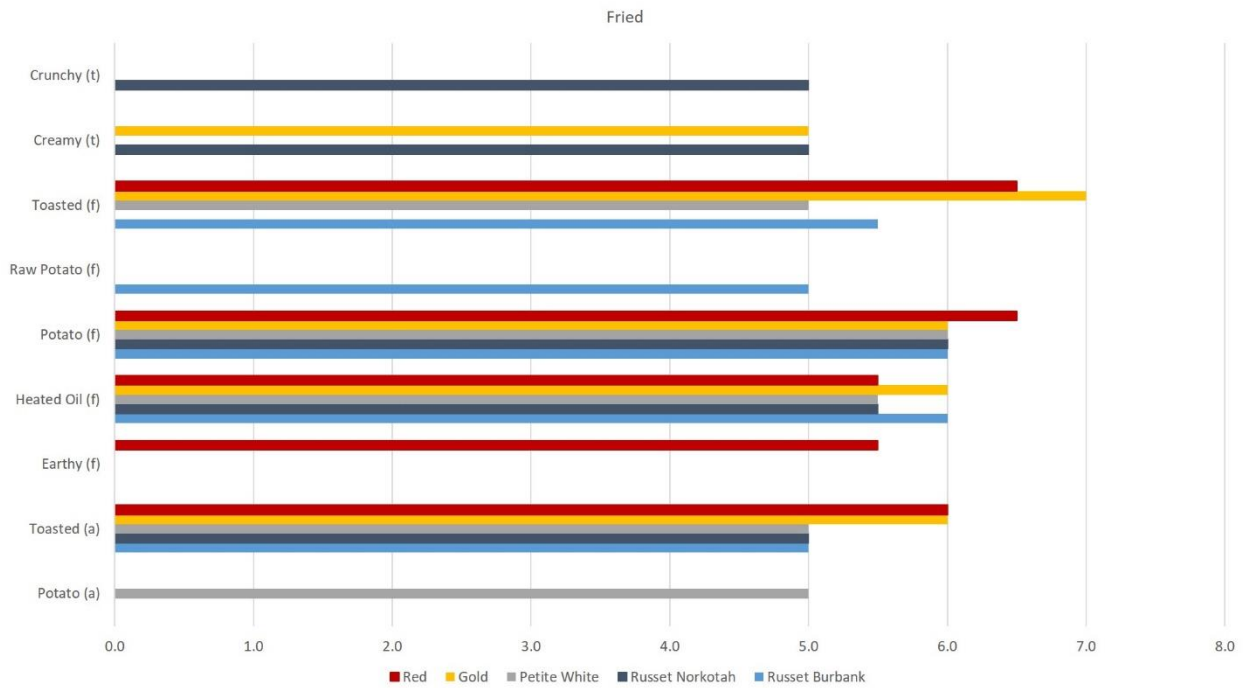


Figure 2.4 High Identity Traits (HITS) profiles of the fried potato samples (aroma (a), flavor (f), and texture (t)).

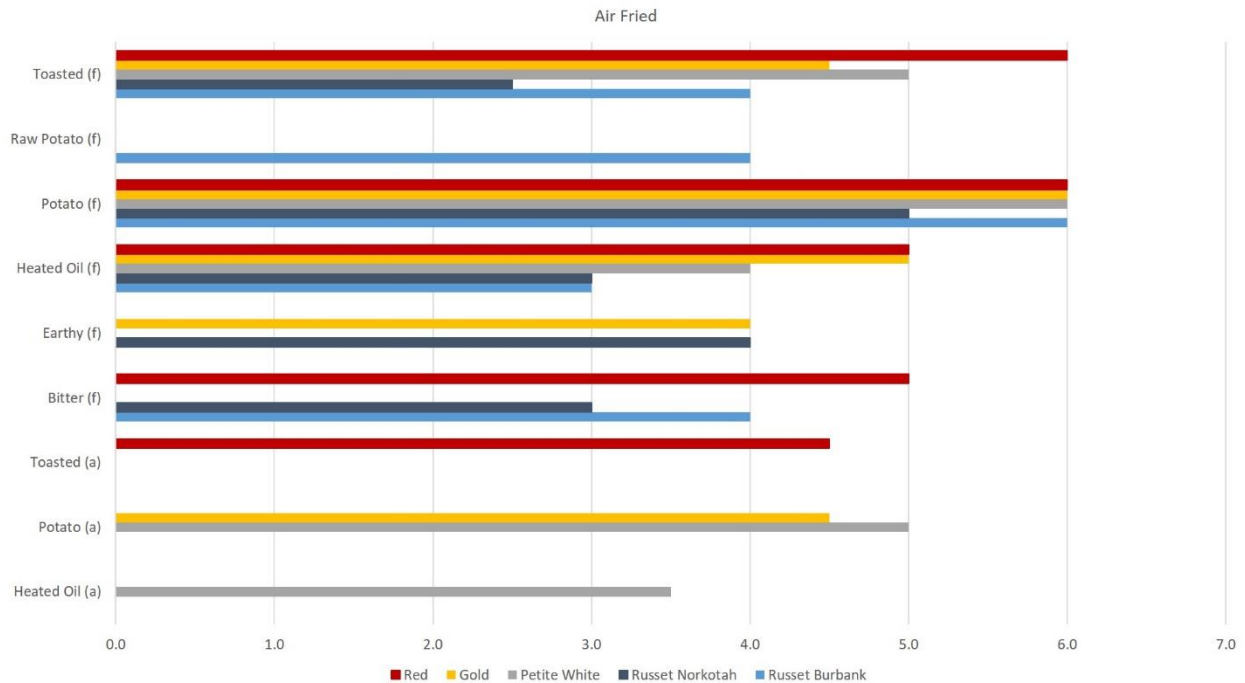


Figure 2.5 High Identity Traits (HITS) profiles of the air fried potato samples (aroma (a), flavor (f), and texture (t)).

samples. Higher intensities of starchy traits are expected in moist heat cooking methods such as mashing and boiling because the water causes the potatoes to release starch as the starch granules swell and burst. Despite having a trait common to several samples, the boiled and mashed cooking methods still produced the highest numbers of differentiating traits. These are traits that were used to describe only one sample within the cooking method and both methods had five differentiating traits.

The differentiating traits for the boiled samples included starchy texture, soft texture, raw potato flavor, metallic flavor, and earthy-dirty flavor (Figure 2.1). Starchy texture was profiled for the Petite White sample, soft texture and raw potato flavor were only used for the Russet Norkotah sample, metallic flavor was differentiating for the Gold sample, and earthy-dirty flavor was unique to the identity of the Russet Burbank sample. A total of ten traits were used to describe the boiled potato samples, including three traits for texture, six for flavor, and only one

for aroma. While there was a high number of differentiating traits, two traits, potato aroma and potato flavor, were used to profile all five boiled samples. Russet Norkotah was scored as the highest intensity for both. The Red sample was the only variety with a HITS profile of fewer than five traits and was described using only four because the panelists could not agree on a fifth trait and ultimately decided that the sample's sensory profile was simpler than the other varieties. It was also the only sample with a HITS profile that did not contain any of the three texture terms, starchy, soft, or mealy because of its simplicity.

The mashed potato samples were also profiled using a total of ten HITS, with three traits for texture, six for flavor, and one for aroma (Figure 2.2). The mashed cooking method was the only one that produced more than one sample that was profiled using fewer than five traits. The profiles of the Gold, Russet Norkotah, and Russet Burbank samples all contained only four HITS, suggesting that the mashed cooking method may produce more simple sensory profiles than the other cooking methods. This could be because the mashing of the samples creates a more homogenous texture and the addition of cooking water in the method may dilute the aroma and flavor. Starchy flavor and potato flavor were the only two traits out of the ten that were used to profile all five of the mashed samples, with the Red and Russet Burbank samples receiving the highest intensity scores for both. Unlike the boiled cooking method, potato aroma was only present in one sample, which was the Red variety. The Red sample was also differentiated from the other samples by musty-earthly flavor. Other differentiating traits included watery texture, which was only included in the Russet Burbank profile, gummy texture, which was unique to the Petite White profile, and cardboard flavor, which was only present for the Gold sample. According to a study done by Blanda, *et al.*, cardboard is generally considered an off-flavor or

defect, so it is possible that the Gold sample used for mashing was not a very high quality (2010).

A total of ten traits were used to describe the five baked potato samples. The traits included two traits for texture, five for flavor, and three for aroma (Figure 2.3). The Petite White sample was the only variety with a HITS profile of fewer than five traits and was described using only four. Potato aroma and potato flavor were used to profile all five varieties, but Russet Burbank scored highest in intensity for both. Russet Burbank was also the only baked sample that was not profiled using either of the texture traits, firm or creamy. Instead, the profile focused on aroma and flavor traits, also including musty-earthly flavor and aroma and metallic flavor. Traits that were only used to profile one variety included bitter flavor, musty-earthly aroma, and metallic aroma. Bitter flavor was profiled in the Red sample, musty-earthly aroma was used to describe the Russet Burbank sample, and metallic aroma was important to the identity of the baked Russet Norkotah sample.

Like the boiled and mashed methods, frying and air frying also had method-specific traits. Toasted and heated oil aromas and flavors were only used to describe samples cooked using the fried and air fried methods. These were the only two methods that called for oil as part of the procedure, so it was expected that the oil would impart certain aromas and flavors. Additionally, frying and air frying are both dry heat cooking methods, so browning reactions are more likely to occur and create toasted sensory properties. While frying and air frying were differentiated from the other cooking methods by heated oil and toasted traits, they decreased the ability to highlight sample differences within the methods by masking other aroma and flavor properties. Boiled, mashed, and baked samples were each described using a total of ten traits, but the fried and air fried samples were each only described using nine.

