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A Study of Using Mushrooms as a Plant-based Alternative for a Popular Meat-based Dish

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Abstract

Many diet-related chronic diseases are increasingly affecting to the health of the people all around the world because of their unhealthy dietary choices and habits. Nutritionists have suggested the consumers to change their food-intake patterns from the foods that contain high sugar, fat, salt and meat content to a more plant-based diet. Mushroom is one of the plant-based alternatives that can be used as a healthy substitute for meat and a mitigating agent for sodium reduction. Six beef taco blend recipes with different amount of meat, mushroom, and salt were evaluated by a group of 147 consumers, currently living in Northern California. Result from correlation analysis clearly revealed that the most important drivers of liking were flavor and texture. Appearance was not significantly correlated with overall liking. In general, consumers liked the samples without any salt reduction more than the samples with reduced salt. No meat substitute (100% beef), 50% and 80% meat substitute samples were all samples that received the highest degree of liking. The analysis of saltiness on Just-about-right (JAR) scale showed that 50% and 80% meat substitute samples were reported to have 60% just-right level of saltiness whereas 100% beef sample got only 48%. Four clusters were obtained from cluster analysis based on overall degree of liking. Consumers in the first cluster like 100% beef and 80% meat substitute samples. The second cluster was the largest cluster. They preferred to eat meat/mushroom blends. The third cluster was a group of plant based-diet consumers. They disliked 100% beef sample but liked all mushroom-based blends. The last cluster was a group of consumers who liked 100% beef sample most. Among all four clusters, this group of consumers tended to give lower hedonic scores all over samples than the others groups. These findings could be useful to devise culinary strategies and sensory insights to improve the flavor and consumer appeal of health-promoting plant-based foods without negatively affecting nutrition quality.

Keywords : *Mushroom, Meat substitute, Plant-based diet, Cluster analysis, Drivers of liking*

1. Introduction

The dramatic increases in obesity and any chronic diseases in the United States were reported mainly to unhealthy dietary choices and habits (Garcia, Sunil et al. 2012). Food professionals have suggested consumers to alter eating patterns from a food that contains high fat and meat to a more plant-based diet. Unfortunately, evidence shows that those plant-based diets (i.e., produce, whole grains, nuts, seeds, and legumes) are not attractive consumers to consume when compared with less healthful foods (Tucker 2014, Graça, Oliveira et al. 2015).

Salt (Sodium chloride) has traditionally been known and used for cooking. It can improve the sensory properties of foods by increasing saltiness and by enhancing some pleasant flavors for many dishes around the world. However, high consumption of sodium will lead to hypertension, cardiovascular disease and stroke (Mouritsen 2012, Jackson, Coleman King et al. 2015) . Therefore, it is important to develop alternative strategies to reduce the sodium uses in foods which are able to maintain the sensory properties and consumer acceptance.

Mushroom is one of the natural ingredients that contains glutamic acid, a natural version of the flavor enhancer monosodium glutamate (MSG). Unlike MSG, the natural occurring glutamic acid does not have high sodium content. MSG and other amino acids are flavor enhancers and increase the palatability (pleasantness) of foods (Yamaguchi and Ninomiya 1999). Prescott (2001) did some studies on a set of food products including salmon cakes, chicken soup, and spring roll with and without adding MSG formulas by asking the participants to rate the sensory attributes (richness, acceptability, saltiness, sweetness, and natural tastes).

