Journal of Culinary Science & Technology

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/wcsc20

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JOURNAL OF CULINARY SCIENCE & TECHNOLOGY
https://doi.org/10.1080/15428052.2022.2088435

Use of Microencapsulation of Aromatic Plants and Spices as a Strategy for Salt Reduction for Food and Cooking

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ABSTRACT
Excessive salt intake is highly prevalent worldwide, posing as a risk factor for cardiovascular diseases. Scientific evidence supports the need for salt reduction in food. This project aimed for application of microencapsulation of aromas of aromatic plants and spices to decrease/exclude salt. Product was applied in school and adult meals in two canteens. Participants fulfilled a questionnaire for hedonic, salt and overall evaluation. Results for sensorial evaluation show no significant differences for most of the parameters (overall evaluation$_{children}$ – M_{CMc} = 7,5, SD = ±1,6; M_{IMc} = 8,2, SD = ±1,3; salt$_{children}$ – M_{CSc} = 2,9, SD = ±0,7; M_{ISc} = 2,6, SD = ±0,7; overall evaluation$_{adults}$ M_{CM} = 6,8, SD = ±1,1; M_{IM} = 6,5, SD = ±1,3; salt$_{adults}$ – M_{CM} = 3,1, SD = ±0,5; M_{IM} = 2,75, SD = ±0,5)), evidencing good acceptance. This product constitutes a strategy for salt reduction/elimination in catering and people's homes.

ARTICLE HISTORY
Received 23 September 2021
Revised 4 February 2022
Accepted 29 May 2022

KEYWORDS
Salt reduction; cooking; microencapsulation; aromatic plants

Introduction

Excessive salt consumption has been recognized as a worldwide health problem for several years (He & MacGregor, 2014; Li, 2019; Organization, 2020; Wilson et al., 2016; Wong et al., 2017). Several efforts have been made in different countries to reduce salt consumption (Ding et al., 2020; Folta et al., 2019; Graça, 2013; He, Tan, Ma, & MacGregor, 2020; Kilcast & Angus, 2007; Santos et al., 2017; Toldrá & Barat, 2012), but despite all these initiatives populations still consume salt above the recommended levels (Organization, 2020). There is enough evidence linking excessive salt consumption with several diseases, especially cardiovascular disease (CVD), stroke, and cardiac related diseases (He, Li, & MacGregor, 2013; He & MacGregor, 2013; Li, 2019; Populations et al., 2013; Zhu et al., 2014), thus supporting the need to reduce salt consumption (Webb et al., 2017; Wilson et al., 2016).

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Despite the need for salt reduction, sodium is recognized to affect food sensory properties, since, among other flavor effects, it decreases bitterness and increases sweetness, ultimately affecting individual liking and acceptance (Bakke et al., 2018; Liem, Miremadi, & Keast, 2011), which is one of the main reasons why some efforts have found resistance and fail to be successful (Mayor, 2018). Several developments have been made from the technological and industrial point of view to create solutions to reduce the use of salt in foods. There are products that act on the physical structure of salt, creating smaller molecules that are easier to dissolve and perceive, other use aromas and odors that increase the saltiness perception, but must be used in low concentration in order not to affect the profile of the final product. The umami flavor has also been recognized as increasing salt perception and being able to reduce salt content between 17% to 50% (Sobel, 2012). Some products use potassium chloride salts but have been associated with metallic taste perception (Mitchell, Brunton, & Wilkinson, 2011). Aromatic plants and spices have also been used to enhance flavor, while reducing salt (Ghawi, Rowland, & Methven, 2014) and are part of the Portuguese culinary traditions for decades and are well-known for their properties to act as flavors intensifiers, being broadly recommended as an alternative to reduce salt use while cooking. Abundant use of aromatic plants, however, might negatively affect the typical color of characteristic taste of the dish. For this reason, previous research has been conducted by the authors, who developed mixtures of aromatic plants and spices, from which aromas were extracted and microencapsulated using spray drier technique (Serrano, Sapata, Oliveira, Gerardo, & Viegas, 2020). These microencapsulated forms of the mixtures were developed, in order to reduce changes in color and taste, while preserving aromas and flavors. As a microencapsulated form, they also allow for longer shelf storage preserving aromatic and flavor compounds, which is smaller for fresh or dried aromatic plants. They also have a spherical form and a white color, which resembles salt in appearance and use (Serrano et al., 2020).