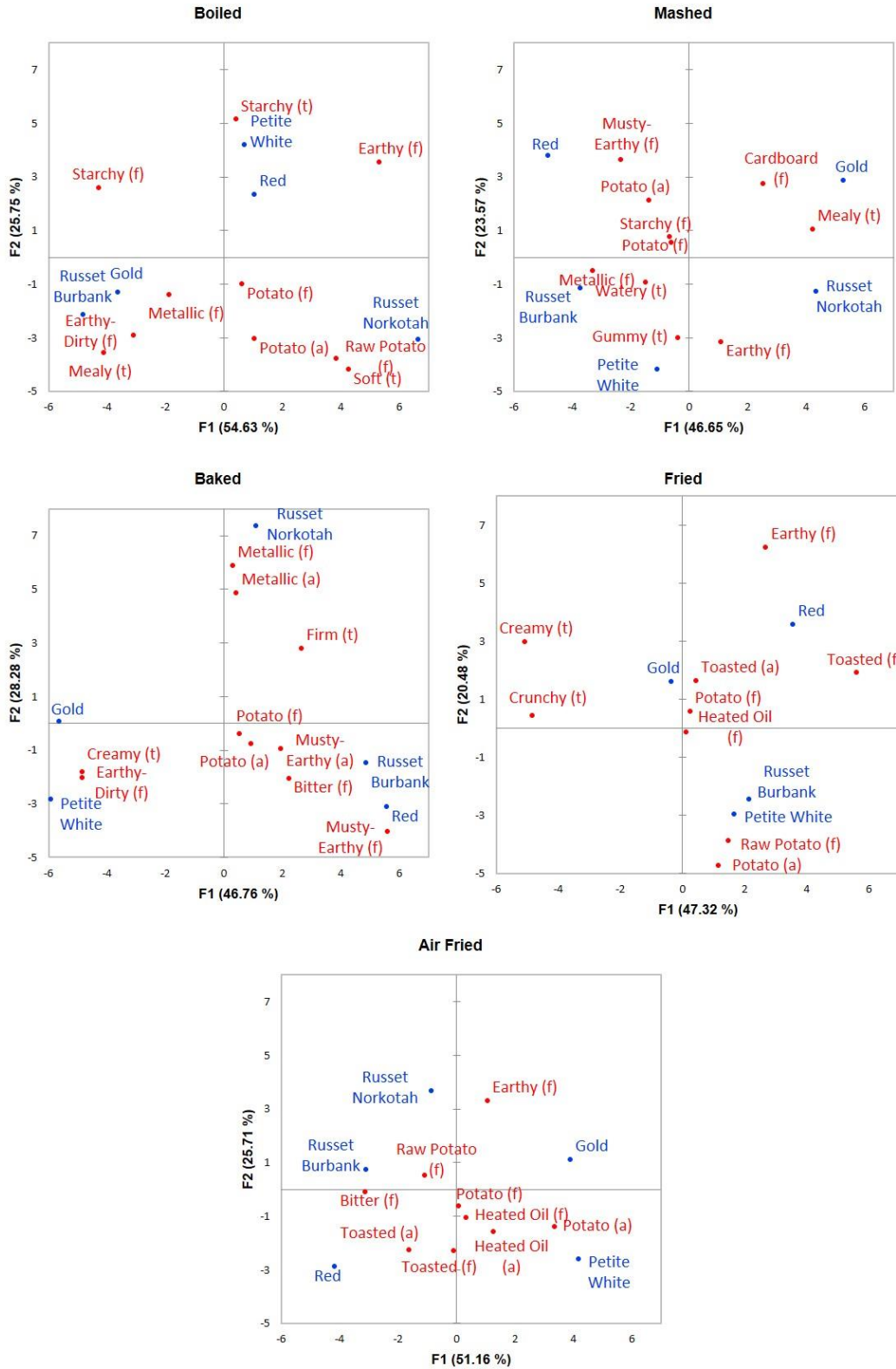


Figure 2.6 Principal Component Analyses (PCA) by cooking method of aroma (a), flavor (f), and texture (t) HITS for all potato varieties.

The nine overall traits for the fried samples included two for texture, five for flavor, and two for aroma (Figure 2.4). All five samples were profiled using the maximum of five HITS, although potato flavor, heated oil flavor, and toasted aroma were all used as traits for all varieties. As previously mentioned, these traits dominated the profiles of the fried samples and prevented clear differentiation among varieties. However, there were still four differentiating traits: crunchy texture, raw potato flavor, earthy flavor, and potato aroma. Crunchy texture was unique to the Russet Norkotah sample, raw potato flavor to the Russet Burbank, earthy flavor to the Red, and potato aroma to the Petite White.

The five air fried samples were also profiled using only nine traits, with three for aroma and six for flavor (Figure 2.5). This was the only cooking method where texture terms were not included in the HITS profiles. This is most likely because the exterior texture of the samples was unique but also inconsistent due to the cooking method. Since the texture was new to most of the panelists, they could not determine if the texture of each sample was due to the cooking method or varietal differences, so they avoided using texture terms altogether. A 2015 panel conducted by Teruel, *et al.* also found that air fried samples had a unique texture with a puffy and dry exterior appearance different from their deep-fried counterparts. Like the fried samples, all five of the air fried samples were profiled using the maximum of five traits, but three of the traits were the same across the samples: potato flavor, toasted flavor, and heated oil flavor. Again, the profiles were dominated by oil and browning-related traits, so only three of the samples had differentiating traits. Raw potato flavor was unique to Russet Burbank, toasted aroma to Red, and heated oil aroma to Petite White.

By comparing the PCA bi-plots for the individual cooking methods, some insight can be gained about the ability of each method to differentiate samples (Figure 2.6). As previously

mentioned, the fried and air fried samples were dominated by heated oil and toasted properties, so the samples lie closer to the center of their respective bi-plots than the samples for each of the other three methods. However, despite the lower number of differentiating traits, the air fried samples appear more differentiated across their bi-plot than the fried samples. This is most likely because the air fried samples showed more differences in intensity for the traits that were shared by all five samples, allowing for more separation on the map. Neither method appears to be great for sample differentiation, but the air fried method could be somewhat more effective if a comparison of browning effects across varieties is desired.

Based on the PCA bi-plot alone, mashing appears to be the best method for sample differentiation. All samples lie close to the edge of the plot, with each sample appearing in its own space. This is interesting because the mashed method produced the most samples with four-term profiles, so it would seem like the homogenization of the samples by mashing would dilute the sensory properties and prevent differentiation. This result is also contradictory to a previous study that found less variation among mashed samples compared to boiled and oven-fried samples and concluded that the lack of variation was due to the mashing homogenizing the sample (Seefeldt, *et al.* 2011). However, the results for the present study showed that the mashed samples were still profiled using a high number of overall HITS and the highest number of differentiating traits and the mashed method is capable of differentiation.

Degree of Difference

The addition of Degree of Difference (DOD) scores can help provide more information about the differentiation of samples than the HITS profiles alone. This is because panelists are considering all aspects of aroma, flavor, and texture at once and comparing them to a control sample. Since the control sample was the same variety as one of the evaluated samples, the DOD

score for the Red sample each day can give insight into a few different experimental factors. Some degree of difference between the control sample and the evaluated Red sample is acceptable as it may be a result of natural variation within the potato variety. However, DOD scores greater than 2.0 may suggest either inconsistencies with sample preparation or an issue with panel calibration. Since the panel used for this study was highly trained, any higher DOD scores for the Red potato samples is most likely due to problems with sample preparation consistency for some of the cooking methods. The control sample was served at the beginning of the panel every day, but due to sample randomization, the Red evaluated sample was always in a different serving position. Therefore, the control sample and Red sample were prepared separately to allow for consistency in the time between cooking and serving.

As shown in Figure 2.7, the fried Red sample produced the highest DOD score from the control. Frying is a difficult process to control because the oil temperature can be hard to regulate, the samples may cook unevenly in different parts of the fryer, and sample texture can change drastically with increased time between cooking and serving. The boiled Red sample also produced a higher DOD score than expected. The sample for the boiled preparation is cut into small cubes, so it is possible that within sample variation is more noticeable if the texture or flavor is different from cube to cube. Additionally, despite frequent stirring, the cubes may cook unevenly during boiling based on their locations in the pot, leading to inconsistent texture.

Since the Red samples showed that the DOD scores may be affected by preparation variation, all of the DOD scores were adjusted to account for that. The Red sample DOD scores were set to zero to represent that they were equal to the control sample. Any samples with DOD scores lower than the Red sample were also set to zero because they were not found to have more differences from the control than the Red sample. Varieties with DOD scores higher were

adjusted down proportionally to their original differences with the Red samples. The adjusted DOD scores are shown in Figure 2.8 and the remaining discussion will focus on these scores.