Table 1 Sensory attributes for cooked mushrooms

Attribute	Definition
Overall aroma	Intensity of all aroma attributes taken together
Overall flavor	Intensity of all flavor by mouth attributes taken together
Raw mushroom	Aroma and flavor characteristic associated with raw mushroom
Moss/wet soil	Aroma and flavor characteristic associated with moss or wet soil
Earthy	Aroma and flavor characteristic associated with dry mud or dirt
Nutty	Aromatic associated with nuts or nut meats; character associated with Maillard reaction products, starches, and sugars
Buttery	Aroma and flavor characteristic associated with butter
Yeasty	Aroma and flavor characteristic associated with yeast and fermented products such as bread or beer
Rancid/stale oil	Aroma or flavor associated with rancid oil; gives a mouth-coating sensation and/or a bitterness perceived on the back of the tongue
Smoky	Aroma and flavor characteristic associated with any type of smoke; may be phenolic or tar-like
Caramelized	Browned character associated with Maillard reaction products, starches, and sugars
Burnt/charred	Aroma and flavor characteristic associated with heated, scorched, or blackened substances
Toasted/roasted	Browned character of Maillard reaction products, starches and sugars; aroma and flavor characteristic associated with roasted nuts and coffee beans
Cardboard/paper	Aroma and flavor characteristic associated with slightly oxidized fats, reminiscent of wet cardboard
Salty	Basic taste on tongue stimulated by sodium chloride
Umami	Taste on tongue produced by substances such as monosodium glutamate (MSG) in solution; a meaty, savory, or mouth-filling sensation
Bitter	Basic taste on tongue stimulated by solutions of caffeine, quinine, and other alkaloids
Sour	Basic taste on tongue stimulated by acids
Sweet	Basic taste on tongue stimulated by sugars and high potency sweeteners
Astringent	Puckering and palate drying sensation
Oily/greasy	Ease with which tongue, sample, and roof of mouth glide relative to each other due to the oil and/or grease present in the sample
Moist/juicy	Inherent moistness of mass
Chewy	Requiring much chewing
Crispy/crunchy	Sound modifier, integrated term (hard, dense, and sound)
Soft-hard	Resistance to strain when force applied
Rubbery/spongy	Returns to original shape, tendency to act like a rubber band after manipulation

Table 2 Sensory attributes for beef taco blend.

Attribute	Definition
Overall aroma	Intensity of all aroma attributes taken together
Overall flavor	Intensity of all flavor by mouth attributes taken together
Meaty	Aroma and flavor characteristic associated with cooked meat
Mushroom	Aroma and flavor characteristic associated with mushrooms
Veggie	Aroma and flavor characteristic associated with vegetables
Onion	Aroma and flavor characteristic associated with onion
Garlic	Aroma and flavor characteristic associated with garlic
Black pepper	Characteristic sharp, penetrating aroma and hot, biting flavor
Spicy (cumin, chili, and paprika)	Aroma and flavor characteristics associated with the spices cumin, chili pepper, and paprika
Rancid/stale oil	Aroma or flavor associated with rancid oil; gives a mouth-coating sensation and/or a bitterness perceived on the back of the tongue
Smoky	Aroma and flavor characteristic associated with any type of smoke; may be phenolic or tar-like
Earthy	Aroma and flavor characteristic associated with dry mud, dirt, or damp soil
Burnt	Aroma and flavor characteristic associated with heated, scorched, or blackened substances
Pungent—spicy hot	Sharp trigeminal sensation perceived in the nasal passage and oral cavity
Salty	Basic taste on tongue stimulated by sodium chloride
Umami	Taste on tongue produced by substances such as monosodium glutamate (MSG) in solution; a meaty, savory, or mouth-filling sensation
Bitter	Basic taste on tongue stimulated by solutions of caffeine, quinine, and other alkaloids
Sour	Basic taste on tongue stimulated by acids
Sweet	Basic taste on tongue stimulated by sugars and high potency sweeteners
Acidic	Basic taste on tongue stimulated by acids
Astringent	Puckering and palate drying sensation
Oily/greasy	Ease with which tongue, sample, and roof of mouth glide relative to each other due to the oil and/or grease present in the sample
Moisture	Inherent moistness of mass
Chewy/tough	Requiring much chewing
Crispy/crunchy	Sound modifier, integrated term (hard, dense, and sound)
Firmness	Resistance to deformation
Rubbery/spongy	Returns to original shape, tendency to act like a rubber band after manipulation

He found that adding MSG to each of these foods significantly increased rating scores of richness and acceptability. Some food samples were reported to be saltier with the addition of MSG, while "sweetness" and "natural taste" did not increase. Yamaguchi and Ninomiya (1999) also described results from the United States Army, who tested the effects of MSG on 50 foods that they added MSG to. Results showed that food preferences of 28 foods were improved when MSG was added, 18 were unchanged, and four worsened. The researchers found that not all foods were improved when

adding MSG. Meat, fish, and canned vegetables or recipes containing these foods were improved by MSG. Interestingly, this

indicates that adding MSG to amino acid rich foods further enhances their flavor. This implies that adding mushrooms to other protein rich foods increases overall palatability. Conversely, cereals, milk products, or sweet-flavored recipes were made worse by the addition of MSG.

The main purpose of this proof-of-concept research is to determine how much salt and meat reduction in a popular meat dish can be achieved through substitution with mushroom without compromising the sensory quality and acceptability of the dish. The goal of this collaboration between culinary experts and chefs from the Culinary Institute of America (CIA) and sensory, nutrition and consumer research experts from UC Davis is to increase consumer preference of culinary preparations and menu choices that are in line with national recommendations to reduce salt intake and increase consumption of plant foods. For this proof-of-concept stage of the research, a classic recipe (beef taco blend) was selected to determine how much meat can be substituted with mushroom while maintaining high liking from consumers.

