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Physicochemical Characteristics, Sodium Content And Sensory Evaluation Of Selected Commercialised Soy Sauces In Malaysia

(Ciri-Ciri Fizikokimia, Kandungan Natrium dan Penilaian Deria Kicap Komersial Terpilih di Malaysia)

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Abstract

In Malaysia, the government has made it mandatory to label sodium content on food packaging effectively from 1st January 2024. This study evaluated the physicochemical characteristics, sodium content, and sensory evaluation of selected commercial soy sauce without sodium labelling in Malaysia. 25 soy sauce samples were studied. Each soy sauce has a significant difference ($p<0.05$) in physicochemical properties except for the pH value. Results found that the sodium content in light soy sauce was the highest (5766.50±968.37mg) while sweet soy sauce was the lowest (3289.09± 589.14mg). For total soluble solids, sweet soy sauce was the highest (52.73°B). The range of pH values for soy sauce is between 4.90-5.19. Sweet soy sauce showed the highest viscosity (145.78cP) and brightness ($L^* = 2.48$). Light soy sauce showed the highest values for redness and yellowness ($a^* = 1.34$ and $b^* = 1.57$). Soy sauce without caramel has a significantly higher ($p<0.05$) sodium content and is less viscous than the one with caramel. The sensory evaluation shows that sweet soy sauce has significantly ($p<0.05$) the highest score for overall acceptance. Sodium content information on all soy sauce available in the Malaysian market to help consumers make smarter choices.

Keywords: Soy Foods, Sodium, Food Preferences, Food Labelling, Food Analysis

Abstrak

Di Malaysia, Kerajaan telah menjadikan penglabelan kandungan natrium pada pembungkusanmakanan sebagai mandatori berkuatkuasa mulai 1 Januari 2024. Kajian ini telah menilai ciri-ciri fizikokimia, kandungan natrium, penilaian deria bagi kicap soya komersial terpilih tanpa penglabelan natrium di Malaysia. 25 sampel kicap soya telah dikaji. Setiap kicap soya mempunyai perbezaan yang ketara ($p<0.05$) dalam sifat fizikokimia kecuali untuk nilai pH. Keputusan mendapati bahawa kandungan natrium dalam kicap soya cair adalah yang tertinggi (5766.5± 968.37mg). manakala kicap soy manis adalah yang terendah (3289.09±589.14mg). Untuk pepejal larut keseluruhan, kicap soya manis adalah yang tertinggi (52.730°B). Julat nilai pH bagi kicap soya adalah antara 4.90-5.19. Kicap soya manis menunjukkan kelikatan (145.78cP) dan kecerahan ($L^* = 2.48$) tertinggi. Kicap soya cair menunjukkan nilai tertinggi untuk kemerahan dan kekuningan ($a^* 1.34$ and $b^*1.57$). Kicap soya tanpa karamel mempunyai kandungan natrium yang jauh lebih tinggi ($p<0.05$) dan kurang likat berbanding dengan kicap soya yang mengandungi karamel. Penilaian deria menunjukkan bahawa kicap soya manis mempunyai skor tertinggi yang ketara ($p<0.05$) untuk penerimaan keseluruhan. Maklumat kandungan natrium mengenai semua kicap soya yang tersedia di pasaran Malaysia untuk membantu pengguna membuat pilihan yang lebih bijak.

Kata kunci: Makanan Berasaskan Soya, Natrium, Keutamaan Makanan, Pelabelan Makanan, Analisis Makanan

INTRODUCTION

Soy sauce, also known as jiangyou in Chinese, shoyu in Japanese, and soya sauce in British English, is one of the most famous products in the market and is produced from the fermentation process of soybeans, wheat, salt, and water and involves enzymatic catalysis by various microorganisms (Diez-Simon et al. 2020; Guo et al. 2019). Soybeans have various benefits due to their rich composition of protein, lipid, fibre, moisture, and several types of vitamins and minerals (Dukariya et al., 2020). Additionally, soy sauce can stimulate the secretion of gastric juice in the human body, aiding in digestion (Zhao et al., 2018).