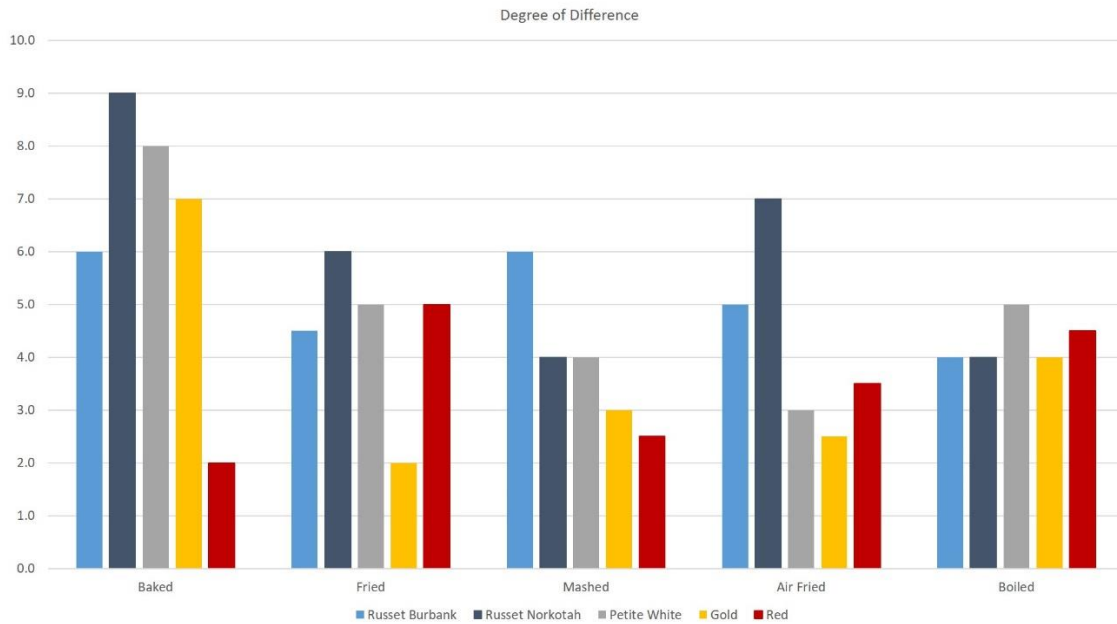


Figure 2.7 Degree of Difference (DOD) from control scores for all varieties and cooking methods.

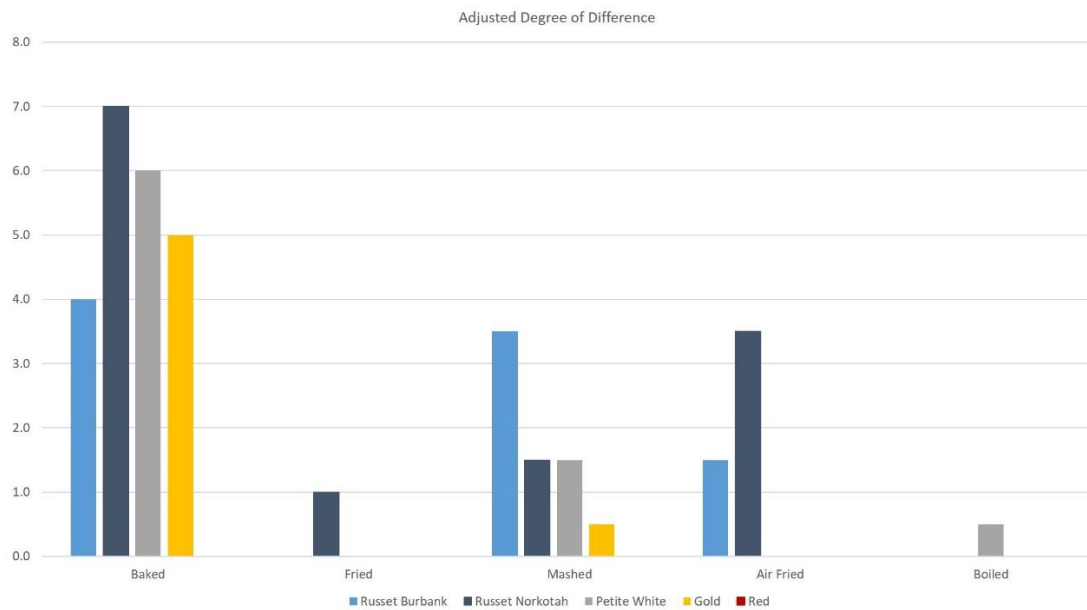


Figure 2.8 Adjusted Degree of Difference (DOD) from control scores for all varieties and cooking methods.

Baking and mashing were the only two cooking methods within which all four non-Red varieties exhibited differences from the control, with the baked samples producing the largest differences. The baking method is the only one that does not directly introduce water or oil to the sample, so the lack of interference may allow for more of the varietal differences to stand out. Out of the baked samples, the Russet Norkotah received the highest DOD score. Looking at the HITS profile for the baked Russet Norkotah sample, it was the only sample scored for metallic aroma and also received a high intensity score for metallic flavor, so these characteristics may have contributed to the DOD. The mashed method may be the most resistant to sample preparation variation because inconsistencies in texture due to cooking are ultimately homogenized during mashing. Russet Burbank received the highest DOD score of the mashed samples. This was mostly because of the watery texture that was unique to only that sample because it did not absorb the added water as well as other samples.

The fried and boiled methods produced the least amount of differences from the control sample. Both methods had only one sample that was scored differently from the control after adjustments and the DOD scores for the single sample were 1.0 or below for both preparations. Frying and boiling both introduce a factor into the preparation that is not present in the natural samples (oil and water, respectively), so the added noise may dilute any differences in the samples due to potato variety.

Conclusion

The combination of High Identity Traits profiles and Degree of Difference scores proved to be useful in conducting a preliminary sensory study. The HITS profiles can help compile quick and simple information about the sensory modalities of interest which can begin highlighting characteristic differences among samples. While the range of HITS used and the

number of differentiating traits can begin to show how well a cooking method can highlight differences among samples, the DOD scores provided the most information about differentiation and was a valuable addition to the methods of this study.

Based on the results of this study, the cooking methods that are most useful in differentiating potato varieties are mashing and baking. One of these two methods is recommended for use in future sensory studies to compile more information about or compare potato samples, such as a lexicon development study. If the objective of a study is to determine differences in potato flavor, mashing is recommended because it was found to homogenize differences in the sample texture due to preparation inconsistencies. This allowed the panel to focus more on flavor characteristics. If the objective of a study is to evaluate the full sensory profiles of potato samples, then baking is recommended because it is the only cooking method tested that does not introduce additional noise in the form of water, oil, or texture manipulation. It is worth noting that neither mashing or baking allow the potatoes to participate in browning reactions, so if a key objective of a study is to observe sensory differences based on those reactions, then an air fried cooking method is recommended. Air frying is recommended over frying because it is an easier process to control that could provide more consistent results.

Whichever method is chosen to cook potato samples, it is important to keep in mind that consistency with the preparation procedure is key to ensuring that any differences found among samples are as unaffected by external noise and sources of error as possible. A specific procedure should be developed and strictly followed, with special attention paid to sample shape, sample size, cooking time, and cooking temperature.

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Chapter 3 - Comparison of sensory profiles generated by trained and untrained panels using a modified High Identity Traits (HITS)

method

Abstract

A High Identity Traits (HITS) method was created to allow trained panelists to develop descriptive product profiles with only a few, simple traits that could save time while still differentiating samples. However, the use of trained panelists requires time and money to be dedicated to panel training, so many new methods are developed for the use of semi-trained or untrained consumer panels. The objective of this study was to determine if an untrained consumer panel could provide similar sensory profiles to a highly trained panel using a modified HITS method. A trained panel was conducted with six, highly trained panelists and a separate untrained panel was held with six consumers. Each panel evaluated five potato varieties, cooked by mashing, baking, and air frying, to develop profiles of up to five HITS for each of the fifteen total samples. The panelists rated the intensity of each HIT and rated each sample for Degree of Difference (DOD) from a control. The consumer panel was able to identify some of the same traits as the trained assessors, but did not develop similar sensory profiles overall. The consumers found differences among the samples within each cooking method, but the size and direction of the differences were not the same as the trained panelists'. While the highly trained assessors were able to identify complex aroma and flavor traits, the consumers focused mainly on texture, which prevented them from finding more subtle product differences.

Introduction

Descriptive sensory analysis can be used to identify and quantify characteristics related to the appearance, aroma, flavor, and texture of products. However, descriptive testing requires the use of a highly-trained panel of assessors, which can be costly to obtain and time-consuming to properly train. Previous studies have been conducted to explore the possibility of using untrained or semi-trained panels to carry out sensory analysis methods to cut costs and save time on training. Chambers, *et al.* (2004) looked at how different amounts of training time affected the discrimination abilities of a descriptive panel and found that panelists can detect product differences with limited training. The discrimination abilities of untrained panelists were also noticed by Chollet (2001) and Guerrero, *et al.* (1997). While the use of semi-trained or untrained panelists in descriptive panels can result in sufficient sample differentiation, the above studies also noted that the attributes developed were generally “less specific” (Guerrero, *et al.*) and not as precise (Chollet) as those generated by a highly trained panel. Roberts and Vickers (1994) also found that the attribute intensities were different between trained and untrained panelists, with trained assessors rating cheese attributes as less intense than an untrained panel. One final limitation is that semi-trained or untrained assessors may not be able to discriminate among samples that have very similar sensory profiles, as concluded by Guerrero, *et al.*

In an attempt to overcome the cost and time limitations of conducting a descriptive panel, several alternative methodologies have been developed that provide more rapid results and can be completed by panelists with little to no training. Some novel methods that can help categorize products more rapidly include sorting, flash profiling, projective mapping, and check-all-that-apply, or CATA, questioning (Varela and Ares, 2012). Flash profiling is a commonly used method and its ability to differentiate products based on panelist-generated profiles in

combination with product ranking has been widely studied (Albert, *et al.*, 2011; Delarue and Sieffermann, 2004; He and Chung, 2019; Liu, *et al.*, 2018). Another frequently studied rapid methodology is Temporal Dominance of Sensations, or TDS (Albert, *et al.*, 2012; Labbe, *et al.*, 2009; Oliver, *et al.*, 2018; Pineau, *et al.*, 2012). TDS involves having assessors identify and quantify dominant sensations as they appear throughout the evaluation of a product.