Table 3 the composition of the beef taco blend Recipes

Sample ID	Salt content	Meat content	Mushroom content	Beef content
100B	None	0% (none)	100%	0%
100B/25LS	25%	0% (none)	100%	0%
50M50B	None	50%	50%	50%
50M50B/25LS	25%	50%	50%	50%
80M20B	None	80%	80%	20%
80M20M/25LS	25%	80%	80%	20%

2. Materials and Methods

Samples

A set of white mushrooms was prepared using four different cooking methods – seared, sautéed, steamed and roasted and evaluated by the Quantitative Descriptive Analysis panel. A total of six beef taco blend recipes as shown in Table 3 differing in salt and meat levels were used for sensory evaluation. The recipes were developed by a CIA chef-instructor with varying amount of salt and ratios of meat and mushrooms as well as cooking methods for the mushrooms. The recipes were prepared, cooled, vacuum sealed in rethermalization bags, and frozen at the CIA in Greystone. On testing days, the samples were transported to UC Davis, rethermalized and portioned for testing at the sensory facilities of the Robert Mondavi Institute for Wine and Food Science at UC Davis.

Descriptive analysis

The intensity of sensory attributes of the mushrooms preparations (Table 1) and beef taco blend (Table 2) was evaluated in triplicate by a trained panel of 13 judges (7 male, 6 female) using Quantitative Descriptive Analysis method. A randomized complete block design was used for each training session and the actual sessions. The intensity of each attribute was evaluated

across the products on an unstructured, 10-cm line scale in the order.

All products were served in 2 oz plastic portions cups. Approximately 1 oz of each product (mushrooms and beef taco blends) was placed into each portion cup and covered with a plastic lid. The samples were kept in a tired steamer to keep them warm and then removed from the steamer and placed onto individual serving trays. Serving temperature ranged from 50-60 ˚C. The tests were conducted in isolated booths with proper lighting and pressure. Judges rinsed between samples with filtered drinking water and all samples were expectorated. All instructions, scale presentations, and data collection were carried out using the FIZZ software version 2.45A (Biosystemes, Couternon, France).

Consumer study

The sensory acceptability of the products was assessed by 147 consumers – users and likers of meat, vegetable, and mushroom-based dishes from the Davis and Sacramento areas, representing three age groups (18-30; 31-45; 45-65), with fairly even gender representation. Each consumer was assigned a log number, given a brief explanation of the test objectives and seated at a test booth with partitions in Sensory Theater of the Robert Mondavi Institute for Wine and Food Science at UC Davis. All protocols for this study were approved by the Human Subjects Committee of the UC Davis Office of Research. Once seated and briefed, each person received a questionnaire packet including tasting part and exit survey. Each consumer was provided with a set of 6 spoons, napkins, unsalted tacos and a cup of water. Approximately 1 oz of each recipe of beef taco blend was placed into each portion cup and covered with a plastic lid. Samples were presented on a white plastic tray and identified by three digit codes. The order of presentation of the samples was completely randomized and a William's Latin square design provided by the FIZZ sensory software version 2.45A (Biosystemes, Couternon, France). The order was applied to balance out any potential serving order or carry-over effects. The 9-point hedonic scale anchored from "dislike extremely" to "like extremely" was used to assess the acceptance of the various products (overall liking, liking of appearance, flavor, and texture). Then they assessed levels of saltiness on 5-point just-right (JAR) scale. Finally, consumers completed an exit survey that assessed their demographics and consumption behavior.

Data Analysis

The descriptive analysis data was analyzed using univariate statistics. The descriptive results were presented by spider web plots as a product sensory profile. The consumer hedonic rating scores were also analyzed using a univariate statistics. ANOVA was performed to assess differences in acceptance among the samples. To find the driver of liking, correlation analysis was performed. Overall liking was predicted by using consumer liking of appearance, flavor, and texture/mouthfeel as predictors. The matrix of hedonic ratings of samples across consumers was then analyzed for cluster analysis to assess preference market segmentation. Frequency was summarized for Just-about-right scale data, categorical preference, and demographic data from exit surveys. All the statistical analyses were performed using SAS version 9.3 (SAS Institute Inc., N.C., U.S.A.) for Windows, XLSTAT 2012 for Windows (Addinsoft, Paris, France).

