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Consumer acceptance of dishes in which beef has been partially substituted with mushrooms and sodium has been reduced

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ABSTRACT

We tested the hypothesis that because of their flavor-enhancing properties, mushrooms could be used as a healthy substitute for meat and a mitigating agent for sodium (salt) reduction without reduction in sensory appeal among consumers. In a fully-randomized design for each product, 147 consumers evaluated blind two carne asada and six taco blend recipes in which beef had been partially substituted with mushrooms and/or salt had been reduced by 25%, for overall liking, liking of appearance, flavor, texture and mouth feel on the 9-point hedonic scale, and adequacy of level of saltiness, spiciness and moistness on 5-point just-about-right (JAR) scales. Overall consumer acceptance of the carne asada, and liking for its appearance, flavor and texture/mouth feel decreased significantly when half the steak was substituted with mushrooms. The taco blend recipes with full sodium were also liked more overall than those with 25% less sodium. But there was no significant difference in overall liking among the three full-salt recipes, nor among the three reduced-salt recipes, indicating that across the consumer population we tested, acceptance of the mushroom-containing recipes was on par with that of the 100% beef recipe. The preference mapping analysis of the overall liking ratings of the taco blends uncovered four preference segments, two of which, representing a majority of the consumers, gave higher acceptance scores to the mushroom-substituted recipes. Furthermore, the largest preference segment liked the full- and reduced-sodium recipes equally, and another liked the reduced-sodium recipes significantly more. This research demonstrates that through their flavor enhancing properties, mushrooms can be used successfully to substitute for beef and even possibly mitigate sodium reduction without significant change in acceptance for a majority of consumers.

1. Introduction

In issuing the *2015 Dietary Guidelines for Americans*, the USDA and the USDHHS called for consumers to "consume a healthy eating pattern that includes a variety of vegetables from all the subgroups-dark green, red and orange, legumes (beans and peas), starchy and other; fruits, especially whole fruits; grains, at least half of which are whole grains; and a variety of protein foods, including seafood, lean meats and poultry, eggs, legumes (beans and peas), and nuts, seeds and soy products" (http://health.gov/dietaryguidelines/2015/). The Guidelines further called out the value of such largely plant-based dietary patterns as the traditional, healthy Mediterranean diet, which is associated with reduced rates of chronic diseases and increased life expectancy. The icon illustrating the messages of the Dietary Guidelines, *MyPlate*, represents an optimal American dinner plate on which half of the main area is filled with fruits and vegetables (http://www.choosemyplate.gov/). Unfortunately, there is ample evidence to suggest that for many of the foods that nutrition researchers are urging Americans to eat more

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of—especially produce, whole grains and legumes—liking, or sensory appeal, is low in comparison to other foods (Fabbri & Crosby, 2016; Poelman, Delahunty, & de Graaf, 2013). And by contrast, the foods that nutrition experts are urging consumers to avoid often have high sensory appeal because of their high sugar, high salt, and high fat content – all compounds for which we have an innate liking (Beauchamp & Engelman, 1991; Bowen et al., 2003; Drewnowski, 1997; Drewnowski, Mennella, Johnson, & Bellisle, 2012; Obbagy, Condrasky, Roe, Sharp, & Rolls, 2011). When devising culinary and sensory strategies to increase consumption of plant-based foods and fish, the culinary community is being asked to use less sodium, to reduce the use of ingredients with high levels of saturated fat like cheeses and meats, and to minimize the use of highly refined carbohydrate products. Clearly, the challenge of developing healthful foods with high consumer appeal underscores the need for integrated culinary, sensory, and consumer research in this area.

Nutritionally, mushrooms are low in energy, fat and sodium (5 mg/100 g of raw white), but high in protein, carbohydrate, and dietary fiber (USDA National Nutrient Database, 2011). They contain a variety of minerals and trace elements such as potassium and copper, and vitamins such as riboflavin, niacin, and folates. Bioactive secondary metabolites found in mushrooms include phenolic compounds, sterols and triterpenes, all with documented antitumor, antioxidant, antiviral, hypocholesterolemic and hypoglycemic effects (Cheung, 2008, 2010). What made mushrooms an attractive candidate for this proof-of-concept study, though, was the fact that they contain umami tastants glutamic acid, aspartic acid and 5′-ribonucleotides (Cheung, 2010; Liu, Vijayakumar, Hall, Hadley, & Wolf-Hall, 2005; Yang, Lin, & Mau, 2001; Zhang et al., 2013) which also have flavor enhancing properties (Fuke & Shimizu, 1993; Fuke & Ueda, 1996; Hong, Kwon, & Kim, 2012; Manabe, Ishizaki, Yoshioka, & Oginome, 2009; Zhang, Venkitasamy, Pan, & Wang, 2013).

Sodium improves the sensory quality of foods by increasing their saltiness and by enhancing other flavors (Keast & Breslin, 2003; Kemp & Beauchamp, 2006). In industrialized nations, about 75% of sodium in the diet comes from manufactured foods and foods eaten away from home (Liem, Miremadi, & Keast, 2011). Despite well documented negative health consequences and associated health care costs of high sodium consumption, most developed nations consume well above the recommended levels of sodium, thus making sodium reduction in the diet a public health priority (Cordain et al. 2005). Various strategies have been applied to reduce sodium in foods, with the 'stealth' approach of gradual sodium reduction and consumer habituation thereof showing the most promise (Liem et al. 2011).

Our hypothesis is that consumer acceptance of foods in which sodium has been reduced can be maintained by using healthy principles with flavor-enhancing properties. Specifically, we assessed whether mushrooms could be used as a healthy substitute for meat and a mitigating agent for sodium reduction because of their flavor-enhancing properties.

We first showed that because of their umami principles (Zhang et al. 2013), mushrooms can be used as a healthy substitute for meat and a mitigating agent for sodium reduction in meat-based dishes without loss of overall flavor (Myrdal Miller et al. 2014). We measured the effects of beef substitution with crimini or white mushrooms (*Agaricus bisporus*) on the flavor profiles of carne asada and beef taco blends with a descriptive analysis panel. Sensory mitigation of sodium reduction through the incorporation of mushrooms was also investigated in the taco blends. The substitution of beef with mushrooms in the carne asada did not alter the overall flavor strength of the dish, but the incorporation of 50 or 80% ground mushroom in the beef taco blend did enhance its overall flavor as well as mushroom, veggie, onion, garlic and earthy flavors, and umami and sweet tastes. Overall flavor intensity of the 25% reduced-salt version of the 80% mushroom taco blend matched that of the full-salt versions of the 100% and 50% beef formulations, thus indicating that the substitution of 80% of the meat with mushrooms did mitigate the 25% sodium reduction in terms of the overall flavor impact of the dish, even if it did not quite compensate for the reduction in salty taste (Myrdal Miller et al. 2014).

We then tested the consumer acceptance component of our hypothesis. Could consumer acceptance of meat-based dishes in which meat had been substituted with mushrooms and sodium had been reduced be maintained? The outcomes of our consumer research are presented herein.