Figure 1 shows the soy sauce production process. The bacteria that are often used in the process of making soy sauce are *Aspergillus Oryzae*. The soy sauce production process involves several fermentation steps. The first fermentation process is koji fermentation, a type of fermentation that occurs in a solid state. In this situation, a mixture of soybeans, wheat, and *Aspergillus Oryzae* bacteria will be left for two to three days in humid conditions at a temperature of 30°C to allow the growth of koji fungi (Diez-Simon et al. 2020; Ito & Matsuyama 2021). This is followed by the addition of brine to the compound, which continues the second fermentation process and produces moromi, a liquid state of fermentation. The moromi production process takes approximately six to eight months before it undergoes the next steps of filtering, pasteurisation, and packaging, and is then sold in most stores and supermarkets (Diez-Simon et al. 2020; Ito & Matsuyama 2021).

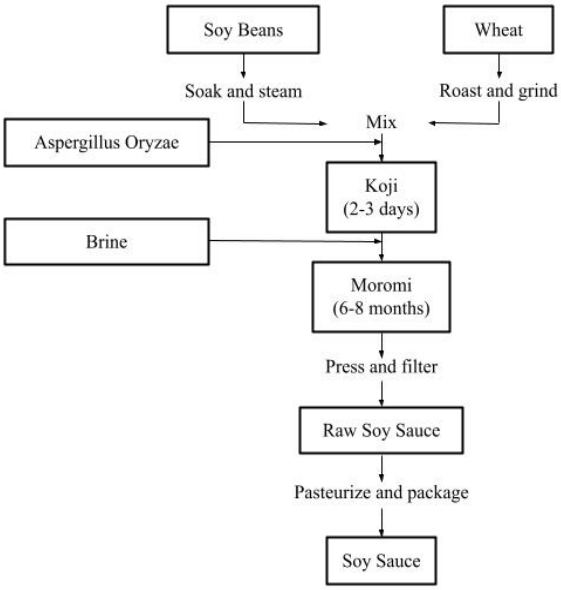

Figure 1. Soy sauce production process

Soy sauce is usually used in cooking as a seasoning because of its rich flavour, combining sweet, salty, and umami notes. The use of soy sauce in cooking is very popular in East and Southeast Asian countries and it is also quite popular in Western countries (Diez-Simon et al. 2020). For each country, the soy sauce produced will exhibit several distinct characteristics due to the ingredients used and the various methods of preparation, which vary according to the country of origin (Park et al. 2016). Four types of soy sauce are commonly used in cooking: sweet soy sauce, salty soy sauce, light soy sauce, and dark soy sauce.

Sweet soy sauce has a dark colour, a strong molasses sweetness, and a thick consistency with a distinctive aroma due to the continuous heating process and the addition of brown sugar (Shurtleff & Aoyagi 2012; Syifaa et al. 2016). Salty soy sauce has the characteristics of a bright colour, a saltier taste, and a lower consistency than sweet soy sauce, due to the addition of a high amount of salt (Syifaa et al. 2016). It also goes through a similar production process as tamari shoyu, which is soy sauce from Japan, and the difference is in terms of the heating process that is done after the fermentation process (Shurtleff & Aoyagi 2012).

Light soy sauce has the smoothest flavour and is a light brown colour. It is suitable for use as a dipping sauce or in cooking, such as stir-frying; however, due to its bright colour, it may not provide an attractive appearance to the food (Shurtleff & Aoyagi 2012). As for the dark soy sauce, caramel is added during the soy sauce preparation process to enhance the colour of the soy sauce, which is a dark reddish-brown (Diez-Simon et al. 2020; Shurtleff & Aoyagi 2012). For every type of soy sauce produced in Malaysia, most of them use permitted flavouring and colouring additives, such as monosodium glutamate (MSG) and caramel, to enhance the taste and colour of the soy sauce. Unlike soy sauce produced in China or Japan, which relies on the duration of the soy sauce processing through fermentation and heating to produce a variety of flavours and colours (Diez-Simon et al. 2020).