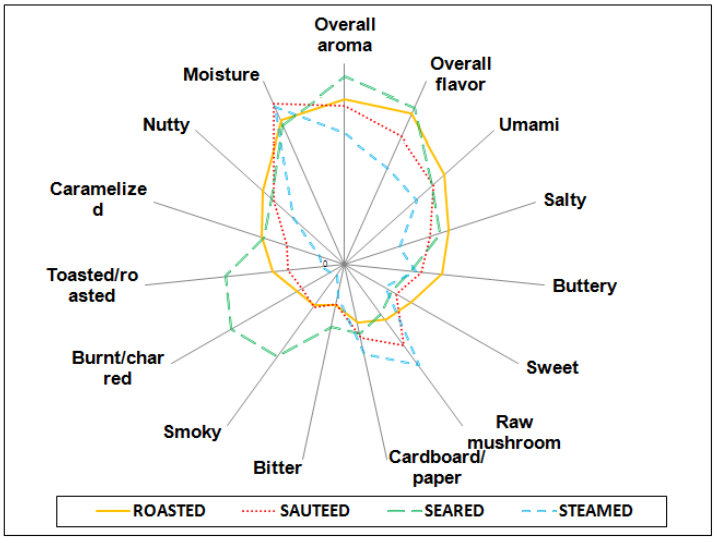

Figure 1. Sensory profiles of mushrooms cooked by 4 cooking techniques-roasted, sautéed, seared, and steamed. Only attributes that were significant differences were found among the 4 preparations are included in the spider plot ($p<0.05$)

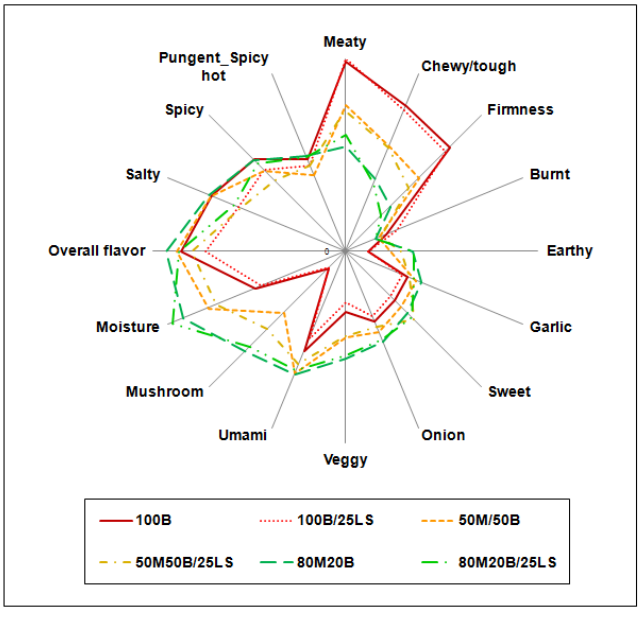

Figure 2. Sensory profiles of beef taco blend. All attributes that were significant differences were found among the 6 recipes are included in the spider plot ($p<0.05$) except salty attribute

3. Results and Discussion

Effect of cooking method on mushroom sensory quality

A significant effect of cooking method on sensory quality was found (Figure 1). Seared technique had the highest intensity of overall aroma, overall flavor attribute but this cooking method also provided highest in bitter, smoky, brunt/charred, toasted/ roasted. Roasted mushrooms gained strongest ratings in umami, salty, buttery, sweet, and nutty attributes. Steamed mushrooms had higher intensity on cardboard/paper and raw mushroom flavor. Finally, sautéed and steamed technique had higher intensity in moisture attribute than roasted and seared methods. Based on the highest overall aroma and flavor, seared technique would be used to provide the overall aroma and flavor in foods. However, roasted mushrooms could be used to provide the highest umami taste. Nevertheless, in consumer study, CIA chefs chose to use sautéed method because this method showed lower moisture loss than other method. Furthermore, sautéed method is more convenient for a large-batch production. To date, there has not been any study of the effect of cooking method on the flavor of mushrooms, thus this result should be the beginning step on how the cooking method affects the sensory profile of the mushroom.

Effect of mushroom substitution on beef taco blend sensory quality

Mushroom substitution clearly did some effect on the sensory quality of beef taco blend. Figure 2 shows that the recipes with 50% or 80% of the meat substituted with mushroom (without salt reduction) did have a significantly higher overall flavor, moisture, mushroom, umami, veggy, onion, sweet, garlic, and earthy but lower meaty, chewy/tough, and firmness than those with 100% beef recipe ($p<0.05$). This result met our expectation that the meat substituted recipes should have higher intensities of mushroom, earthy, umami, and veggie related flavors. However, the using mushroom as the flavor enhancer in meat-based dishes had not been studies yet.

