Optimally accepted salt reduction across cultures
Naturally brewed soy sauce used in three countries with different food cultures

INTRODUCTION

Over five decades, scientific evidence amounted on the adverse effects a high salt intake could have on human health (1-3). Excessive intake of salt increases the risk of hypertension and is directly related to the development of cardiovascular disease (4-6). In reaction, the World Health Organization (WHO) published recommendations to reduce salt intake to 5g/day (7, 8). Currently, a reduction of salt in food is still a key issue, especially for the food industry, since processed foods are thought to account for 80 percent of salt-intake in the daily diet (9, 10). Consequently, food manufacturers in both Western and Asian countries are pressed by their authorities and consumer groups to reduce sodium content. Although several studies on salt reduction were published in the last decades, the average sodium content of processed foods decreased only by 0.3 percent per year between 1983 and 2004 (11). This finding suggests a general reluctance and/or hesitance by the food industry to apply the results of these studies.

It has been reported that perception and preference might be dependent on early childhood food experiences and specific cultural cuisines that might cast some doubts on the general applicability of cross-cultural research results (12-15). Reviewing the cultural comparison field, Sobal stated: “Cultural comparisons may be complex and problematic with many conceptual differences, difficult nuances and subtle methodological considerations. Disagreement exists among researchers and disciplines about solutions to the many methodological dilemmas involved in making cultural comparisons” (16). This might explain why there are not so many cross-cultural studies on the perception and preference of food.

From previous studies (17-19), we learned that naturally brewed soy sauce can act as a salt replacer that is accepted by Dutch, Chinese and Japanese consumers. The present paper presents the results of these earlier studies in order to make a comparison between three cultures. It explores whether the degree of acceptable salt reduction in the three countries is comparable. In this paper “salt” refers to “NaCl”, “soy sauce” to “naturally brewed soy sauce”, and “overall taste” to the overall taste intensity of all taste sensations.

Please note that the fore-mentioned studies differ in methodology from the traditional research methods used to compare the reactions to food in different populations. Instead of applying the same experimental stimulus conditions in each of the populations to guarantee the methodological comparability of the results from a scientific perspective, the present authors have chosen for a methodological approach that tries to find the optimal salt replacement (i.e. maximal salt reduction without loss of hedonic appreciation) in each of the three countries and then to compare the end results. Thus, in this strategy, the same research methods to obtain the optimum have been applied in all countries, but the stimulus ranges used have been adapted to the particular country to account for intrinsic differences between the three countries due to...
No clear pattern could be detected. Taking differences in food culture into account, these exchange rates established the maximum salt replacement by soy sauce without loss in overall taste, i.e. indicated the 100 percent soy sauce variant to be used in Step 2. The Optimal Exchange Rate, i.e. the highest concentration of soy sauce that can replace (part of) the salt without decreasing both overall taste intensity and pleasantness is determined in this second step. The standard sample (as shown in tables 5, 6, and 7) and four samples with varying salt/soy sauce content were respectively assessed for pleasantness, overall taste, salty taste and a product specific taste. The results of the first three attributes are depicted in Figure 1.

RESULTS

A short explanation of Step 1 and Step 2 of the approach is needed to understand the results. In Step 1, the Exchange Rate (ER) i.e. the concentration of soy sauce with equal overall taste intensity as the standard product was determined by means of five 2-alternative forced choice (2-AFC) tests. The panellists were given five pairs - each containing the standard product and one of the five fully soy sauce variants - in a row (pair 1 to pair 5), and were asked to choose the sample that had the stronger overall taste. The variant highest in soy sauce that was not significantly different from the standard in overall taste intensity was chosen as the ER (see Table 1) and was subsequently used as the 100 percent soy variant in Step 2. The results show that the perception of taste intensity is not the same in the three countries. With regard to the salad dressing, Japanese consumers (JP) needed a higher concentration of soy sauce (1.20 percent) to find it equal in taste intensity as the standard sample, whereas the consumers from Singapore (SG) and the Netherlands (NL) both needed the 1.00 percent w/w salt concentration. In tomato soup, the Dutch needed a higher soy sauce content (0.75 percent) than consumers in Japan and in Singapore (0.60 percent), and the Singaporeans needed lower soy sauce content (0.40 percent) in the fried pork than the Dutch and Japanese consumers (0.50 percent).