2. Materials and methods

2.1. Development, formulation and preparation of the carne asada and taco blend recipes

We first developed and bench-tested various recipes for carne asada and beef taco blends in which meat had been partially substituted with mushrooms and sodium reduced (Myrdal Miller et al. 2014). While CIA chefs preferred the intense meat flavor and texture developed through roasting, they recommended sautéing the mushrooms for both the taco blend and carne asada since it is a quicker cooking method (compared to roasting) that can be done in large batches in volume foodservice operations. Representatives from the Mushroom Council supported this recommendation due to lower moisture losses with this cooking method, losses that would impact food costs for the final dish, another important consideration for volume foodservice operations. The team agreed that the mushrooms for carne asada should be diced the same way the steak was. This distinction allowed us to compare the respective effects of the mushrooms, side-by-side or mixed within, on the flavor appeal of each dish. White mushrooms were selected for the taco blend due to cost. CIA chefs recommended using Crimini mushrooms for the carne asada because of their size, density, flavor and perceived value. Based on existing research that shows that few consumers can detect the first 20% reduction in sodium (Beauchamp, Bertino, Burke, & Engelman, 1990; Bolhuis et al., 2011), and on bench testing of various salt-reduced versions of the recipes as well as the potential umami flavor benefits of mushrooms, we elected to go with a 25% sodium reduction for the reduced-sodium versions of the dishes.

A total of six (6) beef taco blend recipes differing in added salt and meat/mushroom ratios and two (2) carne asada recipes differing in meat/mushroom ratios were formulated as shown in

Table 1
Recipe composition and codification.

Sample ID	Meat substitution level	Mushroom content	Steak content
Carne asada			
100STEAK	0% (none)	0%	100%
50ST/50MR	50%	50%	50%

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

Table 1. Nutrition analysis for the recipes was conducted by a CIA Registered Dietitian using Nutritionist Pro software (Axxya Systems, Version 4.7.0). The culinary protocol for this study, the recipes, and complete nutrition information are available from the authors upon request. The recipes were prepared, cooled, vacuum sealed in rethermalization bags, and then frozen at the CIA. On testing days, the samples were transported to UC Davis, warmed in water baths to 160 °F, and portioned for testing at the sensory facilities of the Robert Mondavi Institute for Wine and Food Science. Thirty-gram portions of all samples were used for this study.

2.2. Consumer tests

One hundred and forty seven (147) users and likers of meat-, vegetable- and mushroom-based dishes participated in this study. Recruitment materials specified "We are looking for consumers to participate in a joint UC Davis and Culinary Institute of America study of ground beef, vegetable and mushroom tacos and related recipes". The desired number of consumers was determined by power analysis based on a minimum detectable difference of 1 point on the 9-point hedonic scale – a well-established value in consumer testing with that scale. Recruited primarily from the Davis and Sacramento areas of Northern California, the consumer population was pre-segmented for gender (42% men, 58% women) and age (even distribution among 18–29, 30–44 and 45–60 years age groups). Sessions were held on a Friday and a Saturday at lunch (12–2 p.m.) or dinner (5–7 p.m.) time and lasted about 45 min. Consumers received a $30 gift certificate for their participation in the study.

The products were presented as "carne asada" and "taco blend" samples, respectively. Consumers rated their degree of liking of the recipes – overall degree of liking, and liking of appearance, flavor and texture on the 9-point hedonic scale from 1 = 'dislike extremely' to 9 = 'like extremely', with 5 = 'neither like nor dislike' (Peryam & Pilgrim, 1957). They also assessed the levels of saltiness, spiciness and moistness on a 5-point 'just right scale' with 1 = 'not salty enough' to 5 = 'much too salty', with 3 = 'just right' (Lawless & Heymann, 2010). Within each recipe type, the order of presentation of the recipes was randomized across consumers. After evaluating the recipes, consumers completed an exit survey about their demographics, attitudes and food usage.

Upon review of the human subject protocol, this study was deemed exempt by the University of California, Davis Institutional Review Board.

2.3. Data analysis

The consumer hedonic ratings were analyzed using a combination of univariate and multivariate statistics. Occasional missing data was replaced with relevant least square mean scores which could be defined as a linear combination of the estimated effects from a linear model. Analysis of variance (ANOVA) was performed to assess differences in acceptance among the samples and means were compared using Duncan's Multiple Range Test. A correlation analysis among the hedonic ratings was performed across the samples to investigate the relation between 'overall degree of liking' and liking for specific attributes. The matrix of hedonic ratings of samples across consumers was then analyzed by cluster analysis and principal component analysis for preference mapping purposes – a combination of factor analysis and classification methods designed to assess preference market segmentation and to identify drivers of liking for the uncovered market segments. Additional ANOVAs were run on the hedonic ratings across all consumers with products, (preference) clusters and product × cluster as sources of variation to validate the preference clustering procedure, and on each preference cluster's hedonic ratings. Partial least square (PLS) regression was also performed to examine the relation between the hedonic ratings by consumers and the sensory attributes measured by the descriptive analysis panel (Myrdal Miller et al. 2014). Frequency was summarized for Just-about-right scale data and was analyzed using both a Chi-Squared Test and Penalty Analysis to identify decreases in acceptability associated with sensory attributes not at optimal levels in a product. Finally, analysis of variance, Student's t-tests or chi-squared tests were used to compare genders and age groups for the measured variables. All statistical analyses were performed using SAS version 9.3 for Windows (SAS Institute Inc., Cary, USA), XLSTAT 2012 for Windows (Addinsoft, Paris, France) and Unscrambler 9.7 (CAMO Software, Oslo, Norway).

3. Results

3.1. Carne asada

3.1.1. Hedonic ratings

A paired-sample *t*-test showed a significant difference ($p < 0.05$) between the two recipes for each of the liking measures (overall liking, and liking of the appearance, flavor and texture/mouth feel of the food). For all four variables, the recipe with 50% mushrooms was liked significantly less than the recipe with 100% beef. But it still received hedonic ratings above 6 ("like slightly") on the hedonic scale, indicating good consumer acceptance of the dish (Fig. 1).

3.1.2. JAR scaling

More than 55% of the consumers indicated the saltiness of the sample was just right for both recipes though more reported so for the 100% steak recipe (i.e. 66% vs. 56%; Fig. 2). Both recipes were reported as not spicy enough by over 70% of the population (Fig. 2). More than 60% of the consumers indicated that the moistness of the sample was just right for both recipes though more so for the 100% steak recipe (i.e. 71% vs. 62%). Moreover, 29% of the consumers indicated that the recipe with the mushrooms was too moist (Fig. 2). Penalty analysis showed that, for carne asada, saltiness and moistness are important variables that will drop overall liking more than 1 point on a 9 point scale when expectations are not met.

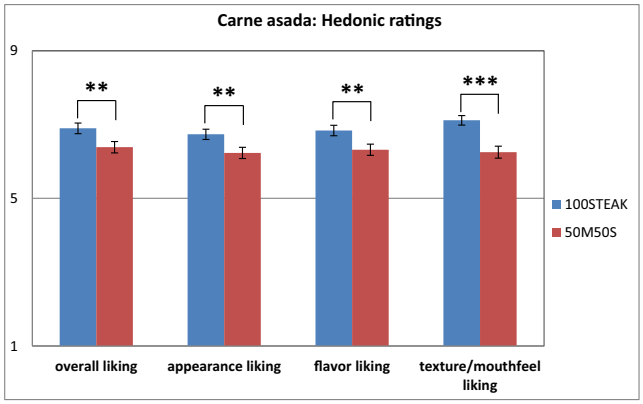


Fig. 1. Mean hedonic ratings and standard errors of the means (sem) for the two carne asada recipes (100% beef and 50% each beef and mushrooms) [n = 147]. *, **, *** (P < 0.05, 0.01 and 0.001, respectively).