The characteristics of food products are influenced by the chemical and physicochemical composition of the food. For the manufacturers to avoid losses, physicochemical analysis is done to identify the factors that can determine the characteristics of food and then plan steps that can be taken to increase the shelf life of their products and how to handle the product correctly so that it can last longer (Martinez & Carballo 2021). With this, food product manufacturers can produce soy sauce with consistent characteristics and quality for each of their products. The characteristics of a food product can affect the level of consumer acceptance of the product.

In Malaysia, there are still soy sauces that do not have sodium labels sold in the market. According to the Food Regulation 1985 (2021), the salt content in food products must be labelled on food packaging. The government has made it mandatory to label sodium content on food packaging, effective from January 1, 2024. Tan Sri Dr Noor Hisham Abdullah, the Director General of Health, stated that the labelling of sodium or salt content on food and drink products will be enforced starting in January 2024 (Disease Control Division, MOH, 2021). According to the Malaysian Community Salt Survey 2017-2018 (MyCoSS), the daily sodium intake rate for adults is high at 7.9 grams/day, exceeding the recommendations set by the Malaysian Ministry of Health (MOH). Due to the high salt content in soy sauce products, consumers should consume them in moderation. Since a person's intake cannot be controlled, a program called the "Salt Reduction Program" was implemented in Malaysia to reduce the sodium content in food. Therefore, it is essential to conduct a study on the physicochemical characteristics, sodium content, and sensory evaluation of soy sauce samples in the market that lack sodium labelling.

MATERIALS AND METHODS

The sample used in this study is based on the research report "Sodium content in sauces – a major contributor of sodium intake in Malaysia: a cross-sectional study" by Shahar et al. (2019). The soy sauce used in this study is a type of soy sauce without sodium labelling. Therefore, the sample size used in this study consists of 25 types, including 11 sweet soy sauces, 5 salty soy sauces, 4 dark soy sauces, and 5 light soy sauces. All analyses were carried out in duplicate.

Determination and comparison of the ingredients of soy sauces

The ingredients list was obtained from the label on the soy sauce bottles. All ingredients were listed. Each ingredient of interest was checked against the label of every product. If the ingredient was present, it was recorded as "Yes"; if absent, it was recorded as "No." A total of 19 ingredients were identified, which are soybean extract, water, sugar, sodium benzoate, caramel, monosodium glutamate (MSG), high fructose corn syrup, soy sauce, soy protein sauce, thickener, spices, wheat, wheat flour, conditioner, soybean, preservative, acetic acid and sucralose.

Sample preparation

Twenty-five samples without sodium labelling, representing various types and brands were purchased from several selected supermarkets in Malaysia. For each sample purchased, two bottles of soy sauce from the same brand were purchased from two different supermarkets and homogenized into one sample using a magnetic stirrer. The sample was then divided into smaller containers and stored in a freezer at -18°C until analysis for determination of sodium content, total soluble solids, pH value, viscosity, and colour determination were ready to be carried out.

Determination of physicochemical characteristics

The sodium content of each soy sauce sample was determined using Inductively Coupled Plasma Optical Emission Spectrometry (Agilent Technologies, Santa Clara, CA, USA, 5100 ICP-OES) (Haron et al., 2022; Lai, Gardner, & Geddes, 2018). The amount of total soluble solids in soy sauce was determined using a °Brix refractometer (Atago, Tokyo, Japan, ATC 0-53% Brix & 45-82% Brix). pH was measured using a pH meter (Mettler Toledo, Columbus, Ohio, USA, Model Delta 320). A Tuning Fork Vibro Viscometer (A&D Company, Tokyo, Japan, Model SV-10) was used to determine viscosity. The colour of the soy sauce sample was determined using a spectrophotometer or colour meter (Konica Minolta, Chiyoda, Tokyo, Japan, Model Chroma Meter CR-400/410).