Table 1. Determination of the exchange rates (ER) per country per product. The number of ‘stronger taste’ choices per pair of product type and soy sauce variant. All percentages are given in w/w NaCl content.

Although the Dutch consumer panel clearly noticed the decrease in saltiness with increasing soy sauce content in the dressing, neither its pleasantness nor its overall taste was significantly affected by this decrease, indicating that even variant4 with the lowest salt and highest soy sauce ratio was not significantly different from the standard in overall taste intensity. The x-axis displays a decreasing order of NaCl content (percent w/w) of the samples, starting with the standard sample with a salt-soy sauce ratio in percentages of 100/0 followed respectively by the 75/25, 50/50, 25/75, and 0/100, based on the ER’s per product per country as determined in Step1.

Figure 1. Determination of the Optimal Exchange Rate.

Assessments of pleasantness, overall taste intensity and salty taste of the standard and the four variants for the determination of the Optimal Exchange Rate (OER) in the three countries, depicted by diamonds (NL), squares (JP), and triangles (SG). Solid lines indicate a significant difference between the standard and at least one of the variants, while dotted lines mean there is no such difference. Filled markers indicate a significant sample difference with the standard. The x-axis displays a decreasing order of NaCl content (percent w/w) of the samples, starting with the standard sample with a salt-soy sauce ratio in percentages of 100/0 followed respectively by the 75/25, 50/50, 25/75, and 0/100, based on the ER’s per product per country as determined in Step1.
(0.87 percent w/w salt) were perceived as weaker in overall taste than variant12 to variant14. As for stir-fried pork, the reduction of salt by soy sauce had no positive or negative effect on the pleasantness or perception of overall taste intensity. This means that in the Netherlands the OER for both tomato soup and stir-fried pork is determined by its variant14. Thus, for Dutch consumers, the optimal salt reduction is 50 percent ((2.0-1.0)/2.0) in the salad dressing, is 17 percent in the tomato soup ((0.90-0.75)/0.90), and is 29 percent ((0.7-0.5)/0.7) in the stir-fried pork.

The Japanese consumers clearly noticed a decrease in saltiness in the tomato soup with increasing soy sauce content, the overall taste intensity was not affected and pleasantness was increased. In dressing and in pork the decrease in saltiness had neither a significant impact on pleasantness or on overall taste intensity. Therefore, in Japan the OER for dressing, soup and pork is determined by their variant14 and the optimal salt reduction is 40 percent ((2.0-1.2)/2.0) in the salad dressing, is 33 percent ((0.9-0.6)/0.9) in the tomato soup, and is 29 percent ((0.7-0.5)/0.7) in the stir-fried pork. In Singapore, an effect due to the decrease in salt content was only noticed for stir-fried pork, where a significant increase in pleasantness (variant14-variant1) and a significant decrease in overall taste intensity (variant1-variant2) were found with increasing soy sauce content. Hence, the OER (SG) for stir-fried pork was set at variant2 (0.55 percent w/w). Since no significant effect was found for dressing or tomato soup, the OER (SG) for these two products was set at variant4. Thus for the Chinese consumers in Singapore, a salt reduction in the salad dressing of 50 percent ((2.0-1.0)/2.0) of 33 percent in the tomato soup ((0.90-0.60)/0.90) and of 21 percent ((0.7-0.55)/0.7) in the stir-fried pork is feasible. An overview of possible reductions is given in Table 2. The three countries seem to be quite comparable (32 percent - 34 percent - 35 percent) with respect to their degree of acceptable salt reduction within a product type.

Taken over the three products, the feasible percentage reduction is respectively 32 percent (NL), 34 percent (JP) and 35 percent (SG). Taken over the three countries, the differences between the product types are more pronounced. The highest percentage of 47 percent salt reduction is feasible in salad dressing, followed by a percentage of 28 percent and 26 percent in tomato soup and in stir-fried pork respectively.