During the previous research the authors have tested the use of the microencapsulates in different cooking procedures, and preliminary results within the research team suggested that they were suitable for allowing a reduction in the use of salt for traditional and industrial use. Therefore, the purpose of this study was to test the use of the microencapsulates in real life context and evaluate the perception in salt and taste of the public, hypothesizing that replacing salt for the microencapsulate would result in no differences in taste, salt perception and overall evaluation of food.

Method

Participants

This study was performed including two different populations: students from a public elementary school, ages from 7 to 9 (3rd and 4th grade) and adults working in an Information Technology company, including workers from different company sectors. These populations were selected by convenience, because both had their canteens meals provided by the same catering company, who had previously agreed to test the microencapsulates. Both canteens had previous satisfaction evaluation with good/very good results.

Study design

Children population (school)

The study was performed in two consecutive weeks, on the same day of the week, using the same meal for each day (vegetable soup, rice chicken with salad). On week 1 the meal was cook as usual, using the typical amount of salt – control soup (CSc) and Control Main Course (CMc). On week 2 the meal was cook as usual, but all the salt was replaced by the microencapsulate – intervention soup (ISc) and intervention Main Course (IMc). A chef from the researchers' team accompanied and supervised the cooking of the meals in both weeks. Immediately after finishing the meal, children were asked to fulfil a form evaluating the meal (soup and main course separately) for taste on a scale from 1 to 5, and salt perception using a scale from 1 to 5, where 3 stands for adequate. Both scales used written and image descriptors (Figure 1). Overall meal evaluation was performed from 1 to 9 (don't like at all – like very much). Intensity for species and aromatic plants was also evaluated on a scale from 1 to 3, were 2 stands for adequate.

Parents were previously asked to authorize the participation of children in this study. Children gave written, freely given, enlightened, informed assent for participation (with previous children's legal guardian approval and signature). As mentioned in the informed consent this study does not represent risks, costs, or harm to the participants.

	1 Very bad ☹☹	2 Bad ☹	3 Reasonable 😐	4 Good ☺	5 Very good ☺☺
Taste					

	1 Very unsalted ☹☹	2 Unsalted ☹	3 Adequate ☺	4 Salty ☹	5 Very salty ☹☹
Salt					

Figure 1. Example of used scales with written and image descriptors.

Adult population

From the four main courses available and served on the chosen day of the week, two were selected, cooked as usual but 50% of salt commonly used was replaced by the microencapsulate – Intervention Main Courses (IMa). The others were cooked as usual with the typical amount of salt – Control Main Courses (CMa). The ration of salt replacement was approximately one (salt) to three (microencapsulate). A chef from the researchers' team accompanied and supervised the cooking of the dishes and controlled for the amount of salt used. A form, containing a page with informed consent, was distributed with the meal, to be fulfilled and delivered after the meal was finished. Evaluation of the main course for taste and salt perception, and overall evaluation were performed as previously described for children.

Statistical analyses

Hedonic, taste and salt perception data were analyzed using descriptive analysis and Mann-Whitney test for testing differences between intervention and control meals, data was presented as means ± standard deviation, p value $< .01$ was considered significant. Spearman correlations were calculated to identify relation between taste and salt perception. R (version 3.4.1) was used for all statistical analysis.

Study approval

This study was part of a project approved by the Science and Technology Foundation from Portugal (SAICT 24003). It did not require Ethics Committee Approval, since no personal data was retrieved from participants, and it posed no risk for participants.