While recent studies have found that flash profiling and TDS procedures provide similar profiles to traditional descriptive methods (He and Chung, 2019; Oliver, *et al.*, 2018), these alternative methods still present limitations. Flash profiling allows assessors to develop their own individual attribute lists, so the sample descriptions can vary widely and be difficult to interpret (Varela and Ares). Additionally, the samples must be evaluated simultaneously to allow ranking based on the developed attribute list, so the entire procedure would need to be repeated for additional samples (Delarue and Sieffermann). Despite alternative methods becoming more rapid, they can still involve a long list of complex sensory attributes. Pineau, *et al.* looked at how many attributes are actually selected by assessors during a TDS evaluation and found that they, on average, only use four different attributes to describe the dominant sensations of a product over time.

High Identity Traits (HITS) profiling was developed by Talavera-Bianchi, *et al.* (2010) to help differentiate products using more simplified lists of attributes, with no more than five traits to describe each sample. Talavera-Bianchi, *et al.* compared the HITS profiles developed by a trained panel to the results of a detailed descriptive analysis and found that while the sensitivity of the HITS method is reduced, the panel was still able to find differences and classify products effectively. The previous application of the HITS method was performed with a highly trained panel, so it would be worth exploring if similar results can be obtained using an untrained

consumer panel to help save time and money on training sessions. The objective of this study was to determine if a consumer panel with no previous experience in descriptive sensory analysis could develop similar product profiles and differentiation patterns to a highly trained panel using a modified HITS method.

Materials and Methods

Potato Samples

For this study, five varieties of raw potatoes were purchased from a local grocery store in Manhattan, Kansas. The five varieties were Red, Gold, Petite White, Russet Norkotah, and Russet Burbank. These varieties were chosen for their commercial availability, consumption popularity, and range of sensory properties. Two varieties of Russet potatoes were included to test the sensory method's ability to differentiate between similar samples. After purchase, samples were kept in a cool, dark room in their original packaging. All samples were used within ten days of purchase.

Sample Preparation

Based on the results from Chapter 2, three cooking methods were chosen to allow maximum differentiation among the five potato varieties: mashing, baking, and air frying. The methods cover both moist and dry heat preparations to provide a range of sensory profiles. The following procedures were followed as written for the Red, Gold, Russet Norkotah, and Russet Burbank varieties. Due to the size of the Petite White potatoes, the skin was not removed prior to cutting the potatoes into slices for the mashed and air-fried methods. The skin was removed by hand with a knife as the Petite White slices were reduced to their final form. Mashed and baked samples were considered done when a fork could be easily inserted through the center of the sample, meaning the potato is tender all the way through. A similar method for determining

doneness was also used by Tian, *et al.* (2016). Deionized water was used to rinse and cook samples as needed. The use of ultra-purified water was suggested by Trong, *et al.* (2011) to help prevent additional substances present in water from affecting the properties of the final samples.

Mashed

The skin of each potato was removed using a vegetable peeler, then each potato was rinsed under deionized water to remove any remaining dirt. Each potato was cut into slices using a Vollrath Redco® InstaCut™5.0 countertop food slicer (The Vollrath Company, LLC, Sheboygan, Wisconsin, USA) fit with a ½” stainless steel dicing blade, then the slices were cut down to ½” cubes using a knife. In a large saucepan, 450g of ½” cubes were covered with 800mL of deionized water. The saucepan was covered with a lid and brought to a boil on a gas stovetop. Once boiling, the heat was reduced to a medium simmer and the potato cubes were cooked until a fork could be easily inserted into the center. The pan was then removed from the heat and the cooked cubes were drained, reserving the cooking water. The cooked potatoes were pressed through a potato ricer (OXO, New York City, New York, USA) into a bowl. Thirty-five milliliters of the reserved cooking water was added and the potatoes were stirred with a fork until smooth and consistent in texture.

Baked

Potatoes of similar size were chosen for each variety. The outside of each potato was scrubbed with a sponge to remove dirt from the skin, then each potato was thoroughly dried with a clean cloth. Two opposite sides of each potato were punctured ½” deep to allow for steam to escape. Next, the potatoes were individually wrapped in foil. All potatoes of the same variety were placed on a single baking sheet and baked at 425F (218C) until a fork could be easily inserted into the center. The potatoes were removed from the oven, left to cool slightly, and then

unwrapped. The flesh of each potato was scooped out of the skin using a spoon and cut into ½” cubes.

Air Fried

The skin of each potato was removed using a vegetable peeler, then each potato was rinsed under deionized water to remove any remaining dirt. Each potato was cut into slices using a countertop food slicer fit with a ½” stainless steel dicing blade. Using only slices that were cleanly cut on all four sides, the slices were cut into 2” long pieces with squared off edges. The slices were soaked in deionized water for 30 minutes at room temperature. After soaking, the pieces were drained and the surface of each slice was dried with paper towels. The dried slices were then placed in a non-porous bowl, where they were evenly coated with 5mL of canola oil. The coated slices were arranged with even spacing on a copper-coated crisping tray and baked in a 425F (218C) oven until golden brown in color, rotating the tray 180 degrees halfway through cooking.

Sensory Evaluation

Panels

Trained Panel

The trained panel consisted of six, highly trained panelists from the Center for Sensory Analysis and Consumer Behavior at Kansas State University in Manhattan, KS, USA. The panelists all received a minimum of 120 h of general descriptive sensory analysis training prior to completing this panel.

Consumer Panel

The consumer panel was made up of six people from the Manhattan, KS area (2 male, 4 female; ages 44-58). The consumers were recruited from a pool of known discriminators who

have all previously completed a discrimination screening test. However, these panelists were untrained and had no prior experience in the area of descriptive sensory analysis testing. Accepted consumer panelists had no food allergies or dietary restrictions, consumed potatoes at least once in the last three months, and were comfortable participating in a panel with group discussions.

Orientation

Each panel participated separately in two, 90-minute orientation sessions prior to beginning evaluation of the potato samples. During the orientation sessions, panelists were introduced to the modified HITS method and were provided with two potato varieties for each cooking method to practice developing traits and rating intensities. The first orientation session for the untrained consumers additionally included an introduction to intensity and degree of difference scaling, with basic taste solutions for practice. The untrained panelists were given a brief explanation of common sensory attributes used to describe the aroma, flavor, and texture of potatoes, but neither panel was provided with an existing list of attributes or reference materials.

Evaluation Procedure

Sample Serving

Samples were labeled with random, three-digit blinding codes and were served one at a time according to a randomized order. Each panel evaluated five samples from a single cooking method per day. The samples were served in the following amounts: 8-10 cubes for boiled and baked methods, 65 g for the mashed method, and 3 pieces for deep fried and air fried methods. All samples were served in 4oz glass jars covered with watch glasses. The glass jars were placed on top of heated tiles in metal trays to maintain a serving temperature range of 40-45C.

High Identity Traits

The sensory profiles of the potato samples were determined using a modified High Identity Traits (HITS) method, which can be used to develop shorter, more simplified lists of terms to describe products (Talavera-Bianchi, *et al.* 2010). The simplistic nature of the profiles allows for more rapid evaluation of products. The panelists were instructed to develop a list of no more than five traits (HITS) to describe aspects of the aroma, flavor, and texture that are most important to the identity of each sample. After tasting each sample, the panelists decided on a consensus list of traits through group discussion. Then, the panelists used a consensus evaluation to rate the intensity of each HIT on a scale from 0-15 with 0.5 increments, where 0 means the trait is not present and 15 represents an extremely high intensity. This was different from the original Talavera, *et al.* study which only rated the intensities as slight, moderate, or strong (2010). The more complex scale used in this study potentially allows for more differentiation among samples with the same HIT. Group discussion was also used to establish a definition for each HIT identified. There were no references used during the evaluation of the samples.

Degree of Difference

Panelists also evaluated the Degree of Difference (DOD) from Control for each sample. In addition to the five varietal samples served each day, panelists were blindly served a second Red potato sample labeled as the control. After developing the HITS profiles for each sample, the panelists rated how different the sample was from the control sample based on aroma, flavor, and texture. After group discussion, the DOD was rated by consensus on a scale from 0-15 with 0.5 increments, where 0 represents no perceived difference and 15 represents the greatest possible difference. The DOD scale was treated as product-specific, so any perceived differences are only rated against other varieties of potatoes.

Data Analysis

All data analysis was performed using Excel 2016 and XLSTAT 2018. Bar charts were used to display HITS intensity and DOD scores. Principal Component Analyses were run using the covariance matrices for each cooking method and for all samples combined for each panel. Zeros were used to fill in intensity scores for traits that were not present in samples to provide a complete matrix for analysis. Agglomerative Hierarchical Cluster Analysis was also run using this same matrix for all samples for each panel.

Results and Discussion

High Identity Traits

The trained panel developed a list of twenty-one total traits across the three cooking methods and the consumer panel used twenty-six total terms. While the totals are not that far off, the differences in how the two panels operated are clear when looking at the breakdown of trait numbers between aroma, flavor, and texture. The trained panel used five traits for aroma, eleven for flavor, and five for texture, but the consumer panel used seven traits for aroma, only five for flavor, and fourteen total traits to describe texture. This result was not too surprising, as consumers' gravitation towards the use of texture terms to describe products has been discussed in the past (Chambers, *et al.*, 1981; Chambers, *et al.*, 2004; Delarue and Sieffermann, 2004). Texture terms come more easily to consumers because they generally have more concrete definitions and can be used to describe products outside of food, making them more familiar. Regarding aroma and flavor, consumers may be able to detect that differences exist, but without proper training or education, they may not be able to put a name to what they smell or taste.