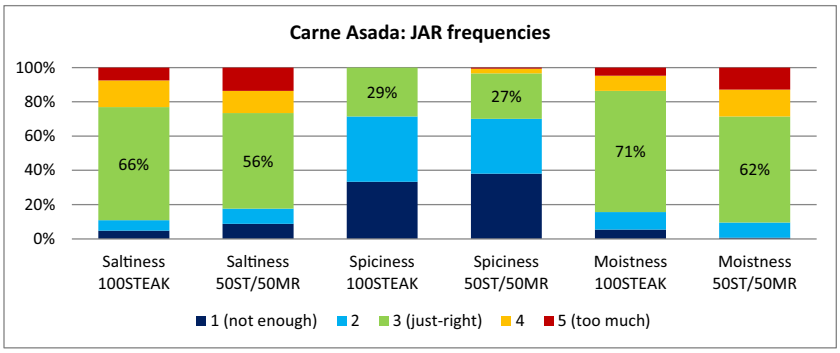


Fig. 2. Distribution of just-about-right scale ratings for saltiness, spiciness and moistness received by the two carne asada recipes – 100% beef and 50% beef and 50% mushrooms (n = 147).

3.2. Taco blend

3.2.1. Hedonic ratings

An analysis of the variance in the hedonic ratings revealed a significant difference ($p < 0.05$) in consumer acceptance scores among the beef taco recipes. Hence, the 'sample' source of variation was partitioned by 'salt reduction', 'meat substitution level' and the interaction of the two factors to reveal which factor accounted for the greatest variance (Table 2). The lone significant effect of meat substitution was on appearance liking, whereas salt reduction had a significant effect on all hedonic measures (Table 2). The interaction of these two factors did not have a significant effect on any of the hedonic ratings (Table 2). Since the products were significantly different, Duncan's multiple range mean comparison test was employed to compare the recipes' mean hedonic ratings (Fig. 3a–d).

There was no significant difference in overall liking among the three full-salt recipes, nor among the three reduced-salt recipes, indicating that on average across the consumer population we tested, the acceptance of the mushroom-containing recipes was on par with that of the 100% beef recipe.

On average, consumers liked recipes without any salt reduction more than those with reduced salt. Liking of flavor and texture/mouth feel followed the same pattern. It should be noted, however, that the decreases in overall and flavor liking from salt reduction were not as pronounced for the recipes with 80% beef (i.e. 80M20B and 80M20B/25LS). Appearance wise, consumers preferred recipes with no mushrooms (Fig. 3b). This suggests that unlike what was observed in the descriptive analysis of the recipes, where 'meat substitution level' was the main determinant of sensory differences, 'salt reduction' was the dominating factor driving consumer acceptance for the beef tacos.

This, however, is an account of consumer acceptance on average, and it does not consider inter-individual differences among consumers. Those were uncovered through preference mapping and they are discussed below.

An examination of the correlations between overall degree of liking and liking for appearance, flavor (taste &smell) and texture/mouth feel revealed that liking for flavor was the best predictor of overall liking ($r = 0.971$, $p < 0.001$), followed by liking for texture/mouth feel ($r = 0.919$, $p < 0.05$). Liking for appearance was not related to overall liking ($r = 0.131$).

3.2.2. Just-about-right (JAR) scaling

In general, all six taco blends except 100B were reported to have just-right saltiness (more than 50% of consumers selected the 'just-right' category). However, it should be noted that ratings of just-right saltiness decreased for all salt-reduced blends, which were reported to be not salty enough by 30% or more of consumers. The 100B blend was stated to be too salty by 31% of the consumers (Fig. 4a).

All six blends were found not to be spicy enough, with more than 45% of consumers selecting one of the 'not spicy enough' categories (Fig. 4b). More than 50% of consumers indicated the moistness of the 6 samples was just right. However, 29% reported that samples 100B and 100B/25LS were not moist enough; and more than 27% of the population indicated all the meat and mushroom blends except 50B50M/25LS were too moist (Fig. 4c).

Penalty analysis was performed on overall liking and JAR scores to gain an understanding of the product attributes that most affected liking, which in turn allows for the identification of potential directions for product improvement. The penalty is a weighted difference between the means (Mean of Liking for JAR - Mean of Liking for the two other levels taken together) and it shows how many points on the 9-point hedonic scale are lost for not meeting consumer expectations or preferences. Mean drops show how many points of liking are lost for having an attribute rated as "too much" or "too little" by consumers. Fig. 5 shows the mean drops and penalties for the four blends of meat and mushrooms in the design. Overall, it was found that not meeting the preferred level for 'saltiness', 'spiciness' and 'moistness' was significantly penalized in all cases. For saltiness, all the salt reduced samples (100B/25LS, 50M50B/25LS and 80M20B/25LS) will be penalized when the samples are judged to be 'not salty enough'. 100B sample will show mean drop when the sample is 'too salty' or 'not salty enough'; The 50M50B sample will decrease in overall liking when it is 'not salty enough'; and 80M20B sample will be penalized when the sample is 'too salty'. Similarly, overall liking will decrease when

Table 2
Partitioned F-ratios for the product source of variation in the analysis of variance of the hedonic ratings for 6 beef taco mixes.

Source of variation	Overall liking	Appearance liking	Flavor liking	Texture & mouthfeel liking
Meat substitution	1.1	**19.34**	2.32	0.16
Salt Reduction	**26.08**	**6.15**	**22.93**	**12.66**
Meat × Salt	1.01	0.74	2.79	0.78