Results

Children

Table 1 presents results in both populations. A total of 102 children participated, aged from 7 to 9 years old (3^{rd} and 4^{th} grades).

Overall evaluation showed more positive results for control soup (M_{CSc} = 6,6, SD = ±2,0) when compared to intervention soup (M_{ISc} = 5,2, SD = ±2,6), but no differences were found (W = *392,5*, $p > .01$) between the two soups. Overall evaluation was scored 6 or more by 65,5% of children for control soup vs 52,4% for intervention soup (Figure 2).

As for the main course, the intervention main course scored slightly higher results when compared to the control main course (M_{CMc} = 7,5, SD = 1,6; M_{IMc} = 8,2, SD = ±1,3), but again no statistically significant differences were

Table 1. Mean values and Mann-Whitney tests for differences.

		Overall evaluation			Taste perception			Salt perception		
		M	W	p	M	W	p	M	W	p
Children	Control Soup	6,6 ± 2,0	393	0,08	3,8 ± 1,0	469	**0.002**	2,9 ± 0,7	373	0,200
	Intervention Soup	5,2 ± 2,6			2,9 ± 1,1			2,6 ± 0,7		
	Control Meal	7,5 ± 1,6	211	0,09	4,5 ± 0,6	336	0,662	3,1 ± 0,5	326	0,771
	Intervention Meal	8,2 ± 1,3			4,3 ± 0,8			3,1 ± 0,5		
Adults	Control Meal	6,8 ± 1,1	1991	0,226	3,8 ± 0,6	2181	0,709	3,1 ± 0,3	1734	**0.00056**
	Intervention Meal	6,5 ± 1,3			3,7 ± 0,7			2,8 ± 0,5		

M = mean; W = Result for Mann-Whitney test; p = p-value – significant values are presented in bold type

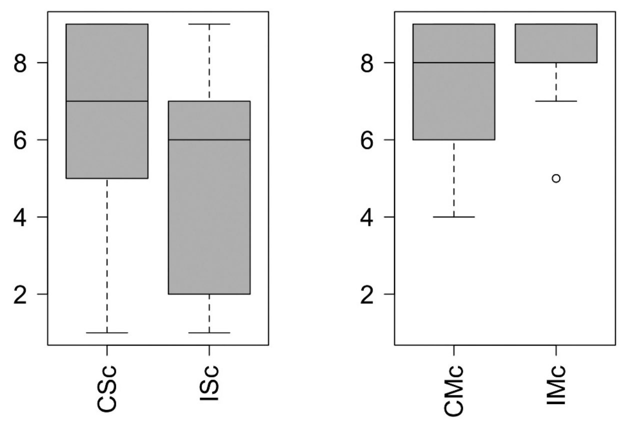

Figure 2. Results for overall evaluation (scale 1 to 9) – soup and meal.

found (*W = 211*, p > .01). Overall evaluation was scored 7 or more by 72,4% of children for control main course vs 90% for intervention main course (Figure 2).

For taste, soups yield better results for the control (M_{CSc} = 3,8, *SD* = ±1,0) than for the intervention (M_{CSc} = 2,9, *SD* = ±1,1) and statistical differences were found (*W = 469*, p < .01). 93,3% of children score 3 or more for the taste of control soup while vs 62% for intervention soup (Figure 3).

Taste results for the main course are very similar (M_{CMc} = 4,5, *SD* = ±0,6; M_{IMc} = 4,3, *SD* = ±0,8) and no differences were found between the two main courses (*W = 336*, p = 0,662). No child attributes negative values (one or two) for neither of the main courses (Figure 3).

As for salt perception for the soups, results are also very similar (M_{CSc} = 2,9, *SD* = ±0,7; M_{ISc} = 2,6, *SD* = ±0,7), with no statistically significant differences (*W = 373*, p > .01).