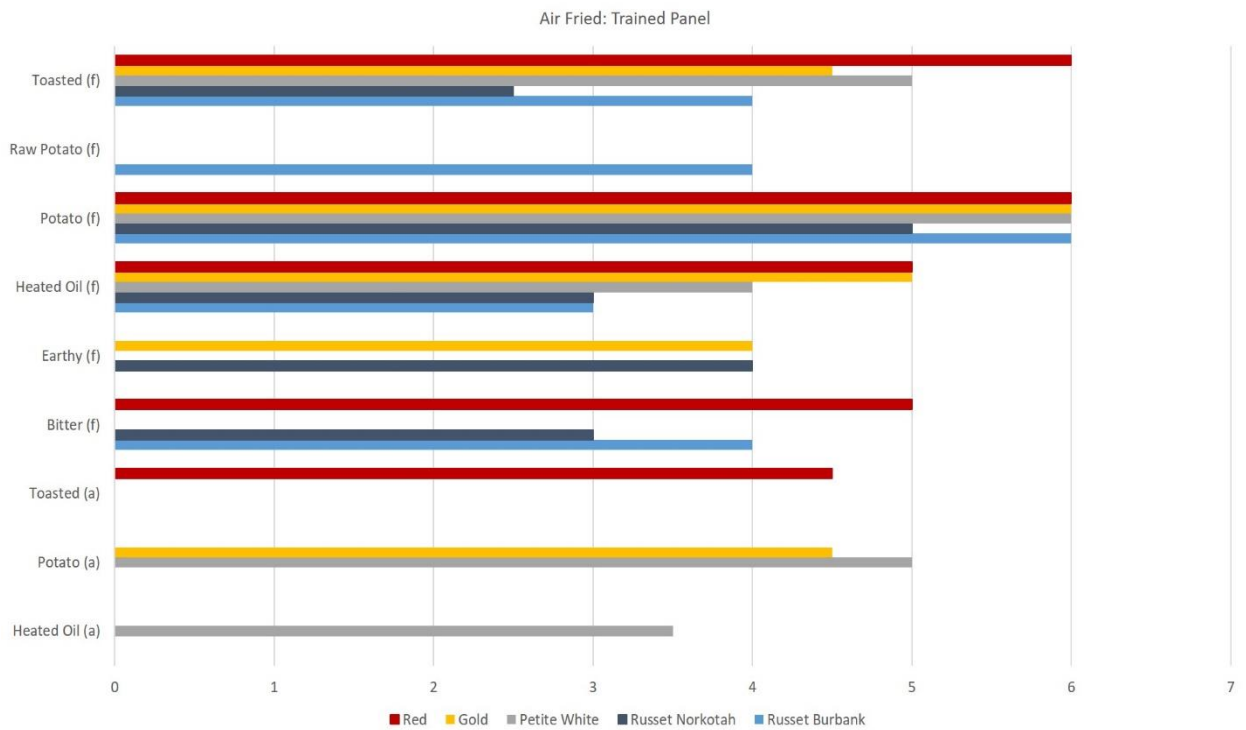
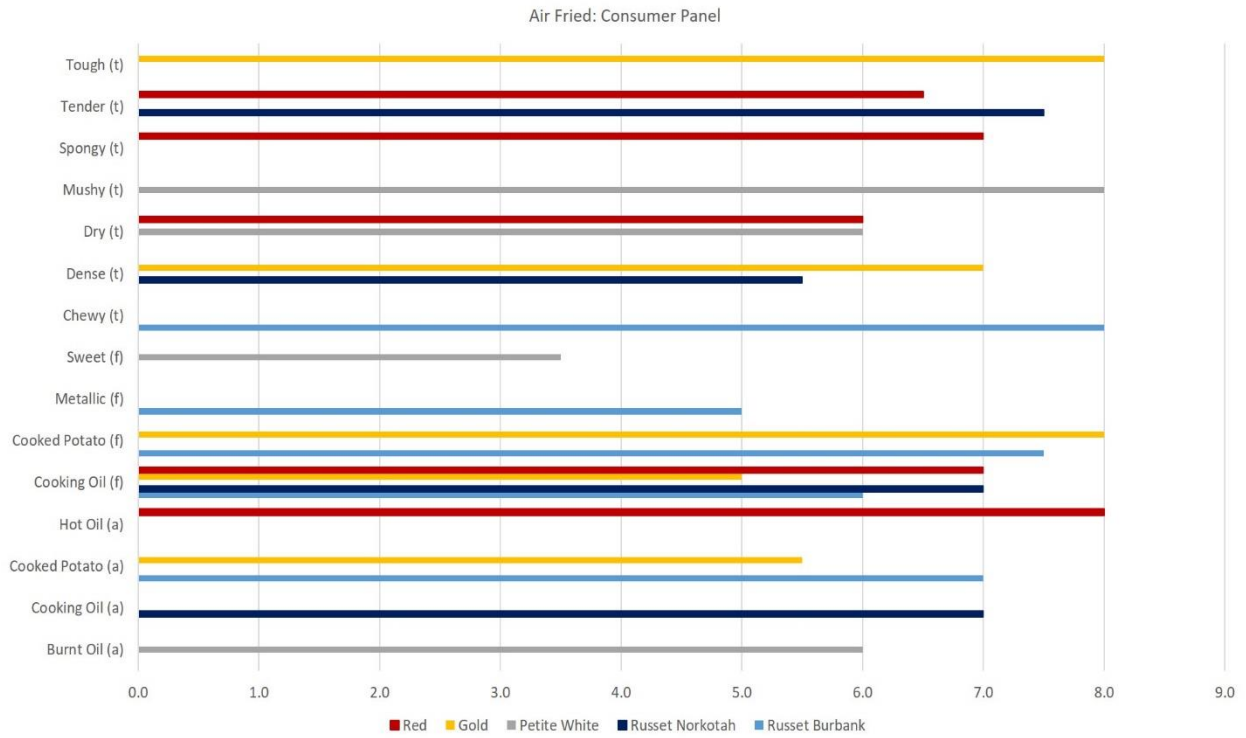


Figure 3.1 High Identity Traits (HITS) profiles of the air fried potato samples for the trained and untrained panels (aroma (a), flavor (f), and texture (t)).

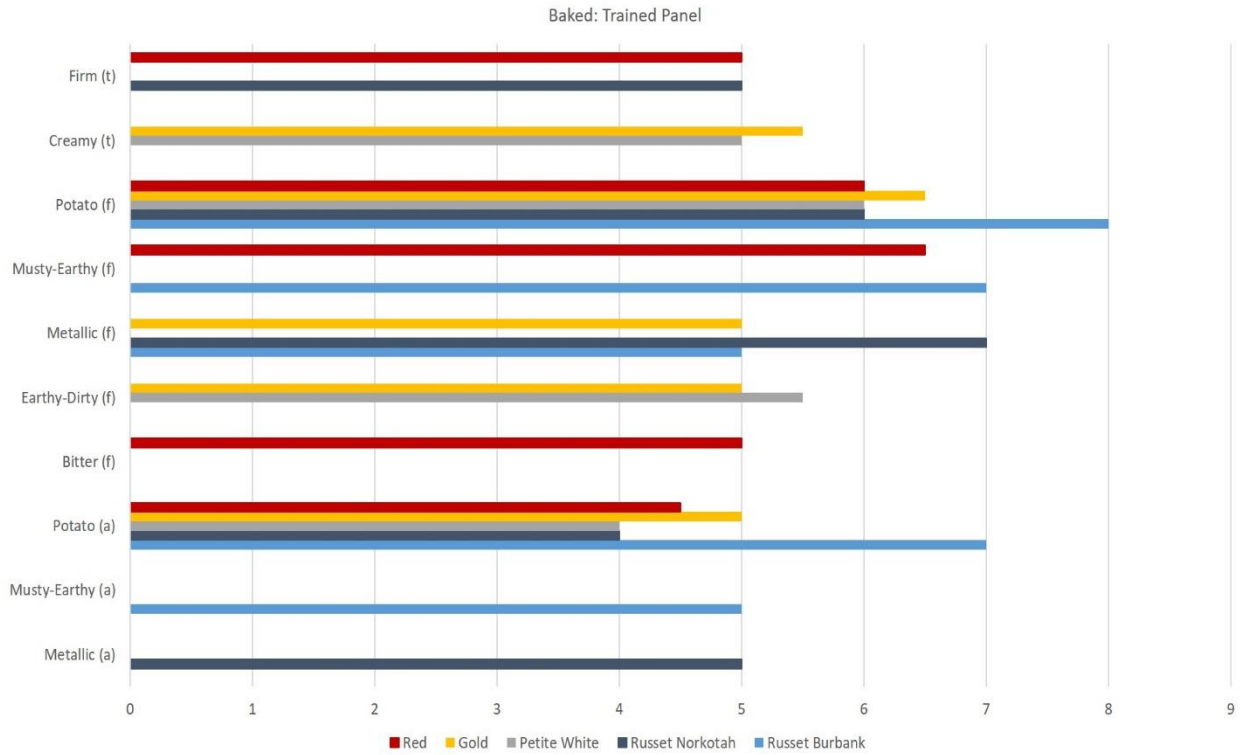
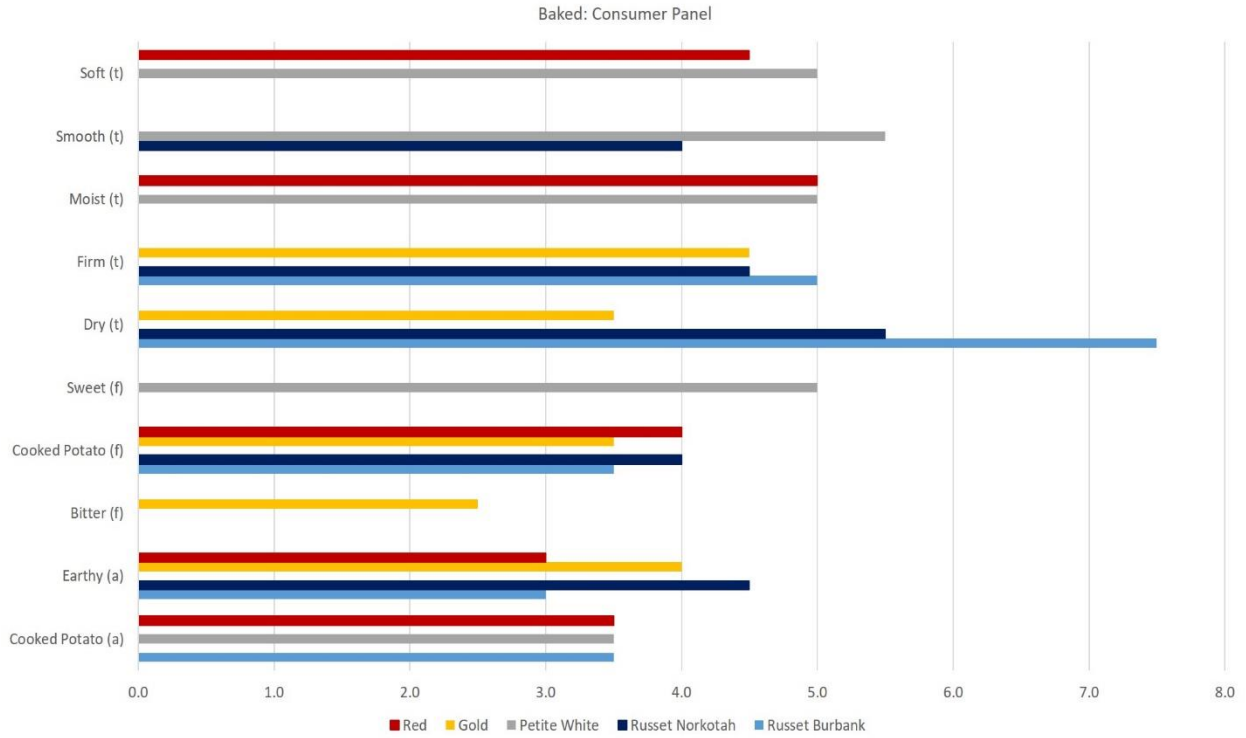