Sensory evaluation

Sensory evaluation was carried out for two days to gather a total number of 40 subjects (Singh-Ackbarali & Maharaj 2014). All subjects who meet the criteria will be selected to participate in this study, and their participation is voluntary. Only data from 38 subjects were considered because two subjects failed to meet the subject acceptance criteria for this sensory evaluation. This sensory evaluation involves UKM students, staff, and FSK lecturers aged 18 to 59 years. Four selected soy sauce samples, each coded with three random digits, were used in this evaluation. This selected sample consists of four types of soy sauce, with the highest sodium content in sweet soy sauce, salty soy sauce, light soy sauce, and dark soy sauce. Soy sauce samples were tested with plain white rice as a carrier and served at room temperature (Cherdchu & Chambers 2014). Aroma, colour, viscosity, taste, saltiness, sweetness, and overall acceptance are the attributes evaluated in this sensory test.

Half a teaspoon (2.5 mL) of the four selected soy sauce samples was measured and placed into a sample container, and a dessert spoon (10 mL) of cooked white rice was placed into another container. Mineral water was also provided for the subjects to rinse their mouths before tasting each sample. Each subject had to indicate their level of liking for the tested attributes, such as aroma, colour, viscosity, taste, saltiness, sweetness, and overall acceptance, on the scale found on the Hedonic form. A five-scale hedonic affective test form, based on the method of Aminah Abdullah (2000), and a questionnaire inquiring about the subject's background and usage of soy sauce were distributed to the subjects to complete.

Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 26. The Mann–Whitney U test was applied to compare the mean ranks of ingredients with the physicochemical characteristics of soy sauce. One-way ANOVA followed by Tukey's HSD post hoc test was used to compare the physicochemical characteristics among soy sauce types. When the data were not normally distributed, the Kruskal–Wallis test was followed by the Mann–Whitney U test.

For the sensory evaluation, descriptive statistics were used to calculate the mean scores for each attribute. As the sensory data were not normally distributed, the Kruskal–Wallis test followed by the Mann–Whitney U test was conducted to compare sensory scores among soy sauces. Spearman's rho correlation was used to assess the relationships between physicochemical characteristics and sensory attributes. Statistical significance was set at $p < 0.05$.

Result and Discussion

Comparison of ingredient contents with physicochemical characteristics of soy sauce

Table 1 shows the mean rank for the comparison of ingredients contained in soy sauce with the physicochemical characteristics. The high mean rank values between the "with" and "without" groups indicate that soy sauce contains a particular ingredient in large quantities. There was a significant difference ($p < 0.05$) between the content of caramel with the sodium content and viscosity of soy sauce. The mean rank for sodium content in soy sauce without caramel (21.67) is higher than that of soy sauce with caramel (11.82). The mean rank of viscosity in soy sauce with caramel is 14.14, while soy sauce without caramel has a mean rank of 4.67. Therefore, it can be stated that soy sauce that does not contain caramel ingredients has a higher sodium content and a lower viscosity compared to soy sauce that contains caramel. Since the formulation for the production of caramel as colouring has no special reference point, the composition of the caramel varies and depends on the characteristics desired by the manufacturer of the product (Sengar & Sharma 2014). According to Kamuf et al. (2003), the basic ingredients used in the production of caramel colouring are milk solids, sugar, and fat. The taste of caramel becomes more bitter as the reaction continues due to the increasing molecular weight. For other ingredients, there was no significant difference ($p > 0.05$) in all the physicochemical characteristics studied.

Table 1. Comparison of mean rank for specific ingredients contained in soy sauce compared to physicochemical characteristics

