LWT - Food Science and Technology 138 (2021) 110806

Contents lists available at ScienceDirect

LWT

journal homepage: www.elsevier.com/locate/lwt

Umami Ingredient, a newly developed flavor enhancer from shiitake byproducts, in low-sodium products: A study case of application in corn extruded snacks

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ARTICLE INFO

Keywords:
Sodium reduction
Umami taste
Mushroom
Sensory analysis
Rate-all-that-Apply

ABSTRACT

Although it is not an easy task, sodium reduction in food is necessary, and in this scenario, the research for tasty food with reduced sodium content has an extremely relevant role. In this study, sodium reduction in corn extruded snacks was evaluated. Four snack samples were evaluated: one control sample (with salt and monosodium glutamate) and three reduced-sodium formulations. To minimize sensory losses caused by sodium reduction, monosodium glutamate (MSG) and Umami Ingredient (a new flavor enhancer ingredient obtained from shiitake mushroom byproducts) were used as flavor enhancers, since the utilization of Umami Ingredient enables the development of MSG-free and low-sodium products. The physical (expansion ratio, density and cutting force) and sensory (acceptance through hedonic scale, Just-about-right scale and characterization by the Rate-All-That-Apply method) characteristics of the snacks were investigated. Snacks with lower sodium content exhibited lower acceptance compared to the control sample, but they were not rejected by the consumers. Umami Ingredient performed similarly to MSG on seasoning flavor, salty and umami tastes. From this result, Umami Ingredient can be considered a potential alternative to replace MSG in low-sodium food, acting as a flavor enhancer and contributing to reducing the use of additives in the product formulation.

1. Introduction

Despite performing important functions in the body, such as maintaining cellular functioning and osmotic pressure of extracellular fluids and the transmission of nerve impulses (Dötsch et al., 2009), sodium can also be a villain to health when consumed in excess. Scientific evidence points out that high sodium consumption can lead to the development of chronic non-communicable diseases, such as hypertension and increased risk of kidney and cardiovascular diseases (Gilbert & Heiser, 2005; WHO, 2012).

In addition to these physiological functions, sodium elicits salty taste (Doyle & Glass, 2010), playing an important role in increasing palatability of foods, such as soups, breads, meats, sauces and snacks (Dötsch et al., 2009). However, its use in food should be cautious, since, to avoid the risk of chronic diseases, the World Health Organization (WHO) recommends the consumption of less than 5 g of salt/day, which corresponds to 2 g of sodium/day (WHO, 2014).

In several countries, sodium consumption is high (WHO, 2014). The Brazilian population consumes on average 9.34-g salt/day (Mill et al., 2019), which is approximately twofold the recommended amount. For this reason, actions have been implemented in Brazil to reduce the sodium content in several categories of processed foods, such as instant noodles and bakery products, dairy products, meat products and snack food (Brasil, 2018). Among them, extruded snacks traditionally have a high content of fat and salt, being regarded as highly energetic, but nutritionally poor (Brennan, Derbyshire, Tiwari, & Brennan, 2013; Hess,

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https://doi.org/10.1016/j.lwt.2020.110806
Received 8 August 2020; Received in revised form 17 December 2020; Accepted 19 December 2020
Available online 24 December 2020
0023-6438/

Jonnalagadda, & Slavin, 2016).

Promoting significant changes in food sodium content is a challenge, as such changes are usually accompanied by technological and sensory modifications (Dötsch et al., 2009), and can reduce consumer acceptance of products (Liem, Miremadi, & Keast, 2011). One of the alternatives to minimize the sensory impacts of sodium reduction in foods is the replacement of sodium chloride (NaCl) with other types of salts such as potassium chloride (KCl) and calcium chloride ($CaCl_2$). Notwithstanding that, such substitutions are unfavorable, as potassium chloride and calcium chloride can also result in bitter and metallic taste in the products (Mitchell, 2019). Another alternative is the improvement of other tastes that enhance the perceived saltiness (Kremer, Mojet, & Shimojo, 2009), as is the case of umami taste (Mojet, Heidema, & Christ-Hazelhof, 2004).