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

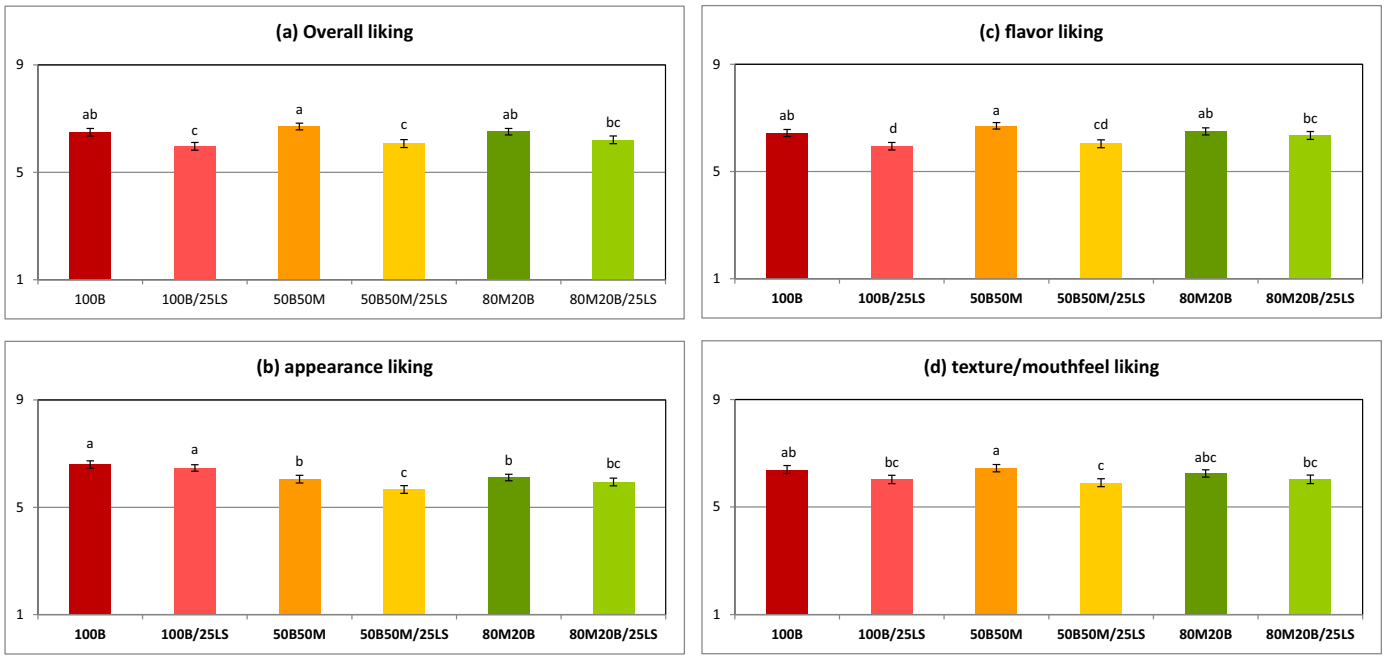


Fig. 3. Mean hedonic ratings on the 9-point hedonic scale and standard error of the means (sem) for the 6 taco blends (n = 147 consumers) – overall degree of liking (a), liking of appearance (b), flavor (taste and smell) (c) and texture and mouthfeel (d). Means sharing superscripts are not significantly different.

the samples are 'not spicy enough'. Finally, the 100% beef blends (i.e. 100B and 100B/25LS) will show a significant drop in overall liking when the samples are 'not moist enough'. And all the meat and mushroom blends (i.e. 50M50B, 50M50B/25LS, 80M20B and 80M20B/25LS) will be penalized when they are considered 'too moist' (Fig. 5).

3.2.3. *Preference mapping*

We then used preference mapping techniques to uncover market segmentation and identify drivers of liking for those segments. The matrix of hedonic ratings of the 6 taco blends across the 147 consumers was analyzed by cluster analysis (or 'preference clustering') and principal component analysis (or 'internal preference mapping' – IPM). The proximity similarity matrix for cluster analysis was based on the Euclidean distance from the original data. Four clusters were obtained from cluster analysis using Ward's Hierarchical technique. A significant 'product × cluster' effect was found by ANOVA, thus validating the procedure (i.e. preference patterns were different among clusters). The preference map with the individual consumers, the preference clusters and the six taco blends are shown in Fig. 6. Internal preference mapping is a factor analysis technique that allows the generation of a biplot or map on which the consumers' preferences are represented as vectors or points. Fig. 6 shows the results of the internal preference mapping analysis as a biplot of the first two principal components; with the main direction (as points) of each individual consumer's preferences for the 6 beef taco samples tested (i.e. each dot represents each individual consumer's main preference direction). The four clusters obtained from the cluster analysis are also shown as ellipses in the internal preference map. The first two preference dimensions (or principal components) in the preference map accounted for 55.5% of the total variance, a high amount given the number of consumers (N = 147). The mean hedonic ratings (overall degree of liking) for the 6 taco blends are then shown for each of the four preference clusters in Fig. 7. ANOVA showed degree of liking varied significantly among blends for each of the preference clusters ($P < 0.05$ or lower).

From the two figures, the preference patterns of each consumer segment can be summarized as follows. Cluster 1 (n = 35) liked recipe 100B the most, but also rated 80M20B highly (both >7 on the 9 = -point scale), but barely liked the 50M50B/25LS recipe (just above 5 on the scale). Cluster 2 (n = 49) consistently gave high ratings to all 6 recipes (all above 7 on the scale, except for 50M50B, barely below 7), and did not show any clear preference for a specific recipe, but liked 50M50B slightly less than the others. Cluster 3 (n = 27) disliked the 100% beef recipe with full salt (100B) and was neutral (neither like nor dislike) for that with reduced salt (100B/25LS), but gave consistently high ratings to all the mushroom-containing recipes, with both 50M50B and 80M20B/25LS at 7 on the scale. Cluster 4 (n = 36) consistently disliked the reduced-salt blends, giving all three ratings below 5 (neutral) on the scale. They gave the highest rating (yet still below 6 or 'like slightly' on the scale) to the 100% beef and full salt recipe. Overall, this group gave lower ratings to the taco blends than the other clusters.

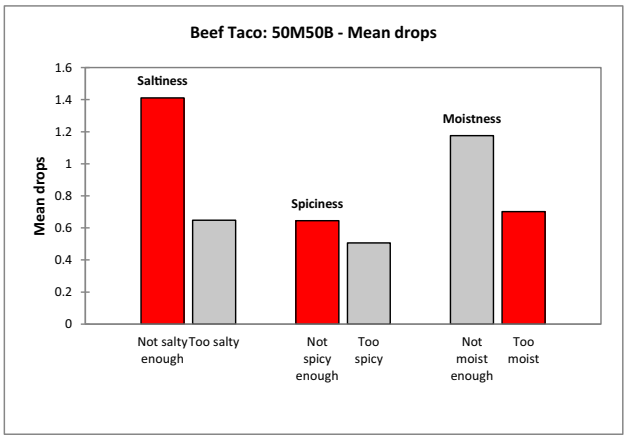
The demographics, attitudes and food consumption patterns for the preference clusters can be summarized as follows. Most consumers in Cluster 1 (46%) were in the medium-income bracket ($50–100K), exercised less than the average, and had more of an animal-based diet (Table 3). Cluster 2 was clearly fond of eating ('foodies'), and focused on flavor. It included more women (69%) and was the most educated group overall. Ninety percent of consumers in Cluster 2 thought that "mushrooms enhanced the flavor of a dish", but 76% of them also indicated that "expense prevented them from purchasing mushrooms". Cluster 3 had more of a plant-based diet, exercised more, included many singles (74%) and students (44%), and few individuals in the high-income bracket (>$100K). Most consumers in Cluster 3 "liked the taste of mushrooms" (93%), and "saw mushrooms as a healthy food" (74%), but again "expense prevented most from purchasing mushrooms" (81%). Cluster 4 had for the most part a plant-based diet, with some chicken, and had limited enjoyment of food. It included more men than women, and older consumers. They included more consumers in the lower and higher income brackets, who exercised more overall.

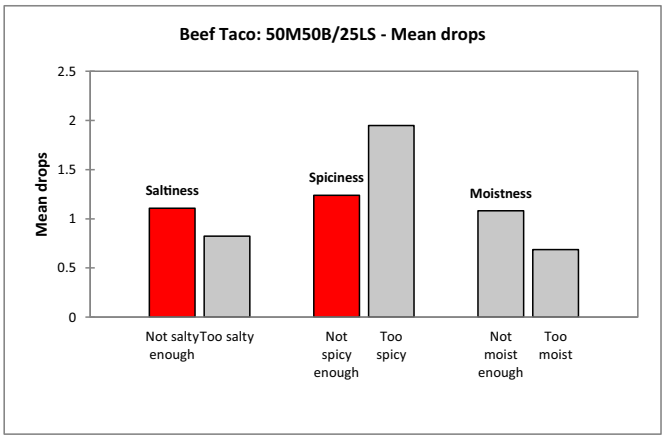
Fig. 4. Just-about-scaling for saltiness (a), spiciness (b) and moistness (c) of the taco blends showing the percentages of consumers selecting the various options (n = 147).