Effect of mushroom substitution on sodium reduction on beef taco blend sensory quality

Based on descriptive result (Figure 2), 80% of the meat substituted with mushroom with 25% sodium reduction recipe received the overall flavor closed to non-sodium reduction of 100% and 50% beef content recipes. Thus the substitution of 80% meat with mushroom with 25% sodium reduction could reduce the use of sodium without difference in overall flavor, even if it did not compensate for the reduction in salty taste.

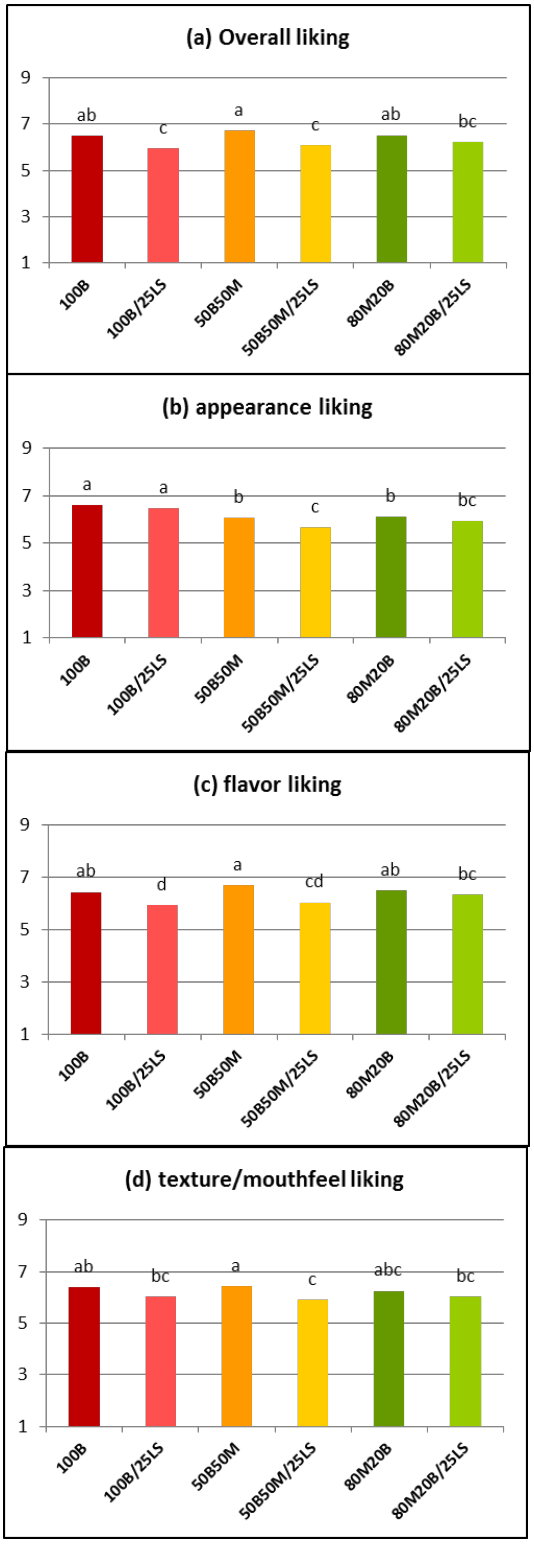

Figure 3. Mean hedonic ratings of 6 beef taco blend recipes for (a) overall degree of liking; (b) appearance liking; (c) flavor liking; and (d) texture/mouthfeel liking (n=147 consumers).

Mouritsen (2012) did a mini-review on addition of glutamate in foods. He found that adding glutamate to the foods was able to reduce 30-40% amount of salt used in foods without affecting the palatability.

Table 4. Pearson's correlation coefficients (df = 6-2 = 4)

Variables	Overall liking	Appearance liking	Flavor liking	Texture/ mouthfeel liking
Overall liking	-	0.131	0.971	0.919

Note: Values in bold are significant at alpha=0.05 or lower

Overall liking showed the highest correlation to flavor liking, then followed with texture liking. Appearance liking was not significantly correlated to overall liking (Table 4). This result suggested that flavor and texture are the drivers of overall liking for beef taco blend.