Umami taste is mainly linked to the presence of glutamic acid and its salt, monosodium glutamate (MSG) (Dermiki, Phanphensophon, Mottram, & Methven, 2013; Yamaguchi, 1991), widely used by the food industry. MSG can be used to reduce the sodium content in several food products, such as soups, meat products, snacks, instant noodles, and milk products. This food additive is classified as a Generally Recognized as Safe (GRAS) substance, offering no health risk (Maluly, Arisseto-Bragotto, & Reyes, 2017). However, there is a trend toward the use of natural flavor enhancers, since consumers have a negative perception about MSG-added products (Radam, Yacob, Bee, & Selamat, 2010). In this context, mushrooms stand out for being rich in umami compounds (Manninen, Rotola-Pukkila, Aisala, Hopia, & Laaksonen, 2018; Phat, Moon, & Lee, 2016; Poojary, Orlien, Passamonti, & Olsen, 2017). The use of mushroom extracts in food has shown promising results, as presented by Dermiki, Phanphensophon, Mottram, and Methven (2013) and Mattar et al. (2018). Nevertheless, there is a lack of studies on the application of extracts obtained from shiitake mushroom byproducts as flavor enhancers in food.

Developed by Harada-Padermo et al. (2020), the Umami Ingredient consists of a new ingredient, rich in umami compounds obtained from shiitake (*Lentinula edodes*) mushroom byproducts, which can assist in maintaining low-sodium food flavor. Therefore, this study evaluates the physical and sensory characteristics of products with reduced sodium content added of Umami Ingredient (new flavor enhancer), having corn extruded snacks as a study case.

2. Materials and methods

2.1. Materials

Corn grits (Master SP Alimentos, Capela do Alto, Brazil) were used for extrusion. Sunflower oil (Soya, São Paulo, Brazil), salt (sodium chloride (NaCl), Cisne, Cabo Frio, Brazil), monosodium glutamate (Ajinomoto, Limeira, Brazil), cheese aroma (Duas Rodas, Jaraguá do Sul, Brazil) and Umami Ingredient were used for flavoring. The Umami Ingredient was obtained from shiitake (*Lentinula edodes*) byproducts, and all information about its obtaining and characterization was described by Harada-Padermo et al. (2020).

2.2. Extrusion process and flavoring

Corn grits with 15% moisture (wet basis) were extruded in an RXPQ Labor 24 single screw extruder (INBRAMAQ, Ribeirão Preto, Brazil) with five independent heating zones. The extrusion conditions were: three helicoidally grooved barrel; screw with a large step of one exit with a compression ratio of 2.3:1 and length-to-diameter ratio of 15.5:1; pre-die extruder with holes of 3.01 mm; extruder die with a diameter of 2.93 mm (round hole); feed rate of 265 g/min; screw speed at 237 rpm; temperatures in zones 1 to 5: off (approximately 25 °C), 70 °C, 90 °C, 140 °C and 140 °C respectively.

After extrusion, the snacks were cut into 50 mm length pieces, placed in plastic packaging and flavored with a mix of ingredients presented in Table 1. The sunflower oil was sprinkled on the snacks and the remaining ingredients were added. The concentration of the ingredients applied in this study (Table 1) was based on previous studies (Menis-Henrique et al., 2019, 2020) and preliminary tests (data not shown).

Table 1
Flavoring ingredients concentration and snacks sodium content.

		Control	R + Glu	R + UI 1	R + UI 1.5
Ingredients (g/100 g of extrudate)	Sunflower oil	6.0	6.0	6.0	6.0
	Cheese aroma	1.5	1.5	1.5	1.5
	Salt (NaCl)	2.8	0.8	0.8	0.8
	Monosodium glutamate (MSG)	0.6	0.6	0	0
	Umami Ingredient	0	0	1.0	1.5
Sodium content (mg/25 g of snacks)		263	89	72	71

The sodium concentration of the snacks was calculated as the sum of sodium from salt, monosodium glutamate (MSG) and Umami Ingredient (determined by Harada-Padermo et al. (2020). The sodium content of the control sample agrees with that of commercial cheese-flavored snacks in Brazil, whose content varies from 99 to 315 mg of sodium per portion of 25 g (survey of commercial samples on the market – data not shown).