Figure 3.2 High Identity Traits (HITS) profiles of the baked potato samples for the trained and untrained panels (aroma (a), flavor (f), and texture (t)).

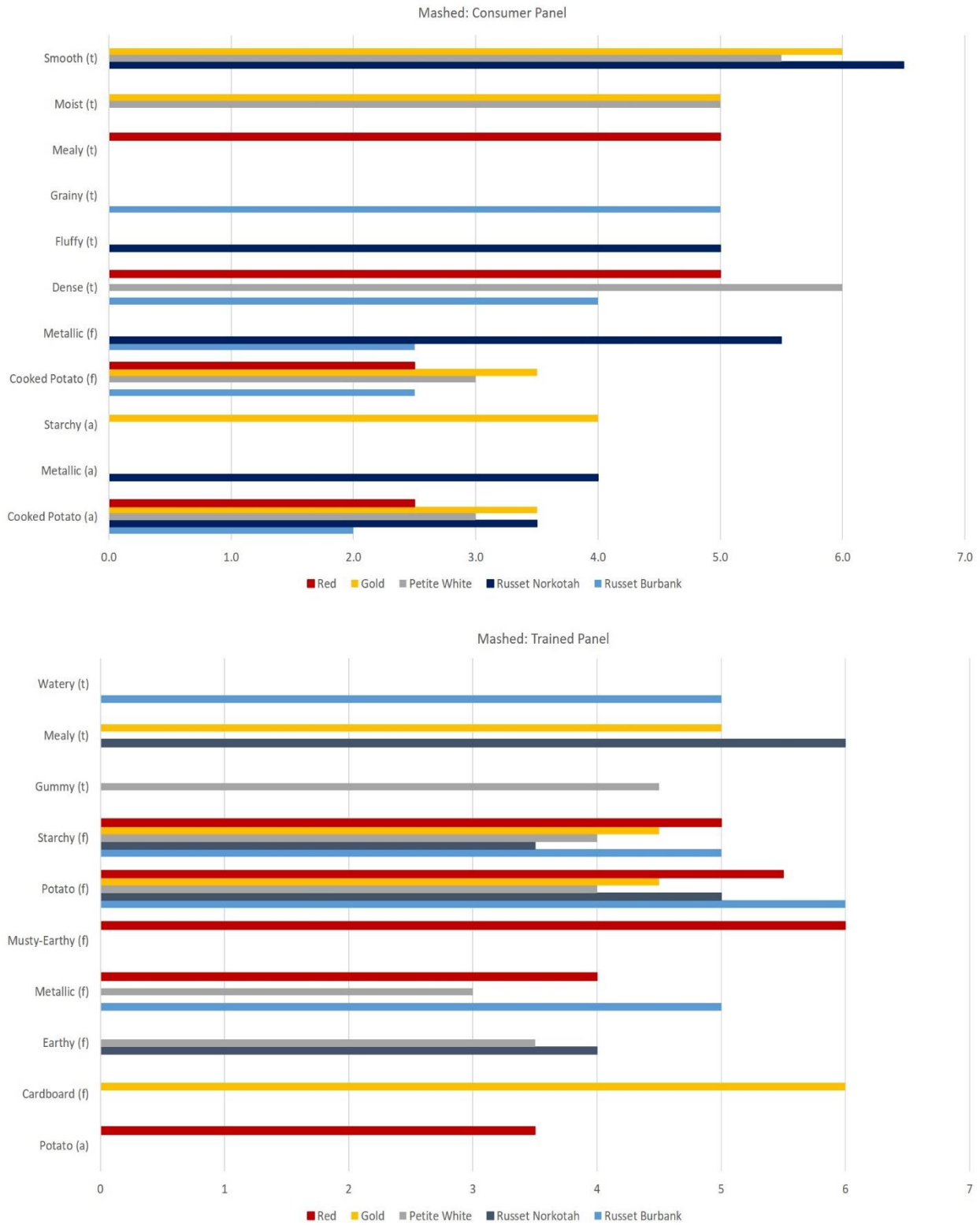


Figure 3.3 High Identity Traits (HITS) profiles of the mashed potato samples for the trained and untrained panels (aroma (a), flavor (f), and texture (t)).

The difference in the use of texture terms between trained panelists and consumers was most evident in the HITS profiles for the air fried potato samples (Figure 3.1). The trained panel used nine traits to describe the five varieties, with zero traits referring to texture. Conversely, the consumer panel developed a list of fifteen total traits, with seven for texture. Additionally, none of the traits used by the consumers for the air fried samples were used to describe all five varieties and nine of the fifteen traits were only used with one sample. As mentioned in Chapter 2, traits that were only used to describe one sample were considered differentiating traits, and nine was the highest number of differentiating traits for either the consumer or the trained panel for any cooking method. The trained panel produced only three differentiating traits for the air fried samples. The extreme differences in traits between the trained and consumer panels could be due to the dry appearance of the air fried potato samples contributing to a unique texture, as discussed in Chapter 2 (Teruel, *et al.*, 2015). When preparing the samples, it was found that the crisp exterior texture upon removal from the oven would become soggy and tough in a span of just a few minutes, so the panelists could experience different textures from sample to sample, depending on the serving timing.

Based on the developed HITS profiles, the two panels appear to have taken different approaches to dealing with the texture inconsistencies. The consumer panel chose to focus on the texture, using a number of terms to try to describe the unique exterior and interior properties. Since the consumers used a high number of differentiating texture terms, it is difficult to conclude whether they were finding that many true textural differences due to variety, or just listing traits in hopes of landing on an accurate descriptor. Alternatively, the trained panel chose to focus on only flavor and aroma traits, suggesting that they did not feel that texture was important to the differentiation of the potato varieties using the air fried method. It is also

possible that the texture of the samples was so different from sample to sample that the trained panelists decided to avoid all texture traits in fear that they would be falsely profiling sample differences. Another key difference between the panels' HITS profiles for the air fried samples was that the trained panel identified toasted, heated oil, and potato flavors in all five varieties, while the consumer panel did not use any traits for all air fried samples. Since there were traits that the samples had in common, there were fewer spots in the HITS profiles from the trained panel for differentiating traits, resulting in only three. Even though the consumer panel did not use any traits to profile all five air fried varieties, they did still use oil-related terms such as "cooking oil" and "hot oil" to describe the aroma and flavor of the samples. This supports the conclusion made in Chapter 2 that the HITS profiles of the air fried samples may be too dependent on traits related to the cooking method to produce traits that differentiate the varieties, regardless of the panelists. Finally, the consumer panel generally rated the intensities of their HITS terms higher than the trained panel, suggesting that the consumer panelists were not accurate in their use of the fifteen point intensity scale. Roberts and Vickers (1994) also found that consumers rated attribute intensities higher than a trained panel because they did not have the same context as the experienced assessors.

For the baked samples' HITS profiles, both the trained and consumer panels used a total of ten terms (Figure 3.2). The consumer panel still focused more on texture, with five overall texture traits, three for flavor, and two for aroma. The trained panel continued to focus mainly on flavor, with five flavor, three aroma, and two texture traits overall. There were some similarities between the two panels involving traits describing specific samples because both panels profiled the Russet Norkotah sample as having firm texture and the Russet Burbank sample as having an earthy aroma. These similarities are especially significant because both firm texture and earthy

aroma were only used by each panel for the baked cooking method. This means that true differences most likely exist between the sensory properties of potatoes based on cooking method because both panels were able to identify them. Both panels also used potato aroma and flavor and bitter taste to describe samples within the baked cooking method, but these traits were not unique to this preparation. While the trained and consumer panelists identified some of the same attributes, they ultimately did not differentiate any of the same samples. The trained panel described the Red, Russet Burbank, and Russet Norkotah samples using differentiating flavor and aroma traits, while the consumer panel found differentiating traits for the Petite White and Gold samples. Additionally, the trained panel rated the HITS terms at intensities that were slightly higher, on average, than the consumer panel. This is the opposite of what was seen for the air fried samples and what was found by Roberts and Vickers, but the baked samples may have presented more subtle flavors and aromas that the trained panelists have experience detecting and can rate against an established frame of reference.