No differences were found between salt perception for the main course (*W = 326*, p > .01) and results are once again very similar (M_{CMc} = 3,1, *SD* = ±0,5; M_{IMc} = 3,1, *SD* = ±0,5). For the control main course 73,3% of children consider salt to be adequate vs 90,5% for the intervention main course (Figure 4).

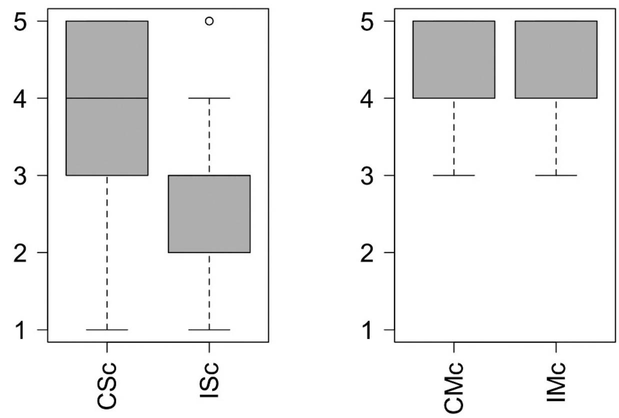

Figure 3. Results for taste evaluation (scale 1 to 5) – soup and meal.

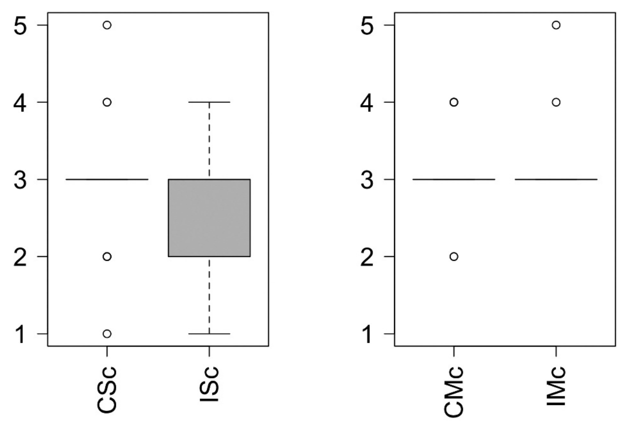

Figure 4. Results for salt evaluation (scale 1 to 5) – soup and meal.

Spearman correlation between taste and salt perception was 0,46 ($p < 0{,}01$) – low (Mukaka, 2012).

Adults

A total of 140 adults participated. Overall evaluation for both Control and Intervention Main Course was positive (M_{CM} = 6,8, *SD* = ±1,1; M_{IM} = 6,5, *SD* = ±1,3) and no differences were found (*W* = *1990.5*, p > .01). Overall evaluation was scored 6 or more by 81% of participants (Figure 5).

Taste evaluation also yield positive results (M_{CM} = 3,79, *SD* = ±0,62; M_{IM} = 3,74, *SD* = ±0,67) and no differences were found (*W* = *2180*,5, p > .01). Taste evaluation was scored three or more by more than 97% of participants for both main courses (CM = 97,87%, IM = 97,92%), a score of four or more was achieved by 72,3% for the controlled main course vs 68,8% for the intervention main course (Figure 6).

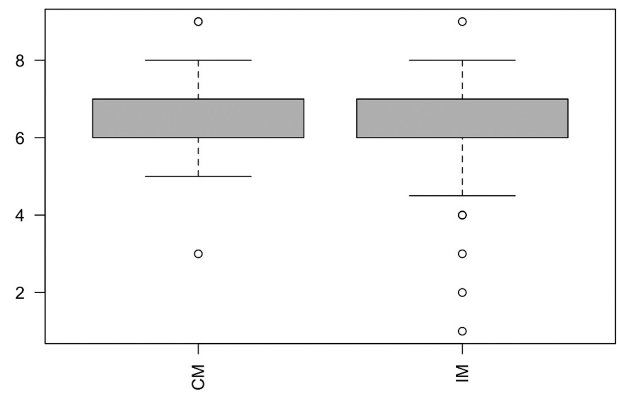

Figure 5. Results for overall meal evaluation (scale 1 to 9).