2.3. Analyses of the physical properties of the snacks

For the analyses of physical properties, ten snack samples taken at random were used. The expansion ratio was determined by the ratio between the snack diameter and the extruder die diameter. Samples diameter and length were measured using a digital caliper (Digimess, São Paulo, Brazil), and they were also weighed on an analytical balance. Density (g/cm^3) was calculated using the equation: $\rho = 4W/\pi D^2 L$, where W (g) is the weight, D (cm) is the diameter and L (cm) is the length of each snack (Chávez-Jáuregui, Silva, & Arêas, 2000).

The cutting force was determined using a TA. XT plus 50 (Stable Micro Systems, Godalming, UK) texture analyzer and the software Exponent 32 (Stable Micro Systems, Godalming, UK). The samples were cut perpendicular using a Blade set probe with guillotine (HDP/BS), using a pretest speed of 5 mm/s, test speed of 1 mm/s and post-test speed of 10 mm/s. The maximum force (N) was considered the cutting force of the snack (Paula & Conti-Silva, 2014).

2.4. Sensory evaluation of the snacks

The sensory analyses were performed at the Sensory Analysis laboratory of the Department of Food Technology and Engineering, Institute of Biosciences, Humanities and Exact Sciences, São Paulo State University. This study was approved by the Research Ethics Committee from "Luiz de Queiroz" College of Agriculture, University of São Paulo (Decision 2.994.710), which contributed to this study.

To participate in this study, ninety-nine consumers (from 18 to 62-year-old, 69% female) were recruited from students and employees of the institution. Among these, 55% of consumers rated the cheese-flavored snack as 'like very much' and 37% rated it as 'like slightly'. Regarding the frequency of consumption, 19% declared to consume cheese-flavored snacks fortnightly and 64% once a month. In addition, 80% of consumers reported concern about sodium consumption from food in general and 70% said that they buy products with reduced sodium content. When asked about the decisive factors for purchasing low-sodium products (multiple-choice question, with the possibility to give multiple answers), 26% of consumers pointed concern for health, 25% price, 24% flavor, 21% quality and 4% brand.

The corn extruded snacks were evaluated regarding to: 1) sensory acceptance of the attributes odor, texture, salty taste, flavor and overall liking, using the nine-point structured hedonic scale (9 = like extremely, 5 = neither like nor dislike, 1 = dislike extremely) (Meilgaard, Civille, & Carr, 2016); and 2) ideal intensity of salty taste and cheese flavor, using the Just-About-Right (JAR) scale of nine points (9 = extremely more intense than ideal, 5 = ideal intensity, 1 = extremely less intense than ideal) (Meilgaard et al., 2016). The choice of using a JAR scale for salty taste and cheese flavor was justified by the aim of evaluating the effects of sodium reduction on the main taste expected in such product (salty), as well as on the predominant flavor in the snacks, i.e., cheese, once a commercial aroma of cheese was used for snack flavoring.

The samples were also evaluated using the descriptive method Rate-All-That-Apply (RATA) performed by consumers (Ares, Bruzzone, et al., 2014). The sensory attributes applied in this test were raised by experts after pretests and obtained from previous studies with corn extruded snacks (Menis-Henrique, Janzantti, Monteiro, & Conti-Silva, 2020). In RATA test, consumers selected the applicable attributes for each sample and indicated their intensity, using a three-point scale (low, medium and high). Attributes that were not suitable for describing the samples were classified as 'not applicable'. Thus, for data analysis, the scale was extended to 4 points and decoded into numerical values according to the recommendation of Meyners, Jaeger, and Ares (2016).

The sensory analyses were performed in individual booths under white light, at 22 °C. The snacks were presented in napkins encoded with random three-digit numbers, in portions containing 3 pieces of 50 mm length each, enough quantity for all analyses. Consumers evaluated samples monadically. Each sample was evaluated on the hedonic scale, then on JAR scale and finally for RATA. Re-tasting was freely allowed when consumers asked for more samples to finish the evaluation. The session lasted approximately 15 min. Along with the samples, consumers received a glass of water to drink between the samples. The presentation order was balanced in complete blocks (FIZZ Sensory Analysis Software, version 2.50) for all tests. RATA attributes were randomized in the evaluation forms for each sample and consumer, following a Williams' Latin Square design, as recommended by Ares, Etchemendy, et al. (2014).

2.5. Statistical analyses

Data from physical analyses was submitted to one-way ANOVA and the sensory data was submitted to two-way ANOVA, considering samples and consumers as factors. Then, for both cases, when the difference between the samples was detected, the comparison of the variables' mean was performed using the Tukey test. The analyses were conducted at Statistica 10.0 (StatSoft Inc., Oklahoma, USA) at 5% significance level.