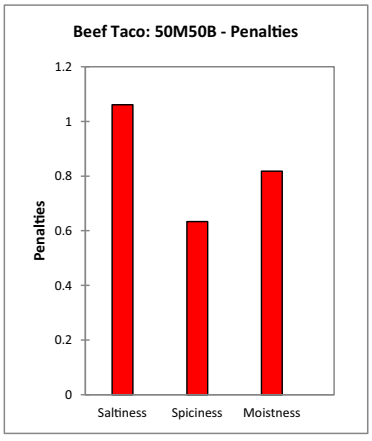
3.2.4. *Drivers of liking*

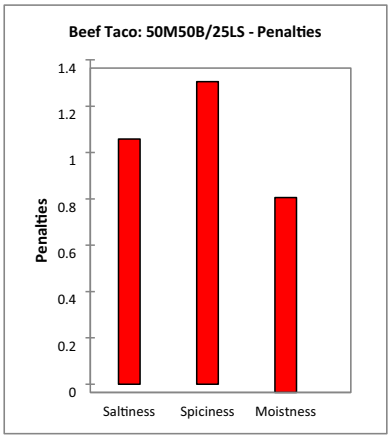
Using Partial Least Square Regression (PLS), we then regressed overall hedonic ratings for the four preference clusters onto the sensory attributes that were measured by descriptive analysis (Myrdal Miller et al., 2014), and identified so-called drivers of liking for the clusters, i.e., which sensory attributes in the taco blends drove their respective liking, or disliking (Fig. 8). Only those sensory attributes that differed significantly among the recipes were included in this analysis. The cluster likings and sensory attributes in the outer portion of the biplot are those that have statistically significant relationships. PC 1 and 2 of the regression model explained 69 and 20% (in total 89%) of the X data (i.e. sensory attribute intensity ratings); and 33 and 35% (68% in total) of the Y data (i.e. overall liking scores of the 4 groups).

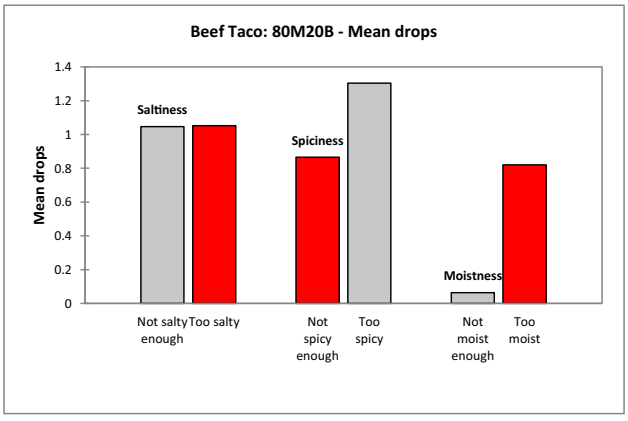
For Clusters 1 and 4, the main drivers of liking were 'salty' and 'spicy'. For Cluster 3, the main drivers of liking were 'sweet', 'mushroom', 'earthy', 'vegie', 'moisture', 'umami', 'onion' and 'garlic', whereas drivers of disliking were 'firmness', 'chewy/tough',

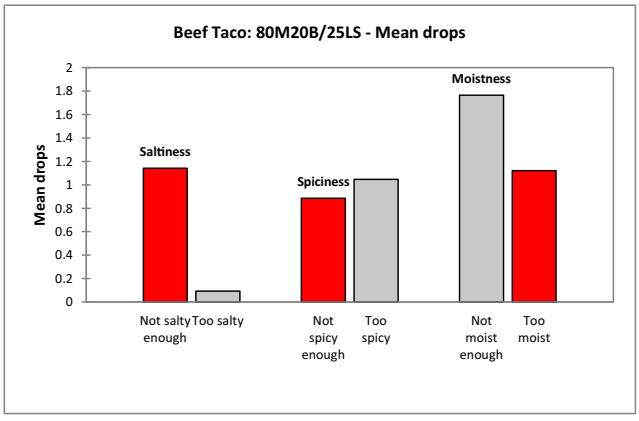


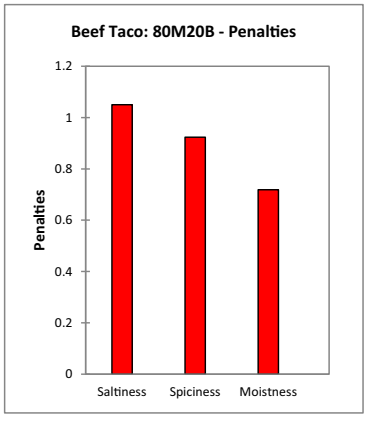












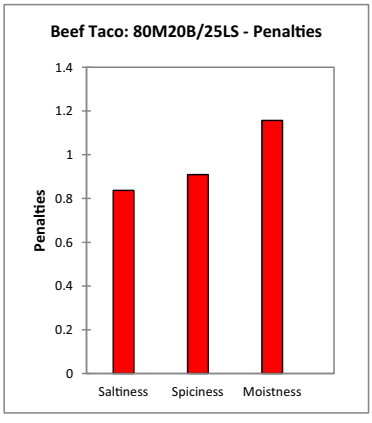


Fig. 5. Mean overall liking drops and penalties from penalty analysis of just-about-right scaling for saltiness, spiciness and moistness and hedonic ratings for the taco blends. For simplicity, only the meat and mushroom blends are shown (n = 147 consumers). Red bars indicate a significant difference in liking ($p < 0.05$) and grey bars indicate that the analysis could not be performed because of insufficient data. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

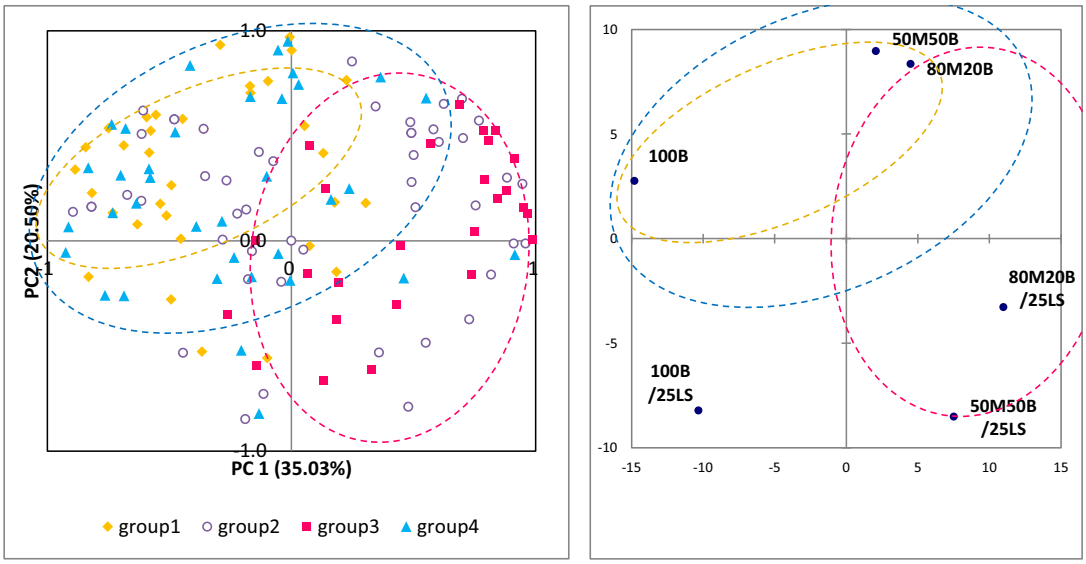


Fig. 6. Internal preference map generated by principal component analysis of the matrix of mean overall degree of liking ratings, showing individual consumers and the 6 beef taco recipes – 4 preference clusters were uncovered by cluster analysis of the same matrix (group 1, n = 35; group 2, n = 49; group 3, n = 27; and group 4, n = 36).