The consumer focus on texture continued with the mashed samples, as the panel used six texture terms, only two flavor terms, and three aroma terms (Figure 3.3). The trained panelists used three texture terms for the mashed samples, which was the most they used for any of the three cooking methods, but they still gave higher priority to flavor, with six terms. Both panels identified mealy texture, metallic flavor, potato flavor, and potato aroma in at least one of the mashed samples, so there were a few points for direct comparison. Again, the trained panel rated the intensities of potato aroma and flavor slightly higher than the consumer panel, so the experienced panelists appeared to be more comfortable using more of the intensity scale for these traits. Metallic flavor was identified by both panels in the Russet Burbank sample, but the trained panelists rated the intensity two times higher than the consumers did. Neither panel found

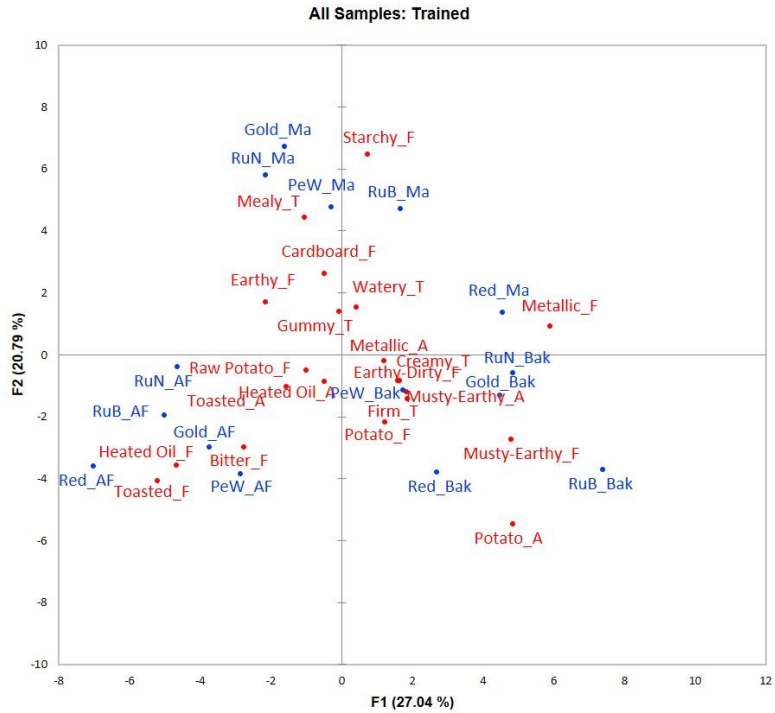


Figure 3.4 Principal Component Analysis (PCA) of aroma (A), flavor (F), and texture (T) HITS for all potato varieties and cooking methods for the trained panel.

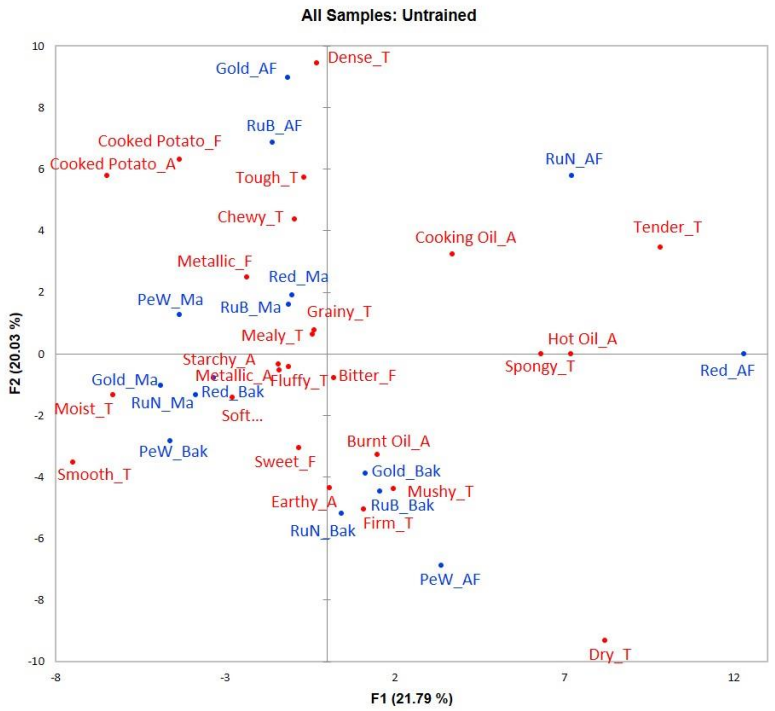


Figure 3.5 Principal Component Analyses (PCA) of aroma (a), flavor (f), and texture (t) HITS for all potato varieties and cooking methods for the untrained panel.

metallic flavor to be a highly differentiating trait, but the panels differed on which other samples were metallic. Metallic was one of the few flavor terms that the consumer panelists identified, so it seems that they are able to recognize this trait and understand how it is defined. The differences in which samples were identified as metallic by the two panels could instead be due to natural, within-variety variation. A major difference in the HITS profiles between the two panels was that the trained panelists identified starchy flavor in all five samples, while the consumer panel did not use this term for any samples. The consumer panel did identify starchy aroma in the Gold sample, but that sample was served toward the end of the session, so it possibly just took the panelists that long to place a name to the property they were experiencing. The consumer panelists were verbally provided with a list of possible terms to describe potato sensory properties during orientation, including starchy, but may not have felt comfortable enough with the term or its definition to use it during evaluation.

By comparing Principal Component Analyses for each panel, overall differences in how the two sets of assessors profiled the samples across the three cooking methods can be identified. Figure 3.4 shows the PCA results for the trained panel. The samples are clearly separated by cooking method in different quadrants of the map, with 2-3 traits driving the differentiation. The mashed samples lie in the upper two quadrants, separated by starchy flavor and mealy texture. The air fried samples lie in the bottom left quadrant, well-differentiated by heated oil and toasted flavors, as well as higher intensities of bitter flavor. The baked samples, in the bottom right quadrant, are not as well differentiated, but the profiles of the Red and Russet Burbank varieties are driven by higher intensities of musty-earthly flavor and potato aroma. The consumer panel PCA results in Figure 3.5 show that the untrained panelists differentiated most of the air fried samples from the other two cooking methods by cooking oil flavor. The air fried samples were

then separated from each other into different quadrants based on some of the many texture terms the consumers identified, such as tender, spongy, dry, and dense. This result implies that the consumers were able to differentiate samples based on texture, which supports similar findings by Chambers, *et al.* (2004). The remaining mashed and baked samples lie close to the center of the map, so they were not well differentiated from each other by the first two dimensions of analysis. This result supports the work of Guerrero, *et al.* (1997), which found that only highly trained panelists were able to discriminate products that were more similar. In this case, due to the simplified nature of HITS profiles, the mashed and baked samples were considered more similar to each other than to the air fried samples.

A cluster analysis of the samples for each panel supported the PCA findings that the trained panelists were able to identify and quantify traits that differentiated samples from the three cooking methods, while consumers' results were less easily separated. An analysis of the trained panel resulted in three clusters, with each cluster containing five samples and representing an individual cooking method. The consumer panel analysis also resulted in three clusters, but they were not equal and each cooking method was split over two clusters.

Degree of Difference

The DOD scores provide a simplified look at each panel's ability to differentiate among the five potato varieties by cooking method (Figure 3.6). As explained in Chapter 2, the DOD scores were adjusted to account for effects due to inconsistencies in sample preparation. Based on the adjusted DOD scores, both the trained and consumer panels differentiated the four non-Red samples from the control for the mashed and baked cooking methods. Additionally, both panels were able to differentiate two air fried samples from the control, with Russet Burbank as