The partial least square (PLS) analysis was applied to the data, considering the overall liking of the snacks as the dependent variable and the sensory attributes from RATA as explanatory (independent) variables. The analysis was performed using the XLSTAT statistical software for Microsoft Excel.

3. Results and discussion

3.1. Physical properties of the snacks

In this study, the extrusion conditions used for the snacks production were the same for all samples. Thus, the density (0.09 g/cm^3 for all snacks) and the cutting force (ranging from 19.5 to 21.9 N) did not differ significantly between products. The expansion ratio ranged from 3.9 to 4.3 among samples, showing a significant difference only between Snacks R + Glu and R + UI 1 (3.9 and 4.3, respectively, $p \leq 0.05$), however, this was probably due to variations that occurred during the extrusion process. The dough degree of puffing after the extruder exit is described by the expansion ratio and density. The expansion ratio considers the expansion in only one direction, perpendicular to extrudate flow, while the density considers the expansion in all directions (Falcone & Phillips, 1988). Therefore, expansion ratio measurement is more subject to variation than density measurements (Meng, Threinen, Hansen, & Driedger, 2010).

Expansion ratio and density measurements are useful to estimate the extrudates degree of expansion (Saldanha do Carmo et al., 2019), while the cutting force correlates strongly with the sensory perception of texture attributes (hardness, fracturability and chewiness) (Paula & Conti-Silva, 2014). The snack samples presented low density and low cutting force. This occurs because high temperatures applied during extrusion (as applied here, 140 °C) reduce the viscosity of the melt, allowing greater expansion and, consequently, less density, reducing the cutting force (Menis-Henrique et al., 2020; Yuliani, Torley, D'Arcy, Nicholson, & Bhandari, 2006). According to Meng et al. (2010) desirable extruded snacks are characterized by high expansion ratio, low density and hardness, characteristics presented by the snack samples evaluated in this study. Similar density, expansion ratio and cutting force results were found by Menis-Henrique et al. (2020) in their study on corn-extruded snacks.

3.2. Sensory acceptance of the snacks

Sodium reduced snack samples (snacks R + Glu, R + UI 1 and R + UI 1.5) had, in general, less sensory acceptance for odor, texture, salty taste, flavor and overall liking ($p \leq 0.05$) compared to the control sample (Table 2). This probably occurred because reducing sodium can have adverse effects on salty taste and influence the entire flavor profile of a product since the flavor perception combines gustative perception of soluble and nonvolatile compounds (basic tastes), volatile compounds through retronasal olfaction (aroma) and chemical sensations through the trigeminal nerve (Conti-Silva & Souza-Borges, 2019; Liem et al., 2011). Nevertheless, the snacks were not rejected by consumers since the sodium-reduced samples had scores around 6 (like slightly, ranging from 5.74 to 6.03) for overall liking. Besides this, the Umami Ingredient (snacks R + UI 1 and R + UI 1.5) showed a performance comparable to MSG (R + Glu) ($p > 0.05$), obtaining a statistically equal score for the attributes from the hedonic evaluation, thus exerting a function of flavor enhancer. This highlights the potential of the umami compounds present in the Umami Ingredient (Harada-Padermo et al., 2020) to enhance salty taste, as reported in previous studies on the interaction of salty and umami tastes (Mojet et al., 2004; Yamaguchi & Takahashi, 1984).

The ideal salty taste intensity showed that Control presented salty taste intensity around 5 (4.96), which represents ideal intensity of salty taste. The other samples received lower scores ($p \leq 0.05$), between 3.38 and 3.95, which corresponds to slightly less intense to moderately less intense than ideal. The ideal cheese flavor intensity for sodium-reduced snacks (snacks R + Glu, R + UI 1 and R + UI 1.5) was lower than that of the control sample (Control) ($p \leq 0.05$). The ideal intensity of certain sensory attributes goes beyond the sensory perception of each individual, being also related to the preferences and consumption habits of each person. Scientific evidence points out that salty taste preference is due to previous sensory experience (Antúnez, Giménez, Alcaire, Vidal, & Ares, 2019; Liem et al., 2011). Considering that the Brazilian population has the habit of consuming sodium in quantities higher than those recommended (Mill et al., 2019) by WHO (2014), it is expected that, initially, reductions in the salt content of food cause a drop in sensory acceptance by consumers. However, the preference for a specific level of saltiness can be modified by repeated exposures to products with less salt (Dötsch et al., 2009), and it is up to the food industry to increase the supply of tasty and low-sodium products.