Ingredients	With and without the specific ingredient	Sodium	Total Soluble Solid	pH	Viscosity	Colour (L*)	Colour (a*)	Colour (b*)
Soybean Extract	With (n=13)	11.12	13.50	12.00	14.62	14.00	12.73	11.42
	Without (n=12)	15.04	12.46	14.08	11.25	11.92	13.29	14.71
Water	With (n=14)	12.79	15.00	14.21	13.29	12.00	12.32	12.29
	Without (n=11)	13.27	10.45	11.45	12.64	14.27	13.86	13.91
Sugar	With (n=23)	13.30	13.07	12.22	12.52	13.83	12.63	13.57
	Without (n=2)	9.50	12.25	22.00	18.50	3.50	17.25	6.50
Sodium Benzoate	With (n=8)	12.19	10.38	12.31	12.13	15.00	14.75	15.19
	Without (n=17)	13.38	14.24	13.32	13.41	12.06	12.18	11.97
Caramel	With (n=13)	11.82	13.61	13.68	14.14*	12.82	12.59	12.50
	Without (n=22)	21.67*	8.50	8.00	4.67	14.33	16.00	16.67
MSG	With (n=24)	12.54	13.02	13.42	13.25	12.63	12.54	12.54
	Without (n=1)	24.00	12.50	3.00	7.00	22.00	24.00	24.00
High Fructose Corn Syrup	With (n=1)	12.00	22.00	20.00	13.00	11.00	15.50	16.00
	Without (n=24)	13.04	12.63	12.71	13.00	13.08	12.90	12.88
Soy Sauce	With (n=3)	17.00	12.67	14.50	10.33	11.33	11.00	15.67
	Without (n=22)	12.45	13.05	12.80	13.36	13.23	13.27	12.64

continue...

...cont.

Soy Protein	With (n=1)	19.00	11.00	8.00	19.00	14.00	20.00	14.00
	Without (n=24)	12.75	13.08	13.21	12.75	12.96	12.71	12.96
Soy Protein Sauce	With (n=2)	7.50	4.00	13.00	12.50	14.00	20.25	16.50
	Without (n=23)	13.48	13.78	13.00	13.04	12.91	12.37	12.70
Thickener	With (n=1)	1.00	7.00	25.00	23.00	5.00	15.50	8.00
	Without (n=24)	13.50	13.25	12.50	12.58	13.33	12.90	13.21
Spices	With (n=1)	16.00	8.00	17.00	5.00	16.00	22.00	22.00
	Without (n=24)	12.88	13.21	12.83	13.33	12.88	12.63	12.63
Wheat	With (n=2)	14.50	16.00	19.00	12.50	10.00	10.75	11.00
	Without (n=23)	12.87	12.74	12.48	13.04	13.26	13.20	13.17
Wheat Flour	With (n=15)	12.93	15.63	14.17	15.07	13.27	14.23	14.03
	Without (n=10)	13.10	9.05	11.25	9.90	12.60	11.15	11.45
Conditioner	With (n=2)	13.50	15.50	8.25	12.00	16.50	15.00	16.25
	Without (n=23)	12.96	12.78	13.41	13.09	12.70	12.83	12.72
Soybean	With (n=15)	13.97	14.37	14.33	13.40	11.40	12.83	12.23
	Without (n=10)	11.55	10.95	11.00	12.40	15.40	13.25	14.15
Preservative	With (n=12)	13.54	13.00	12.54	13.50	11.00	10.88	9.33
	Without (n=13)	12.50	13.00	13.42	12.54	14.85	14.96	16.38
Acetic Acid	With (n=3)	14.67	11.00	8.00	14.00	13.33	16.67	16.67
	Without (n=22)	12.77	13.27	13.68	12.86	12.95	12.50	1250
Sucralose	With (n=1)	1.00	7.00	25.00	23.00	5.00	15.50	8.00
	Without (n=24)	13.50	13.25	12.50	12.58	13.33	12.90	13.21

Comparison of physicochemical characteristics for all types of soy sauce

Table 2 shows the physicochemical characteristics of all four types of soy sauce. According to the Food Regulation 1985 (2021), the salt content in soy sauce must be at least 7%. Among all 25 samples, only two did not comply with this food regulation, comprising one sweet soy sauce and one dark soy sauce. The recommended daily sodium intake by the Malaysian Ministry of Health (MOH) for adults in Malaysia is 1500 mg. Based on the table, the average value for sodium content in sweet soy sauce was significantly lower ($p < 0.05$) than in light soy sauce and salty soy sauce while there is no significant difference ($p > 0.05$) for dark soy sauce with other types of soy sauce. This result can be proven in a study conducted by Shahar et al. (2019) where the highest sodium content was in light soy sauce (4832 ± 2364mg/100g), followed by salty soy sauce (4720 ± 1032mg/100g), sweet soy sauce (4020 ± 2232mg/100g) and dark soy sauce (3032±572mg/100g).