In the present study, the ratings for pleasantness, overall taste and perceived saltiness were significantly and positively correlated (All P’s <0.01; 280-320 observations per correlation) for each of the products in each of the three countries (Table 3). The correlation between pleasantness and overall taste was higher than the correlation between pleasantness and saltiness for all three products, indicating that independently of the country, overall taste was the main driver for pleasantness. Interestingly, the correlation between overall taste and saltiness was higher in Japan and Singapore than in the Netherlands, suggesting once more that due to their diet, the connection between overall taste and salty taste is stronger in these Oriental countries.

<table>
<thead>
<tr>
<th>Product type</th>
<th>Netherlands</th>
<th>Japan</th>
<th>Singapore</th>
<th>Dish average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salad dressing</td>
<td>50%</td>
<td>40%</td>
<td>50%</td>
<td>47%</td>
</tr>
<tr>
<td>Tomato soup</td>
<td>17%</td>
<td>33%</td>
<td>33%</td>
<td>28%</td>
</tr>
<tr>
<td>Stir-fried pork</td>
<td>29%</td>
<td>29%</td>
<td>21%</td>
<td>26%</td>
</tr>
<tr>
<td>Country average</td>
<td>32%</td>
<td>34%</td>
<td>35%</td>
<td>34%</td>
</tr>
</tbody>
</table>

Table 2. Acceptable salt reduction per product per country.

**DISCUSSION**

Probably the most important outcome of this study is the finding that notwithstanding clear differences in traditional use of table salt and soy sauce between the three countries, the use of soy sauce as a salt replacer in three different foods leads to comparable results. This seems to indicate that the potential of soy sauce to partially replace salt without loss of hedonic pleasure in a variety of foods is not dependent on the food cultural background. This potential has also been investigated with reasonable success in bread in the Netherlands (20). The fact that its effect could be noticed even in staple foods, in which normally a very high resistance to any change of perceptual quality is noticed, further corroborates this conclusion.

As pointed out previously (17), one of the reasons for this pronounced suitability of soy sauce to act as a salt replacer may be that - like salt - it is also a taste enhancer and not just a salty taste stimulator. This is illustrated in the present research by the fact that in each country and for all three products the pleasantness judgments correlate stronger with the overall taste intensity than with the salty taste intensity. This result also strengthens a methodological point in the two-step procedure used in the experiments. Rather than trying to look for equivalence in saltiness between the original product and the salt replaced one in step 1, the focus is on equivalence in overall taste intensity. It might be recommendable in future research on food reformulation to take the taste modifying and taste enhancing qualities of salt replacers into account and to check their influence, not restricting attention to perceived saltiness alone.

Another finding corroborates this conclusion. In Japan and Singapore, where people have more experience with the consumption of soy sauce, the correlations between taste intensity and salty taste judgments are higher than in the Netherlands (except for tomato soup in Japan), indicating that in these first two countries salt and soy sauce may be more clearly connected through their taste enhancing qualities.

This may be true for Japanese and Chinese panellists, for whom the saltiness perception might be blurred by the combination of soy sauce with salt, but not for Dutch panellists who could easily notice the decrease in saltiness concentrations (see figure 1). However, since it had no significant effect on their appreciation, their determined OER was based on the pleasantness and overall taste
results. This finding supports the choice of products of the local investigators based on their observation that all three products were fairly familiar in their countries. Another explanation for the better saltiness discrimination by Dutch consumers might be that Japanese and Chinese consumers were less familiar with salad dressing that unfortunately was not prepared according to their own cultural flavour principles (14) and that they were consequently be less sensitive to variation this product. Another reason might be that the lower temperature by which the salad dressing was served caused the decrease in sensitivity, based on a study on identified microscopic channels in our taste buds (TRPM5) which were responsible for different taste perceptions at different temperature (21). We still have to keep in mind that repeated exposure may increase or decrease pleasantness. An initial moderate pleasantness for a reformulated food may change over time (20, 22) with the result that the Optimal Exchange rates might have to be adjusted and that the effect of repeated exposure might be different in the three countries. The food industry could play a crucial role in reducing the gap between the current and the recommended salt intake (23-25), which is 2.7g, 1.8g and 3.3g for NL [19], JP (20), and SG [21] respectively (see Table 4). Assuming that 80 percent of the salt intake stems from processed food, the feasible salt reduction by processed food alone is 32 percent*7.0g=2.2g (NL), 34 percent*8.5g=2.9g (JP), and 35 percent*6.6g=2.3g (SG) as shown in Table 4, which counts for more than two-third of the gaps between the recommended and current salt intake in the Netherlands and Singapore, while for Japan, it exceeds the current gap.