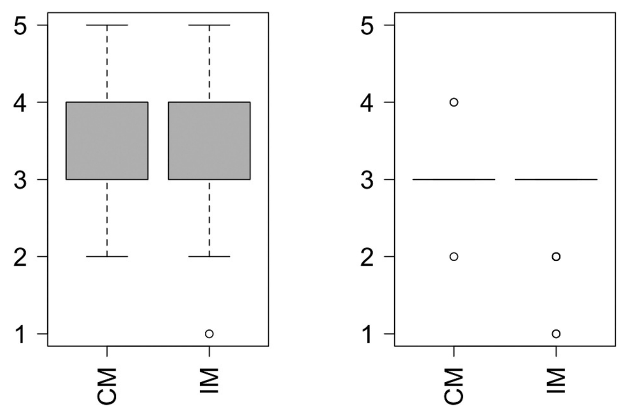

Figure 6. Results for taste and salt meal evaluation (scale 1 to 5).

For salt perception an average of 3,1 was found for controlled main courses (SD_{CM} = ±0,25) and 2,75 for intervention main courses (SD_{IM} = ±0,5), a significant difference supported by Mann-Whitney test ($W = 1734$, $p < .01$). Salt perception was scored three (adequate) by 93,6% of participants for controlled main course and 78,1% for intervention main course (Figure 6).

Spearman correlation between taste and salt perception was 0,301 ($p < 0,01$) – low (Mukaka, 2012).

Discussion

Reduction of salt consumption is an important public health strategy, with implication on individual health, stroke and cardiovascular mortality and health system costs. Some strategies for the reduction of salt consumption act on population level, emphasizing recommendations and nutrition education while others have tried to work on the development of salt replacers or substitution, with variable success (Cappuccio, Capewell, He, & MacGregor, 2013; Curtis, Clapp, Niederman, Ng, & Angell, 2016; Ding et al., 2020; Liem et al., 2011; Riches, Aveyard, Piernas, Rayner, & Jebb, 2019; Santos et al., 2017). Our study aimed to test a product obtained from microencapsulation of aromatic plants and spices (Serrano et al., 2020), on real context catering service, directed at children and adult population. The results from this study may be considered very positive, once, for most comparisons the researchers found no significant differences, suggesting that the microencapsulates may pose as a very good solution for use in traditional cooking as a salt replacer.

Portuguese public schools have engaged in strategies to reduce salt use and limit the use of processed foods in school's meals (Lima, 2018). Nevertheless, these limitations may compromise taste and increase food waste. The school in question for this study already has a predefined limit for salt use (no more than 1,4 g per meal served (Nogueira et al., 2021), which is 30% to 50% less than common salt use in other contexts. As these students are already use to lower salt intakes, researchers decided to total eliminate salt and replace it by the microencapsulate. Main course results are very similar, with no differences and intervention main course having a slightly higher score compared to the control, which might indicate that aroma and flavors present in the microencapsulate may enhance some of the dish's flavors when compared to salt, which may contribute to increase acceptance.

Studies have shown that sodium concentrations needed to be detected by our taste buds differ according to the food matrix being easier to detect in an aqueous matrix vs a solid one (Liem et al., 2011). This fact might account for the differences perceived in soups, as the salt perception would be typically higher in the soup when compared to the dishes. Although the difference is only found for taste, the higher perception of salt could be identified by the children as a difference in taste, rather than salt. Also, Portuguese children have low intake of vegetables and soup (Lopes et al., 2018) and do not usually enjoy eating these food items (Hodder et al., 2017), which might have increased the effect on taste perception.