Table 2. Physicochemical characteristics of soy sauce by type

Soy Sauce (n)	Sodium (mg/100g)	pH	Total Soluble Solid (Brix)	Viscosity (cP)	Colour		
					L*	a*	b*
Sweet (11)	3289.09 589.14[b]	5.10 0.17[a]	52.73 12.18[a]	145.78 114.89 (11.73 – 381.67)[a]	2.48 2.97[b]	0.16 ± 0.09[b]	0.54 ± 0.19[b]
Salty (5)	5511.00 461.35[a]	5.14 0.16[a]	46.93 0.92[ab]	43.28 43.63 (17.03 – 119.00) [ab]	1.10 0.23[a]	0.19 ± 0.10[b]	0.48 ± 0.12[b]
Light (5)	5766.50 968.37[a]	4.90 0.41[a]	34.67 14.72[b]	7.19 4.39 (2.89 – 13.67)[b]	1.84 0.81[a]	1.34 ± 0.83[a]	1.57 ± 0.91[a]
Dark (4)	4151.25 2383.96[ab]	5.19 0.21[a]	40.00 7.34[ab]	86.01 124.91(6.60 – 271.67) [ab]	0.80 0.03[ab]	0.18 ± 0.10[b]	0.33 ± 0.05[b]

•Results are reported in mean ± standard deviation of 2 replicates (for sodium) and 3 replicates (others).

•Viscosity values are presented as mean ± standard deviation (range) of 3 replicates because due to large variability in standard deviations among samples.

•Average values that have different letters in the same column are significantly different ($p < 0.05$).

The pH assessment was conducted to determine the level of acidity and alkalinity of a product. pH is the relative activity of hydrogen ions in solution (IUPAC 2002). The range of pH values is between 1 to 14, where a scale of 7 is considered neutral. A pH value less than 7 on the scale was classified as acidic while a pH greater than 7 on the scale was alkaline. The average pH value that has been studied shows that the pH value for all types of soy sauce was almost the same, with a range of 4.90 - 5.19, and they are in the acidic group. Therefore, there was no significant difference ($p > 0.05$) among all types of soy sauce. Previous studies reported that the pH of soy sauce typically ranges from 4.01 to 4.88 (Syifaa et al., 2016), which is lower than the results of our study. However, Zahidah and Lo (2022) suggested that maintaining a final pH value above 5 may help prevent fungal growth during storage.

The number of dissolved solids affects the dark colour of soy sauce due to the Maillard reaction that occurs during the heating process (Lubis 2019). Brix is a term used to describe the relationship between the refractive index at 20°C and the percentage by mass of total dissolved solids (in grams) in a 100g sample of sucrose solution. The highest number of soluble solids is in the sweet soy sauce sample (52.73 °B) and was significantly higher ($p < 0.05$) compared to the light soy sauce sample, which has the lowest number of soluble solids (34.67 °B). In a study conducted in Brazil by Guidi and Gloria (2012), the results found that the average content of total soluble solids of soy sauce varied considerably among brands, ranging from 22.0°B to 39.0°B.

Viscosity is a measure of the resistance of a fluid and it is often related to concentration. The viscosity of soy sauces showed a wide variation among types, ranging from 2.89 to 381.67 cP. Sweet soy sauce had the widest range (11.73–381.67 cP), followed by dark soy sauce (6.60–271.67 cP), salty soy sauce (17.03–119.00 cP), and light soy sauce (2.89–13.67 cP). The viscosity of soy sauce may be influenced by its moisture content. The average viscosity of light soy sauce (7.19cP) was significantly lower ($p < 0.05$) than the sweet soy sauce (145.78cP). The viscosity was likely due to the high solid content in the soy sauce (Imamura 2016). The lowest viscosity of the commercial soy sauce sample used in the study was 425.00 cP while the highest was 1483.00 cP (Ginting & Tarmizi 2021).