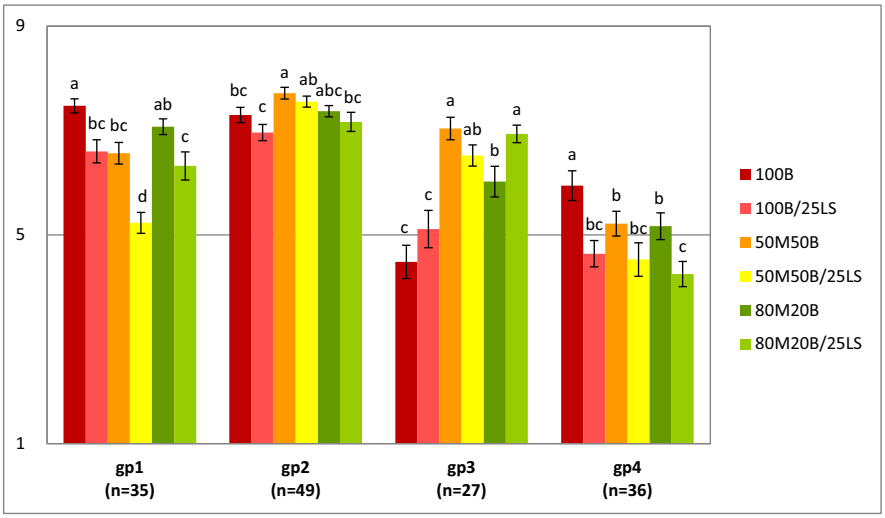


Fig. 7. Mean overall degree of liking and standard error of the means (sem) of the 4 preference clusters uncovered by cluster analysis for the 6 taco blends (n = 147 consumers). Means not sharing superscript are significantly different (P < 0.05 or lower).

'meaty' and 'burnt'. The regression model did not provide a good (significant) account of the drivers of liking for Cluster 2.

3.2.5. *Effects of gender and age*

Somewhat surprisingly, we did not find any significant difference between genders or among age groups in the variables we measured for either dish (carne asada or taco blend) – overall degree of liking, liking for appearance, flavor, and texture/mouth feel; just-about-right scaling for saltiness, spiciness and moistness.

4. Discussion

This proof-of-concept study provides some promise for the notion that healthier ingredients such as mushrooms can be substituted for less healthy ones such as beef in a complex dish like a taco blend while maintaining consumer acceptance, provided that they bring flavor-boosting properties, in this case umami principles (Myrdal Miller et al., 2014). Indeed, mean hedonic ratings across the population of 147 consumers who participated in this study did not differ between the beef-only and the mushroom-substituted taco blends, and the preference mapping analysis of the individual hedonic ratings showed that at least two of the four uncovered preference segments, representing half the consumers, liked the mushroom-containing dishes more than the 100% beef ones. There is even some evidence from our findings, that for some consumers, flavor-boosting ingredients such as those found in mushrooms may mitigate sodium reduction without compromising acceptance.

This study also reinforces the need to treat consumer populations as heterogeneous when it comes to food preferences, and to always go beyond average hedonic ratings across a consumer population and examine that population's segmentation for preferences. Otherwise, one runs the risk of drawing wrong or incomplete conclusions – in this instance, that the 100% salt recipes

Table 3
Consumption and purchase frequencies for select foods by the four preference clusters identified in the preference mapping and clustering analyses, as derived from the exit survey. a. Means and standard errors for the means (sem) for mushroom frequency of consumption and purchase (times/month). Means not sharing superscripts are significantly different (P < 0.05 or lower). b. Means and standard errors for the means (sem) for meat and dairy products frequency of consumption (times/month). Means not sharing superscripts are significantly different (P < 0.05 or lower). c. Means and standard errors for the means (sem) for fruits, vegetables and grains frequency of consumption – daily serving(s).

	Cluster 1 (n = 35)	Cluster 2 (n = 49)	Cluster 3 (n = 27)	Cluster 4 (n = 36)	Total (N = 147)
a.					
Consumption	4.33[a] (0.54)	5.12[ab] (0.56)	6.57[b] (0.87)	6.00[ab] (0.68)	5.42 (0.33)
Purchasing	2.16 (0.31)	2.53 (0.27)	2.73 (0.38)	2.65 (0.33)	2.51 (0.16)
b.					
Red meat (e.g. Beef, Pork, Lamb)	8.46 (1.15)	8.89 (1.36)	7.37 (0.94)	7.22 (0.71)	8.10 (0.58)
White meat (e.g. Chicken, Turkey, Pork)	12.60 (1.20)	12.02 (1.25)	11.13 (1.13)	12.32 (1.50)	12.07 (0.65)
Fish/Sea food	4.59 (1.65)	5.21 (0.46)	4.52 (0.75)	4.15 (0.52)	4.68 (0.29)
Dairy (Milk, Yogurt, Cheese, Ice cream)	27.54[a] (2.52)	30.09[a] (1.96)	19.72[b] (2.09)	21.29[b] (1.63)	25.43 (1.10)
c.					
	Cluster 1 (n = 35)	Cluster 2 (n = 48)[a]	Cluster 3 (n = 27)	Cluster 4 (n = 36)	Total (N = 146)[a]
Fruits	2.13 (0.19)	2.38 (0.16)	2.83 (0.38)	2.68 (0.25)	2.48 (0.12)
Vegetables	2.43 (0.23)	2.49 (0.18)	3.06 (0.31)	2.64 (0.21)	2.62 (0.11)
Grains	2.89 (0.23)	3.03 (0.27)	3.13 (0.31)	3.13 (0.28)	3.04 (0.14)

[a] One missing data in cluster 2, (N) Total consumers = 146.