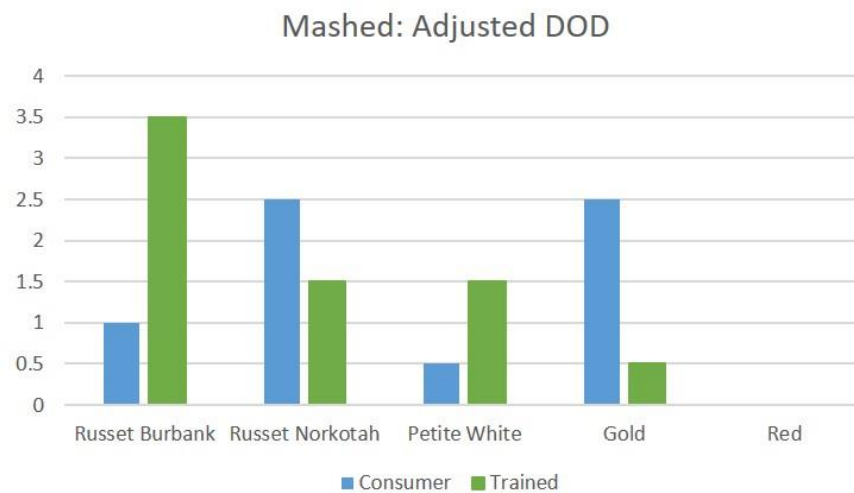
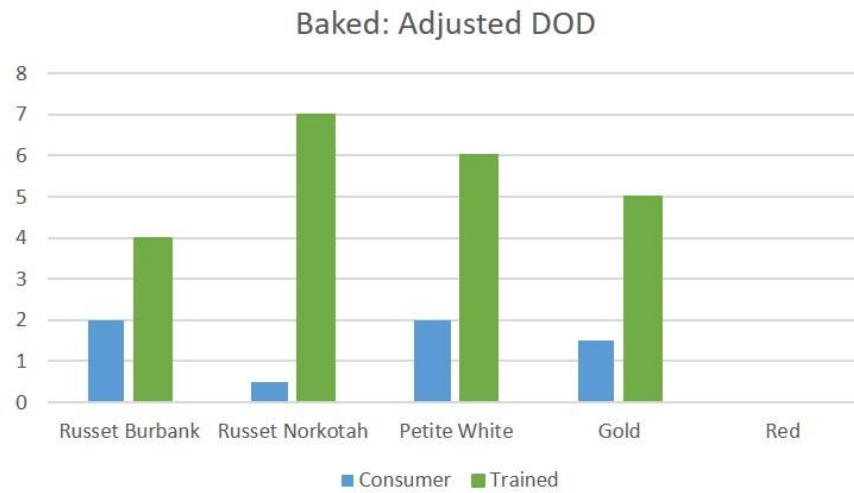
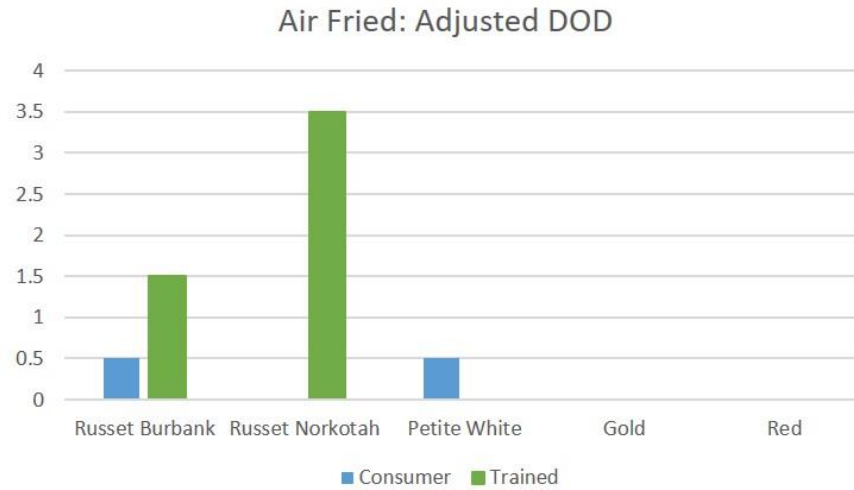


Figure 3.6 Comparison of adjusted Degree of Difference (DOD) from control scores from the consumer and trained panels by cooking method.

one of the two samples. However, the number of differentiated samples per method was the only factor the trained and consumer panels had in common for the DOD scores. For the air fried samples, the trained panelists rated the Russet Norkotah as the most different from the control, but the consumers did not find this sample to be different. Instead, the consumer panel rated the Petite White as different from the control and the DOD scores were lower for both consumer samples than the trained panelists' samples. The low DOD scores suggest that the consumers did not find true differences among the varieties, which could be based on the air fried texture distracting the consumers from any differentiating aroma and flavor traits.

The mashed cooking method allowed for differentiation of all samples from the control by both panels, but each panel scored the samples differently. The trained gave the Russet Burbank sample the highest DOD score and the Gold sample the smallest. The consumer panel scored the Gold sample with the highest DOD score, along with the Russet Norkotah. Overall, the mashed DOD scores for the two panels were the closest of the three cooking methods, so the trained panelists and consumers were at least perceiving the differences at similar magnitudes.

All samples were also differentiated from the control for the baked cooking method, but the differences were perceived to be much larger by the trained panel. The adjusted DOD scores from the trained panel were all greater than or equal to 4.0, while the scores from the consumer panel were all less than or equal to 2.0. The trained panelists found the Russet Norkotah sample to be the most different, but the consumers found this sample to be the least different. As previously discussed, the trained panelists also rated the intensities of the HITS higher than the consumers for the baked samples, so the increased awareness of the aroma and flavor traits could have resulted in the perception of greater differences from the control sample.

Conclusion

Overall, the results of this study suggest that untrained panelists are unable to develop similar sensory profiles to trained panelists using a modified HITS method. The consumer panelists were able to identify some of the same traits as the trained panel, but did not identify them for the same samples and rated them at different intensities. With the exception of the air fried samples, the consumer panel's intensity scores were lower than those from the trained panel. This was especially true for aroma and flavor traits. The differences were most likely due to the trained panelists having a more experienced frame of reference to pull from for comparison and being more comfortable using the intensity scale. The two panels also differed on the number of total traits used to describe the samples. The untrained panel identified more traits than the trained panel, with most traits describing texture properties for the samples. Texture terms seem to come most easily to consumers because they are used universally to describe products across several categories, so consumers are more familiar with the traits and their definitions. Highly trained panelists focused more on terms to describe flavor because their experience has provided them with the tools to identify and describe complex flavor notes.

When comparing the profiles of all samples for each panel, the trained panel was able to differentiate the three cooking methods into individual clusters based on the identified HITS and intensities. The untrained panel differentiated the air fried samples based primarily on texture and oil-related traits, but did not clearly separate the mashed samples from the baked samples, suggesting that consumer panels are less likely to differentiate samples with smaller sensory differences.

Since consumers were able to find differences between the samples and a control using DOD scores, it is possible that they would be capable of developing more accurate scores with

some training on the method. The HITS evaluation was more difficult for the consumers because they generally lack the ability to describe complex aroma and flavor attributes, but they may be able to develop more streamlined and accurate product profiles if they are provided with a predetermined list of terms and definitions.

The HITS method, in combination with DOD scores, can be used to differentiate samples with simplified sensory profiles, but the low number of terms used per sample can also limit the differences that are found among similar samples. Additionally, this study evaluated cooked potato products which are highly susceptible to inconsistencies based on the preparation method. Future studies using methods to compare trained and untrained panelists should consider using products that do not require preparation.

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Appendix A - Agglomerative Hierarchical Cluster Analysis

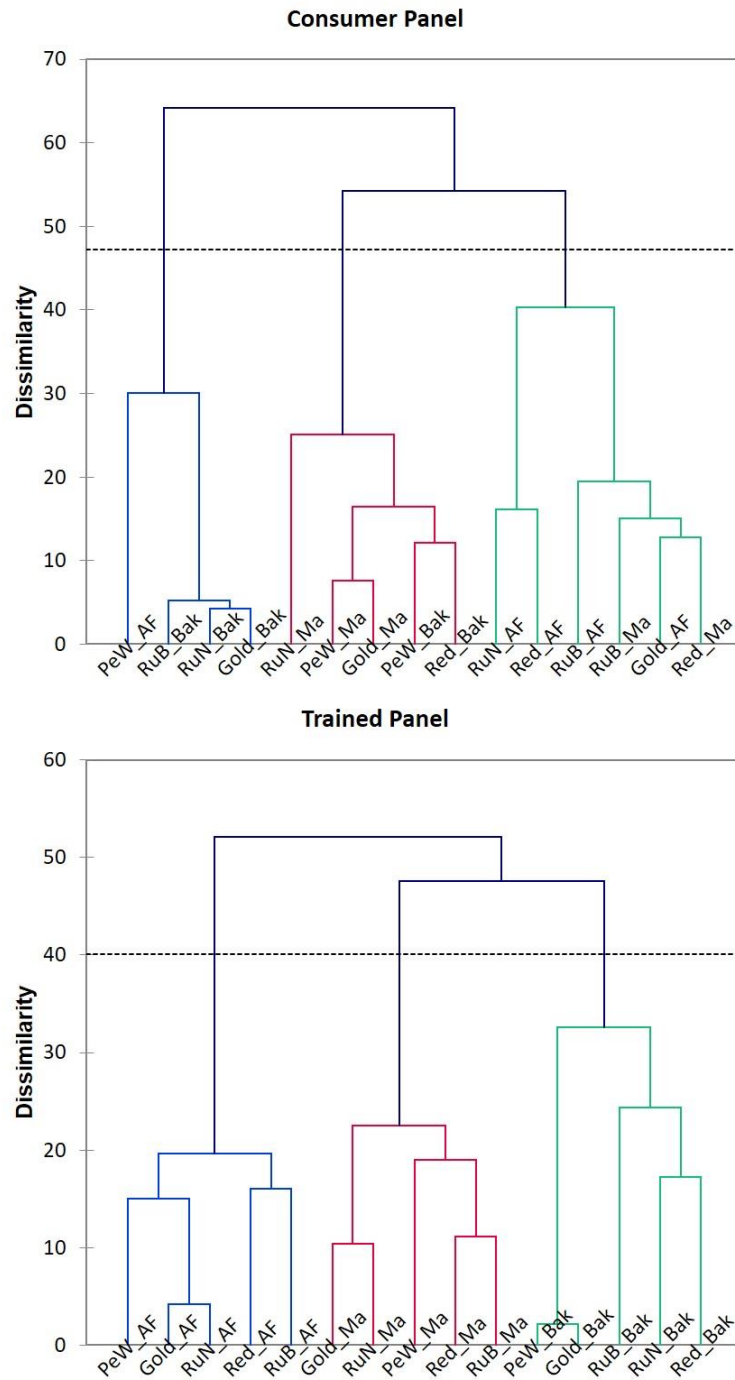


Figure A.1 Dendrograms from Agglomerative Hierarchical Cluster (AHC) analysis run with all samples for the untrained and trained panels (Air Fried (AF), Baked (Bak), and Mashed (Ma)).