Consumer acceptance of beef taco blend

In general, consumers liked the samples without salt reduction more than the ones with reduced salt ($p<0.05$) (Figure 3). Overall degree of liking, flavor liking, and texture/mouthfeel liking indicated the same pattern that all recipes without salt reduction got the highest degree of liking. The significant difference on liking score was not found among 100% beef , 50% and 80% of the meat substituted with mushroom (without salt reduction) recipes ($p>0.05$). In case of appearance liking, consumers preferred the samples that were not substitute with mushrooms more than the substituted ones.

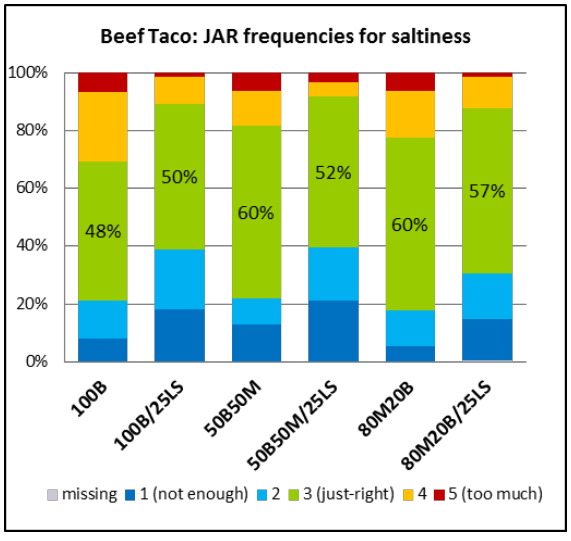

Figure 4. Frequency percentages for JAR (Just-About Right) level of saltiness of 6 beef taco blend recipes

All 6 beef taco blend recipes, except 100% beef recipe, were reported to have just-right saltiness more than 50%. However, it should be noted that the just-right saltiness decreased in all salt reduced samples and were reported to be not salty enough for 30% or more of total frequencies (Figure 4). When compared 100% beef recipe, 50% and 80% of the meat substituted with mushroom (without salt reduction) recipes got higher percentages of just-right saltiness.

Consumer segmentation

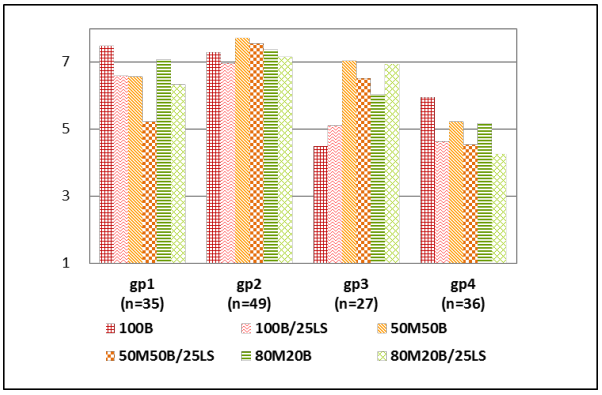

Figure 5. Mean hedonic ratings of the 6 beef taco blend recipes for the 4 preference clusters

Four clusters were obtained from cluster analysis and their mean scores are shown in Figure 5. Consumers in cluster 1 tended to like 100% beef and 80% of the meat substituted with mushroom (without salt reduction) but they disliked 50% of the meat substituted with mushroom (with salt reduction). In cluster 2, consumers did not show any clear preference for any specific recipes. This group, in general, gave high ratings for all tested samples. Cluster 3 was accounted for consumers who disliked 100% beef both with and without salt reduction. Consumers in cluster 4 preferred all recipes that were not reduced of salt but they were not preferred all salt reduction recipes. This group of consumers gave generally low ratings for all tested samples but they liked 100% beef sample most.

4. Conclusion

Different cooking techniques affect the mushroom sensory profile. Seared mushrooms gave the highest overall flavor and overall aroma which can be potentially used as the flavor enhancer. However, roasted mushroom should be selected to have highest umami tastes. The recipes with 50% or 80% of the meat substituted with mushroom (without salt reduction) did have a significantly higher overall flavor than those with 100% beef recipe. Moreover, 80% of the meat substituted with mushroom with 25% sodium reduction recipe received the overall flavor closed to non-sodium reduction of 100% and 50% beef content recipes. Consumers preferred the recipes without salt reduction more than the ones

that reduced salt. No significant difference on liking scores was found among full-salt recipes. Thus 50% and 80% of the meat substituted with mushroom recipes could be some alternatives to apply for the health -promoting plant-based foods which can maintain both sensory and nutrition quality.

5. Acknowledgements

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