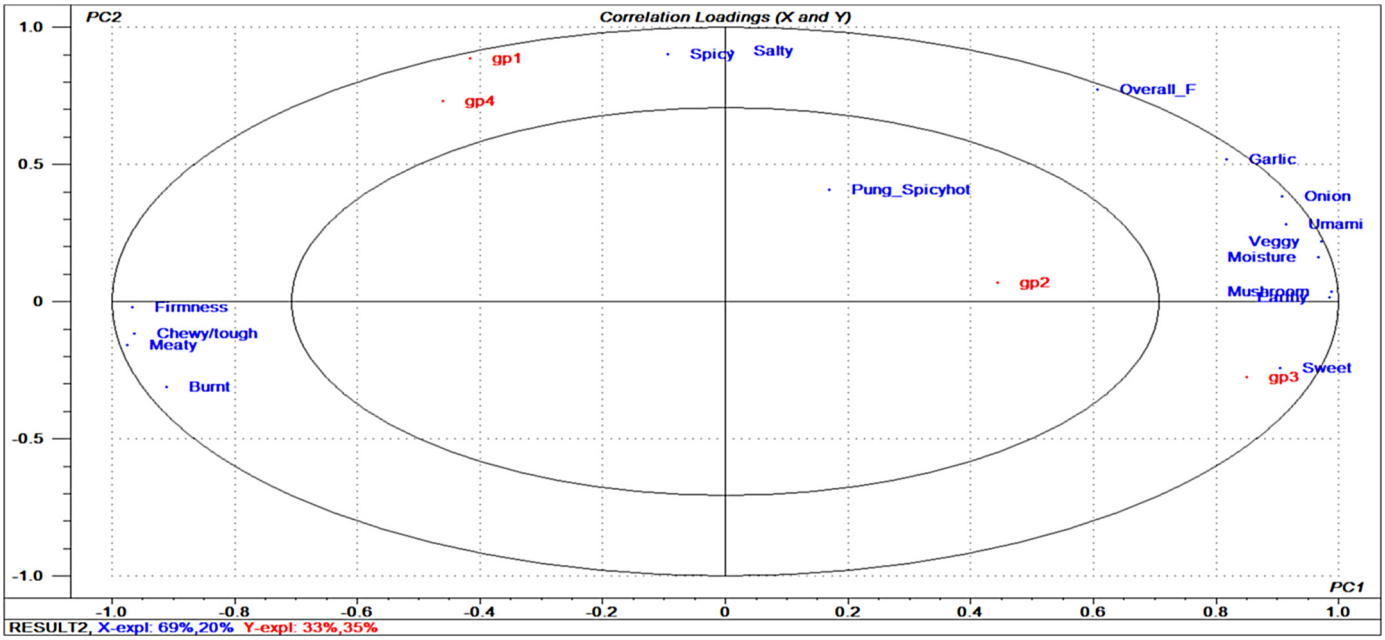


Fig. 8. Drivers of liking for the four preference clusters - PLS regression biplot showing the relation between (or regression of) the overall liking scores of the four preference clusters onto the sensory attributes intensity ratings for the beef tacos.

are always liked best. Indeed, we found that at least one of the four preference segments liked the 25% reduced salt recipes better than the full salt ones.

By in large, this study demonstrates that in a taco blend, mushrooms can be used as a healthy, flavor-boasting ingredient to substitute for ground beef without significant reduction in consumer acceptance. That conclusion is reached by comparing overall mean liking or liking for flavor or texture and mouth feel for the full-salt recipes, where no difference was found between the 100% beef recipe and the two mushroom blends, and again for the reduced-salt recipes, where no difference was found either (Fig. 3). We do acknowledge, however, that those hedonic ratings were significantly lower overall for the reduced-salt versions of those recipes, but some mitigation of salt reduction was successful with the 80% mushroom blend with reduced salt faring as well as the full-salt 100% beef or 50% each beef and mushroom recipes (Fig. 3). Our findings are consistent with those from other studies that showed improved consumer acceptance of pork patties with added shiitake mushroom powder (Chun, Chambers, & Chambers, 2005) or of minced beef steak with added shiitake mushroom extract (Dermiki et al., 2013), yet on a much more dramatic level. Indeed, we replaced up to 80% of the beef with mushrooms with no significant or limited impact on consumer acceptance. Our research adds to already documented food science and culinary applications of ingredients with umami qualities (Barylko-Pikielna & Kostyra, 2007; Marcus, 2005).

But consumer populations are not homogeneous in their food preferences and it is common and best practice nowadays to conduct a preference mapping analysis first to uncover market segmentation for the product being researched, and second to identify the sensory drivers of liking for each of the uncovered preference clusters. And sure enough, this proved paramount for

this proof-of-concept research. The four preference clusters and their characteristics hold a lot of value for behavioral nutrition research, dietary intervention and marketing. Indeed, it can be speculated that similar clusters would be uncovered in any study of consumer acceptance of healthier alternatives to recipes traditionally high in (saturated) fat and salt, or even sugar. In hindsight, and for further characterization of the preference clusters, our exit survey would have benefited from an additional line of inquiry into the consumption of modified versions of foods that are typically meat-based such as turkey burgers, vegie burgers, etc.

It is important to highlight that for two of the preference clusters, including the largest one (Cluster 2, n = 49), the mushroom-containing recipes had greater acceptance than the two 100% beef recipes. It is only for the other two clusters (1 and 4), that the 100% beef (but only full-salt) recipe was liked more than the mushroom-containing recipes. That more than half the consumer population that we tested liked those recipes with mushrooms better holds great promise for future nutrition education and intervention strategies.

With only two recipes tested for the carne asada – one with 100% beef and one with 50% each of beef and mushrooms, we were not able to conduct a preference mapping analysis on the hedonic ratings (at least 6 products are required to achieve adequate statistical power for the regression analyses). But our findings for carne asada demonstrate the importance of expectations to consumer acceptance. The introduction of mushroom strips alongside the beef strips in the recipe proved too much of a departure from what consumers expected for carne asada. And the hedonic ratings clearly reflected that. They were significantly lower for the recipe with 50% beef and 50% mushrooms for overall liking, as well as for liking of appearance, flavor and texture & mouth feel ($p < 0.05$), yet only by half-a-point, and all above 6 on the 9-point hedonic scale (Fig. 1). Furthermore, it is worth pointing out that the percentage of consumers choosing the just-right category was lower for the mushroom-containing recipe for all three attributes rated (saltiness, spiciness and moistness), again signaling that the presence of mushrooms most likely was too much of a departure from the original recipe (Fig. 2).

That the substitution of beef with mushrooms, and thus the incorporation of their flavor-boosting umami properties (Myrdal Miller et al., 2014) did not quite mitigate the sensory challenges of sodium reduction in a recipe like a taco blend for the entire consumer population that we tested was not a surprise (Keast & Breslin, 2003; Kemp & Beauchamp, 2006). Yet, for two of the preference clusters, or half the consumers in this study, there was no significant difference in acceptance between the full- and reduced-sodium versions of the taco blends (Group 2, n = 49) or even a preference for the reduced-sodium version (Group 3, n = 27) (Fig. 7). So the argument can be made than even though across the entire consumer population tested, acceptance of the full-sodium versions of the recipes was higher, there were two of the four preference clusters, representing half the consumers, for whom the reduced-sodium versions were on par or even better liked than the full-sodium versions. That this played out even more significantly for the 80% mushroom and 20% beef blend suggests that mushrooms do indeed have the potential to not only enhance flavor, but also to mitigate the sensory effects of sodium reduction.

That gender and age did not have a significant impact on the acceptance measures we collected came somewhat as a surprise, yet it reaffirmed the value of collecting usage and attitudes data in our exit survey because those turned out to be more effective in differentiating among the four preference clusters we identified. We did not measure a possible effect of the consumers' state of hunger at the time of testing on their ratings, yet we assume that it was fairly homogeneous across consumers as the sessions were held at lunch or dinner times. Even though we achieved a good gender balance in our consumer population with 42% men and 58% women, the younger age demographic (18–29 years), made up primarily of students, represented 35% of our sample. Finally, the conclusion of our research applies to a Northern California consumer population and may not fully extend to others. Indeed, with an average meat consumption of 7–9 times monthly, the population we tested likely consumed less meat than the national average.