3.3. Sensory profile of the snacks

There was no significant difference between samples in relation to the yellow color (Table 3), showing that the application of the Umami Ingredient did not interfere in the snacks coloring. The sensory attributes related to the snacks texture, crispness and hardness, also did not differ among samples (Table 3) ($p > 0.05$), which was expected, as all

Table 2
Sensory acceptance of the snacks.

	Snacks				F-Fisher from ANOVA	p-value from ANOVA
	Control	R + Glu	R + UI 1	R + UI 1.5		
Hedonic scale						
Odor	6.74 ± 1.66^{a}	6.34 ± 1.49^{ab}	6.09 ± 1.78^{b}	6.08 ± 1.77^{b}	5.372	0.001
Texture	7.18 ± 1.45^{a}	6.64 ± 1.80^{b}	6.72 ± 1.81^{ab}	6.52 ± 1.76^{b}	5.180	0.002
Salty taste	7.06 ± 1.41^{a}	5.75 ± 1.80^{b}	5.55 ± 1.95^{b}	5.29 ± 2.08^{b}	30.485	<0.0001
Flavor	7.00 ± 1.55^{a}	5.79 ± 1.77^{b}	5.53 ± 2.09^{b}	5.47 ± 1.93^{b}	24.146	<0.0001
Overall liking	7.03 ± 1.34^{a}	6.03 ± 1.53^{b}	5.88 ± 1.80^{b}	5.74 ± 1.69^{b}	22.335	<0.0001
Just-about-right scale						
Ideal salty taste intensity	4.96 ± 1.01^{a}	3.95 ± 1.17^{b}	3.48 ± 1.25^{c}	3.38 ± 1.34^{c}	46.034	<0.0001
Ideal cheese flavor intensity	4.26 ± 1.07^{a}	3.70 ± 1.13^{b}	3.30 ± 1.22^{c}	3.19 ± 1.20^{c}	21.418	<0.0001

Each value is expressed as mean ± standard deviation (n = 99). Different lowercase letters within a row are significantly different by Tukey test ($p \leq 0.05$).
Control: 2.8% salt, 0.6% MSG, 0% Umami Ingredient; R + Glu: 0.8% salt, 0.6% MSG, 0% Umami Ingredient; R + UI 1: 0.8% salt, 0% MSG, 1.0% Umami Ingredient; R + UI 1.5: 0.8% salt, 0% MSG, 1.5% Umami Ingredient.

Table 3
Sensory attribute scores obtained by Rate-All-That-Apply (RATA) to the snacks.

Attributes	Snacks				F-Fisher from ANOVA	p-value from ANOVA
	Control	R + Glu	R + UI 1	R + UI 1.5		
Yellow color	1.83 ± 0.73	1.73 ± 0.71	1.77 ± 0.73	1.78 ± 0.69	0.695	0.56
Oil odor	0.67 ± 0.76	0.52 ± 0.75	0.60 ± 0.75	0.55 ± 0.66	1.482	0.22
Cheese odor	1.63 ± 0.80^{a}	1.42 ± 0.76^{a}	1.39 ± 0.79^{ab}	1.17 ± 0.77^{b}	8.313	<0.0001
Crispness	2.21 ± 0.66	2.05 ± 0.69	2.09 ± 0.77	2.06 ± 0.78	1.904	0.13
Hardness	1.38 ± 0.79	1.26 ± 0.80	1.41 ± 0.78	1.39 ± 0.73	1.550	0.20
Cereal flavor	0.93 ± 0.87	0.92 ± 0.87	1.07 ± 0.95	1.08 ± 0.91	2.289	0.08
Oil flavor	0.56 ± 0.73	0.51 ± 0.71	0.57 ± 0.74	0.57 ± 0.67	0.303	0.82
Cheese flavor	1.73 ± 0.75^{a}	1.36 ± 0.61^{b}	1.21 ± 0.66^{bc}	1.13 ± 0.63^{c}	20.323	<0.0001
Garlic flavor	0.34 ± 0.63	0.28 ± 0.55	0.22 ± 0.46	0.25 ± 0.52	1.609	0.19
Onion flavor	0.43 ± 0.64^{a}	0.30 ± 0.60^{ab}	0.24 ± 0.54^{b}	0.32 ± 0.57^{ab}	3.287	0.02
Seasoning flavor	1.53 ± 0.85^{a}	1.01 ± 0.75^{b}	0.86 ± 0.67^{b}	0.96 ± 0.65^{b}	23.846	<0.0001
Salty taste	1.95 ± 0.68^{a}	1.23 ± 0.57^{b}	1.28 ± 0.61^{b}	1.20 ± 0.64^{b}	43.109	<0.0001
Umami taste	0.92 ± 0.89^{a}	0.89 ± 0.82^{ab}	0.69 ± 0.75^{b}	0.73 ± 0.81^{ab}	4.080	0.01
Sweet taste	0.24 ± 0.55^{b}	0.34 ± 0.64^{ab}	0.34 ± 0.61^{ab}	0.41 ± 0.73^{a}	2.806	0.04