For the adult population, salt perception, although small and close to the "adequate" perception, a statistically significant difference (3,1 vs 2,8, $p < 0{,}01$) was found. For overall evaluation and taste results found no differences between the control and intervention main courses. There aren't many intervention studies for salt reduction in canteens, but most consider that consumer acceptability as the main barrier (Mota, Padrão, Silva-Santos, Pinho, & Gonçalves, 2021). A recent Portuguese study managed to reduce salt by 30%, in university adult population, with no decrease in satisfaction or food waste (Faria et al., 2022). Our study considered a 50% salt reduction plus the microencapsulate, which may indicate that this formula may be use for further reductions. Other researchers have study suggesting that the addition of herbs and spices is a feasible strategy for achieving a 50% reduction in salt content without compromising hedonic appreciation (Dougkas, Vannereux, & Giboreau, 2019).

A survey reported that restaurant foods have the highest sodium density (mg/1000 kcal) among American diets (Quader et al., 2017). Also, there is a common perception among chefs and catering businesses that reducing salt could result in a decrease of public acceptance and therefore a decrease in sales and profit (Ma et al., 2014; Mallia & Gauci, 2012; Tempels, Verweij, & Blok, 2017). This belief is usually associated with the belief that salt perception is associated with taste. Our study, on one hand shows that the two variables are weakly correlated and, on the other demonstrates that even if salt perception is lower, taste and overall evaluation can be positively evaluated, thus suggesting that there is room for reducing salt without fear of losing customers.

Moreover, in the few studies that have been conducted to estimate sodium content of school meals in Portugal, mean salt content has ranged from 2.83 and 3.82 g (Fontes et al., 2015; Paiva et al., 2011; Viegas, Torgal, Graça, & Martins, 2015). Therefore, salt reduction in restaurants and canteens should be an integral part of overall salt reduction policies.

Strategies to reduce sodium consumption should be based on three main pillars: product reformulation, consumer education, and the environment (World Health Organization, 2006). Changes in the environment should aim at building an environment where choosing the healthiest foods is the easiest and most accessible option. Among other actions, they suggest the availability of foods and meals without added salt or with as little salt as possible, at prices and in places accessible to all consumers (World Health organization, 2013).

Considering that salt reduction has a great impact in terms of health gain in children and adults (Aburto et al., 2013), the use of microencapsulation of aromatic plants and spices may pose as a strategy to adopt on food service business to decrease salt intake in restaurants and public canteens.

Study limitations

One of the limitations of this study is that the variation of salt perception between individual dietary habits was not considered. Nevertheless, the intent was to evaluate general reaction with a broad spectrum of individuals. Moreover, the ratio of microencapsulate used for salt replacement was three to one, but it can be replaced with a higher or lower ratio according to food preferences.

Another limitation may be the fact that in adults study the control and intervention main courses were different. Nevertheless, both were commonly consumed main courses by the canteen population and with a known, previously identified, amount of salt used per meal. Researchers chose this option and not to measure among the same meals a week apart (as for children) so that adults wouldn't be advised of the potential changes in the meal which could affect the responses.

Conclusion

Around the world hypertension is still a major cause of death and disease and has doubled since 1990 (World Health Organization, 2021). Among the different risk factors, salt intake is relevant, with an urgent need to be reduced (He et al., 2020). The results of the sensorial evaluation evidenced good acceptance for all parameters, in which salt perception, flavor and hedonic evaluation stand out.

Although further studies may be necessary to test the product in a wider range of products and population, this research shows that this product can be used as a concrete strategy for salt reduction in industry, public catering and within individual context (people's homes), to use either in a gradual reduction or for total salt elimination.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research was financially supported by: Programa operacional competitividade e internacionalização (POCI) - (Lisboa-01-0145-FEDER-024003), European Union through FEDER funds and by national funds through the Foundation for Science and Technology, COMPETE 2020 – SAICT 24003 – Salt reduction.

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