5. Conclusions

This study demonstrates that because of their flavor-enhancing umami principles, mushrooms can be used to replace ground beef in a taco blend without significant reduction in consumer acceptance, and even with increased acceptance for some segments of the consumer population. Mitigation of sodium (salt) reduction through substitution with mushrooms also occurred for one segment of the consumer population, but not for the majority.

The knowledge of the demographics, consumption patterns and attitudes of the uncovered preference clusters, and of the sensory drivers of their liking for those clusters will allow for improved behavioral nutrition strategies and more efficient marketing of mushroom-containing and reduced-sodium alternatives to full meat and sodium recipes. We are pleased to report that our research has led to the development of "The Blend", a meat-mushroom amalgam now used in burgers served in school districts, office cafeterias and restaurant chains across the US (Jacewicz, 2016).

These findings serve as proof of concept for the Healthy Flavors Research Initiative which aims to substitute food components with nutritional liabilities (such as beef) with healthy components touting flavor-enhancing properties (such as mushrooms) to make up for the potential loss in palatability. They also reinforce the value of culinary professionals and sensory scientists partnering for the successful development of healthier food service strategies.

Acknowledgements

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References

Barylko-Pikielna, N., & Kostyra, E. (2007). Sensory interaction of umami substances with model food matrices and its hedonic effect. *Food Quality and Preference, 18*, 751–758.

Beauchamp, G. K., Bertino, M., Burke, D., & Engelman, K. (1990). Experimental sodium depletion and salt taste in normal human volunteers. *American Journal of Clinical Nutrition, 51*, 881–889.

Beauchamp, G. K., & Engelman, K. (1991). High salt intake. Sensory and behavioral factors. *Hypertension, 17*, I176–I181.

Bolhuis, D. P., Temme, E. H. M., Koeman, F. T., Noort, M. W. J., Kremer, S., & Janssen, A. M. (2011). A salt reduction of 50% in bread does not decrease bread consumption or increase sodium intake by the choice of sandwich fillings. *Journal of Nutrition, 141*, 2249–2255.

Bowen, D., Green, P., Vizenor, N., Vu, C., Kreuter, P., & Rolls, B. J. (2003). Effects of fat content on fat hedonics: Cognition or taste? *Physiology & Behavior, 78*, 247–253.

Cheung, P. C. K. (2008). Nutritional benefits and health value of mushrooms. In P. C. K. Cheung (Ed.), *Mushrooms as functional foods* (pp. 71–110). Hoboken NJ: Wiley.

Cheung, P. C. K. (2010). The nutritional and health benefits of mushrooms. *Nutrition Bulletin, 35*, 292–299.

Chun, S., Chambers, E., & Chambers, D. (2005). Perception of pork patties with shiitake (*Lentinue edode* P.) mushroom powder and sodium tripolyphosphate as measured by Korean and United States consumers. *Journal of Sensory Studies, 20*, 156–166.

Cordain, L., Eaton, S. B., Sebastian, A., Mann, L., Lindeberg, S., Watkins, B. A., et al. (2005). Origins and evolution of the Western diet: Health implications for the 21st century. *American Journal of Clinical Nutrition, 81*, 341–354.

Dermiki, M., Mounayar, R., Suwankanit, C., Scott, J., Kennedy, O. B., Mottram, D. S., et al. (2013). Maximising umami taste in meat using natural ingredients: Effects

on chemistry, sensory perception and hedonic liking in young and old consumers. *Journal of the Science of Food and Agriculture, 93*, 3312–3321.
Drewnowski, A. (1997). Taste preferences and food intake. *Annual Reviews of Nutrition, 17*, 237–253.
Drewnowski, A., Mennella, J. A., Johnson, S. L., & Bellisle, F. (2012). Sweetness and food preference. *Journal of Nutrition, 142*, 1142S–1148S.
Dietary Guidelines for Americans, 2015-2020 (8th ed.). (December 2015). US Department of Agriculture, US Department of Health and Human Services http://health.gov/dietaryguidelines/2015/.
Fabbri, A. D. T., & Crosby, G. A. (2016). A review of the impact of preparation and cooking on the nutritional quality of vegetables and legumes. *International Journal of Gastronomy and Food Science, 3*, 2–11.
Fuke, S., & Shimizu, T. (1993). Sensory and preference aspects of umami. *Trends in Food Science & Technology, 4*, 246–251.
Fuke, S., & Ueda, Y. (1996). Interactions between umami and other flavor characteristics. *Trends in Food Science & Technology, 7*, 407–411.
Hong, J. H., Kwon, K. Y., & Kim, K. O. (2012). Sensory characteristics and consumer acceptability of beef stock containing the glutathione-xylose Maillard reaction product and/or monosodium glutamate. *Journal of Food Science, 77*, S233–S239.
Jacewicz, N. (2016). A twist on the mushroom burger. *Scientific American, 314*, 16.
Keast, R. S. J., & Breslin, P. A. S. (2003). An overview of binary taste-taste interactions. *Food Quality and Preference, 14*, 111–124.
Kemp, S. E., & Beauchamp, G. K. (2006). Flavor modification by sodium chloride and monosodium glutamate. *Journal of Food Science, 59*, 682–686.
Lawless, H. T., & Heymann, H. (2010). *Sensory evaluation of food. Principles and practices* (2nd ed.). New York: Springer.
Liem, D. G., Miremadi, F., & Keast, R. S. J. (2011). Reducing sodium in foods: The effect on flavor. *Nutrients, 3*, 694–711.
Liu, J., Vijayakumar, C., Hall, C. A., II, Hadley, M., & Wolf-Hall, C. E. (2005). Sensory and chemical analyses of oyster mushrooms (Pleurotus sajor-caju) harvested from different substrates. *Journal of Food Science, 70*, S586–S592.
Manabe, M., Ishizaki, S., Yoshioka, T., & Oginome, N. (2009). Improving the palatability of salt-reduced food using dried bonito stock. *Journal of Food Science, 74*, S315–S321.
Marcus, J. B. (2005). Culinary applications of umami. *Food Technology, 59*, 24–30.
Myrdal Miller, A., Mills, K., Wong, T., Drescher, G., Lee, S. M., Sirimuangmoon, C., et al. (2014). Flavor-enhancing properties of mushrooms in meat-based dishes in which sodium has been reduced and meat has been partially substituted with mushrooms. *Journal of Food Science, 79*, S1795–S1804.
Obbagy, J. E., Condrasky, M. D., Roe, L. S., Sharp, J. L., & Rolls, B. J. (2011). Chefs' opinions about reducing the calorie content of menu items in restaurants. *Obesity, 19*, 332–337.
Peryam, D. R., & Pilgrim, F. J. (1957). Hedonic scale of measuring food preferences. *Food Technology, 11*, 9–14.
Poelman, A. A. M., Delahunty, C. M., & de Graaf, C. (2013). Cooking time but not cooking method affects children's acceptance of *Brassica* vegetables. *Food Quality and Preference, 28*, 441–448.
USDA National Nutrient Database for Standard Reference (2011). http://ndb.nal.usda.gov/.
Yang, J. H., Lin, H. C., & Mau, J. L. (2001). Non-volatile taste components of several commercial mushrooms. *Food Chemistry, 72*, 465–471.
Zhang, Y., Venkitasamy, C., Pan, Z., & Wang, W. (2013). Recent developments on umami ingredients of edible mushrooms – A review. *Trends in Food Science & Technology, 33*, 78–92.