Each value is expressed as mean ± standard deviation (n = 99). Different lowercase letters within a row are significantly different by Tukey test ($p \leq 0.05$).
Control: 2.8% salt, 0.6% MSG, 0% Umami Ingredient; R + Glu: 0.8% salt, 0.6% MSG, 0% Umami Ingredient; R + UI 1: 0.8% salt, 0% MSG, 1.0% Umami Ingredient; R + UI 1.5: 0.8% salt, 0% MSG, 1.5% Umami Ingredient.

samples were obtained under the same process conditions (item 2.2).

Regarding the odor, the oil odor did not significantly differ among samples. On the other hand, the cheese odor perception was reduced in R + UI 1.5 compared to the others ($p \leq 0.05$). This sample had a greater concentration of Umami Ingredient (Table 1), which may have caused changes in the sample odor. This was probably because the dried shiitake, as well as its extract, are raw materials for the production of the Umami Ingredient (Harada-Padermo et al., 2020), and have a varied range of volatile compounds (Dermiki, Phanphensophon, et al., 2013; Politowicz, Lech, Lipan, Figiel, & Carbonell-Barrachina, 2017) that may have altered the perception of the cheese odor.

For flavor attributes (Table 3), cereal, oil and garlic flavor did not differ among samples ($p > 0.05$). The cheese flavor was more intense in the control sample (Control) and less intense in samples with less sodium, especially in R + UI 1.5 ($p \leq 0.05$). As previously explained for the cheese odor, the volatile compounds of the Umami Ingredient may have altered the cheese flavor perception (mainly in R + UI 1.5), since the perception of flavor is due to the interaction of compounds linked to basic tastes together with volatile compounds perceived by retronasal olfaction (aroma) and chemical perceptions (Conti-Silva & Souza-Borges, 2019). For the onion flavor, only R + UI 1 differed significantly from the control sample (Control), probably due to the lower salt content associated with the lower concentration of Umami Ingredient. The seasoning flavor was perceived with greater intensity in the control sample than in sodium-reduced samples ($p \leq 0.05$). Altogether, modifications in the snack flavor perception in relation to the control sample are mainly due to the reduction in the salt content (sodium) of the samples (R + Glu, R + UI 1 and R + UI 1.5), since the reduction of perceived saltiness is related to multiple flavor effects. The perceived saltiness is also influenced by the nature of the food matrix (e.g., the salty taste is more easily perceived in aqueous solution than in the solid food matrix, at the same concentration), as well as by interactions with other taste components. Thereby, the general influence of sodium reduction is the reduction of saltiness, reduction of sweetness, increase of bitterness, reduction of appetitive aromas associated with salty and sweet taste and increase of aversive aromas associated with bitter taste (Liem et al., 2011).