Evidently, these figures are speculative since there are cultural differences in the consumption of processed food between countries and within countries between groups, differing in age, rural/urban location, and health beliefs with regard to processed foods. Further research is needed to explore these issues. This finding suggests that naturally brewed soy sauce allows the food industry to substantially reduce the salt content of their products and thus enables them to contribute to a healthier population.

CONCLUSIONS

The results of this study show that for the three food products naturally brewed soy sauce might well be used as (partial) salt replacer. Notwithstanding differences in traditional use of soy sauce, the study led to fairly similar results in countries with rather different food-cultures. It was possible to use naturally brewed soy sauce to reduce added salt in the Netherlands, Japan and Singapore by respectively 32 percent, 34 percent and 35 percent. The feasible salt reduction was respectively 47 percent, 28 percent and 26 percent in the salad dressing, the tomato soup and stir-fried pork, showing that the effectiveness of salt reduction is strongly product dependent. The correlation between pleasantness and taste intensity was in all cases higher than the correlation between pleasantness and saltiness, indicating that independently of the country or product, taste was the main driver for acceptance. The two-step approach provides a practical way to solve the serious health problems caused by salt overconsumption without loss of flavour satisfaction on the part of the consumers.

MATERIALS AND METHODS

Participants

Locally, 64 native consumers were recruited in the Netherlands and in Japan, while in Singapore 60 Chinese consumers were recruited. Respectively 58-52-55, 64-64-64, and 60-60-60 consumers completed the study. In all three countries the age range was 18-60 years (average respectively 38, 40 and 36 years) and male and female participation was near equal. In all three studies the participants gave their consent to participate in the study and to publish the results. The studies were conducted according to the Declaration of Helsinki, and they were approved by the local ethical committees.

Food products

Similar base-materials were used in each country, except for two fresh ingredients (pre-cut salad and sliced pork). These fresh ingredients were locally purchased and prepared. The other ingredients were bought in the Netherlands and sent to Japan and Singapore. Commercially available liquid soy sauce Fancy grade (Kikkoman Food Europe B.V.) was used in the preparation of the salad dressings (per 100g: Energy 264 kJ/63 kcal, Protein 8.8g, Carbohydrates 6.9g, Fat 0.0g, Fibre 0.0g and Sodium 5.76g), whereas spray-dried Kikkoman powder soy sauce KU-20 was used in the preparation of the soups and stir-fried pork. Since both soy sauces were naturally brewed and did not contain any added artificial glutamic acid salts such as Monosodium glutamate (MSG), the sodium (Na) content present in these soy sauces corresponded directly to their total NaCl content (1g Na corresponds to 2.54g NaCl). The concentration ranges of the product variants were based on the results of pre-tests conducted among students and/or non-involved colleagues (n=10-12, untrained subjects) conducted to ensure that the soy sauce concentration range in Step 1 of the main experiment was sufficiently large to contain samples that were stronger, equally strong and weaker in overall taste intensity than the standard product. The recipes for the standard products and their variants are given in Tables 5, 6 and 7.
Procedure
A similar methodology was applied in the three countries. A 2-step reformulation methodology, developed in the Netherlands (17) was applied to efficiently determine the optimal acceptable reduction in salt using naturally brewed soy sauce. Step 1 and Step 2 of the procedure are already described above in the results section to enable understanding of the results.

Data treatment
The two-tailed paired T-test was used to analyse the ER (2-AFC) results, while analysis of variance was performed on the OER results (the ratings of the pleasantness and attribute intensity). Once the F-test indicated a significant difference between the means, post-hoc LSD comparison of means tests were performed to determine which variants were significantly different from the standard. Significance was defined as P<0.05. To reveal the correlation between pleasantness, overall taste intensity and salty taste intensity 2-tailed Pearson correlation coefficients were calculated. The data of the three countries are jointly presented in tables and graphs for cross-cultural comparison.

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References and Notes