For the salty taste, it is remarkable that the reduction in salt content changed the perceived saltiness (Table 3). However, the Umami Ingredient performed similarly to the MSG flavor enhancer (umami taste standard) on the salty taste of the sodium reduced samples (R + Glu, R + UI 1 and R + UI 1.5) ($p > 0.05$). The snack R + UI 1 presented umami taste significantly less intense than the control, possibly because it has a lower concentration of the Umami Ingredient. For umami taste to reach a similar intensity to that of the control sample, it would be necessary to increase the concentration of Umami Ingredient, as observed in the R + UI 1.5. The sweet taste was perceived at low intensity in all samples, being higher in the R + UI 1.5 compared to the control snack (Table 3) ($p \leq 0.05$), which may be related to the presence of maltodextrin in the Umami Ingredient. Despite playing an important role during the production (spray drying) of the Umami Ingredient (Harada-Padermo et al., 2020), maltodextrin may have low or no sweetness, which is related to its DE (dextrose equivalency) since as it increases, greater is the sweetness (BeMiller, 2019).

Another study evaluated low-sodium corn extruded snacks added with MSG (Panzarini, Menis-Henrique, & Conti-Silva, 2020). According to the authors, when the salt percentage increases, the ideal intensity of salty taste, the degree of liking of salty taste and the degree of liking of flavor also increase. This observation is similar to that observed in this study, in which the sample with the highest salt content (Control; Table 1) received higher scores for degree of liking of salty taste and flavor, and ideal salty taste intensity (Table 2). Such findings reinforce the fact that eating habits play a major role in shaping consumer preferences, and thus, the gradual salt reduction should be a strategy for reducing sodium intake (Antúnez et al., 2019; Hoppu et al., 2017).

Substitutes for MSG have been evaluated in other types of food, such as meat products (Dermiki, Mounayar, et al., 2013; Miller et al., 2014) and soups (Wang, Zhang, & Adhikari, 2019). In the latter, mushroom concentrate, tomato concentrate and yeast extract were evaluated separately as new flavor enhancers to replace MSG in chicken soup. Chicken soups with mushroom or tomato concentrate had lower liking scores than soups with MSG, yeast extract or 0.5% of salt. The authors highlighted that the lower chicken flavor and lower salty taste might have been the reason for the failure of mushroom and tomato concentrates in consumer acceptance (Wang et al., 2019).

Although the salt reduction of snacks is not a simple task and the total substitution of salt by flavor enhancers is not possible (Maluly et al., 2017), Panzarini et al. (2020) showed that either the increment of salt or MSG enhanced the ideal intensity of salty taste, the degree of liking of salty taste and the degree of liking of flavor. This indicates that the substitution of salt for MSG may be an alternative to reduce sodium in this type of product, since 1 g of MSG and NaCl has approximately 123 and 393 mg sodium, respectively (Maluly et al., 2017).

The PLS analysis (Fig. 1) resulted in a cumulated R^2 of 67.5% for two components, and showed the effects of the sensory attributes of the snacks on the overall liking. The R + Glu did not stand out in any attribute, which indicates that such sample showed intermediate or even lower intensities of the attributes in the sensory profile. Snacks R + UI 1 and R + UI 1.5 were described as very similar regarding the terms sweet taste, cereal flavor, hardness and oil flavor, while the control snack was characterized by all the other attributes. The attributes that described the control snack were responsible by the great overall liking for this sample. Current studies have shown that, although consumers are more concerned with their health and well-being, most of them still prioritize their preference and consume what they like or are used to, without considering the effects on health, i.e. they are not willing to give up the sensory quality of the product (Carrillo, Varela, Salvador, & Fiszman, 2011; Conti-Silva & Souza-Borges, 2019; Hernández-Carrión, Varela, Hernando, Fiszman, & Quiles, 2015). There were some consumers who liked the low-sodium snacks, especially the snacks R + UI 1 and R + UI 1.5, which shows that even with different sensory profiles, there are different market niches of consumers that search for low-sodium snacks and with good appreciation by such products. As shown by Nguyen and Wismer (2019), p. 52% of consumers perceived sodium-reduced potato chips as *not salty enough*, while the regular version was perceived as *too salty* by 45% of consumers. They also showed that the saltiness perception (as *too salty* or *not salty enough*) was different according to the participants' dietary sodium consumption with higher liking of the reduced version by those with low dietary sodium sources. This ratifies the current market presents different niches due to consumers diversified preference, and it is a challenge to answer all consumer preferences and needs. Therefore, the utilization/application of the Umami Ingredient adds umami compounds naturally present in shiitake mushroom, which can contribute to a good consumer perception about the products to which it is added, known as 'no added MSG' (Radam et al., 2010), besides resulting in food with low-sodium content (Harada-Padermo et al. (2020) and Table 1), helping the development of new products that meet consumers' desire.

4. Conclusions

The snacks presented low density and cutting force, in addition to high expansion ratio. The reduction of sodium in the snacks caused modifications in the sensory profile, as well as in the acceptance of the samples by consumers, especially compared to the control sample. Despite the decrease in acceptance, the sodium reduction did not result in a product rejection, which may be related to the use of flavor enhancers. The Umami Ingredient proved to be efficient as a flavor enhancer, presenting similar results to MSG (standard umami compound) for attributes such as seasoning flavor, salty and umami tastes. This result is promising, since the Umami Ingredient can substitute the MSG, aggregating umami compounds obtained directly from shiitake byproducts, contributing to the development of products with less additives added, especially low-sodium food formulations. We emphasize here that its evaluation in other types of products is recommended to investigate its potential in other food matrices. As it is a complex process, it is expected that, initially, the reduction in sodium content will cause a drop in the product acceptance by consumers. However, these actions are necessary for the population to habituate their sense of taste and be less exposed to the occurrence of non-communicable chronic diseases, such as hypertension and cardiovascular problems.

CRediT authorship contribution statement

Samara dos Santos Harada-Padermo: Conceptualization, Methodology, Formal analysis, Investigation, Visualization, Project administration, Writing - original draft, Writing - review & editing. **Liara Silva Dias-Faceto:** Investigation, Visualization, Writing - review & editing.

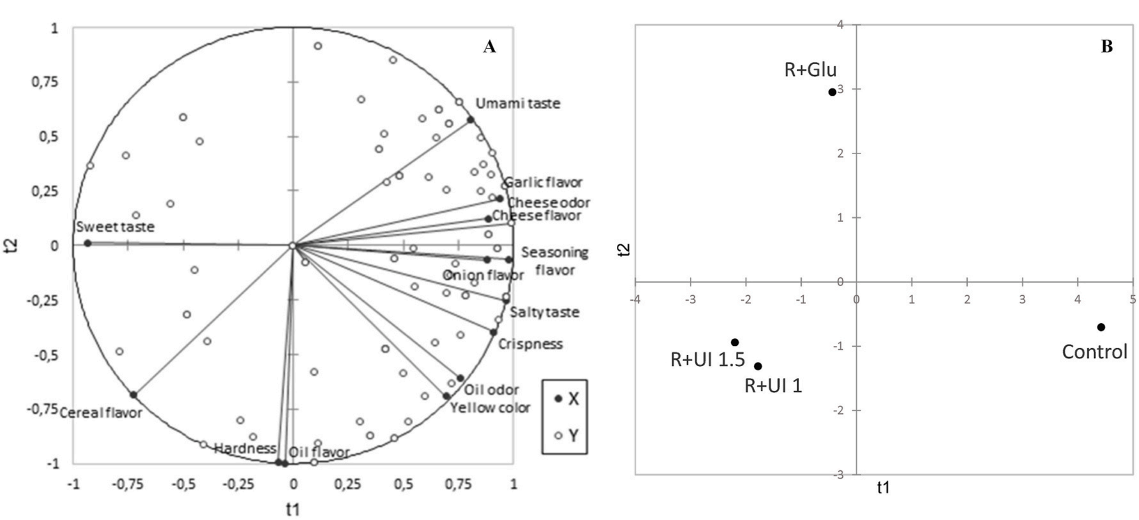

Fig. 1. Results from PLS analysis for snacks. A - Projection of variables (X = explanatory variables - attributes; Y = dependent variables – consumers' overall liking). B - Projection of products. Control: 2.8% salt, 0.6% MSG, 0% Umami Ingredient; R + Glu: 0.8% salt, 0.6% MSG, 0% Umami Ingredient; R + UI 1: 0.8% salt, 0% MSG, 1.0% Umami Ingredient; R + UI 1.5: 0.8% salt, 0% MSG, 1.5% Umami Ingredient.

Miriam Mabel Selani: Visualization, Writing - review & editing. **Ana Carolina Conti-Silva:** Conceptualization, Methodology, Formal analysis, Resources, Visualization, Writing - review & editing, Supervision. **Thais Maria Ferreira de Souza Vieira:** Writing - review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors acknowledge Mélanie Demeure for the help during the sensory sessions. This study was financed in part by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001.

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