Colour meters are widely used to control aspects of colour quality in various applications including ingredients, food, raw materials, and ready-to-eat products. The use of a colour meter to determine the colour of a product is very practical because it is low-cost, quick, and easy. The findings were stated in L*, a* and b* values. Based on the table, the average colour brightness (L* value) of dark soy sauce (0.80) was significantly lower ($p < 0.05$) than sweet soy sauce (2.48) and light soy sauce (1.84). The soy sauce that has the brightest colour with the highest L* value, which is L* = 2.48, was the sweet soy sauce sample. To date, no study states brown (dark) colour has a relationship with saltiness in soy sauce (Wongthahan, Sae-Eaw & Prinyawiwatkul 2020).

The average colour redness (a* value) of light soy sauce (1.34) is significantly higher ($p < 0.05$) compared to other soy sauce samples. The higher the intensity of the reddish colour, the greater the expected saltiness of food (Sukkwai et al. 2018). This finding is supported by the study's results, which revealed that light soy sauce samples have the highest sodium content among the other three types of soy sauce. As for the yellowness of the colour (b* value), the average light soy sauce sample has a significantly higher level of yellowness ($p < 0.05$) compared to other types of soy sauce samples. This may be due to the high ratio of wheat to soybeans used in the production of light soy sauce, which is fermented under conditions that prevent the production of colour during the Maillard reaction (Diez-Simon et al. 2020).

Sensory evaluation on selected soy sauce sample

The majority of subjects (79% females and 21% males) were females. The majority of subjects were aged 19-29 (95%), while only 5% were aged 30-39. The Malay subjects accounted for 84% of the total subjects, while Chinese subjects accounted for 11%, and the remaining subjects accounted for 5%. The majority of the subjects (92%) were single, and 8% were married. The subjects involved in this sensory evaluation consisted of 95% UKM students and 5% UKM staff, respectively. In terms of household income, the majority of subjects (64%) were from the B40 group, followed by the M40 (31%), and the T20 (5%).

Based on the extra questions asked, all subjects have been consuming soy sauce since childhood, with sweet soy sauce (82%) being the most popular, followed by salty soy sauce (13%), and light soy sauce (5%). In terms of soy sauce consumption per week, 71% of the subjects rarely consume soy sauce, while 29% frequently consume it. All subjects used soy sauce in their daily lives, but only 95% of them used it during certain events. The majority of subjects (84%) used soy sauce in their cooking, while 16% did not. Soy sauce was used as a dipping sauce by 58% of the subjects. The majority of the subjects (71%) added soy sauce during meals, while 29% did not.

The average score for each attribute of soy sauce

Figure 2 shows the subjects' preferences for four

different soy sauce samples. According to Figure 2, the average score of the subjects' most preferred aroma was for sweet soy sauce, which has the highest average value (3.45), significantly ($p < 0.05$) compared to the other three types of soy sauce. The aroma of brown sugar was associated with the brown colour of soy sauce (Cherdchu, Chambers & Suwomsichon 2013). According to Ginting and Tarmizi (2021), the type of spices and sugar added to soy sauce, particularly cooked sugar, influences the aroma of soy sauce (caramel). Most foods are sweetened with sugar, a type of disaccharide, and the aroma of caramel is also associated with sweetness (Diez-Simon, 2020). Furthermore, the strong smell of soy sauce can heighten the perception of saltiness in soy sauce (Chokumnoyporn et al. 2015). The strong odour of soy sauce is most likely due to its high salt content (Imamura 2016). High salt content promotes the growth of halotolerant yeasts and bacteria that generate volatile aroma compounds during fermentation (Diez-Simon et al. 2020). Besides, the presence of sodium ions also influences yeast metabolism, enhancing the formation of alcohols, aldehydes, and esters that intensify the characteristic aroma of soy sauce (Belz et al., 2017).

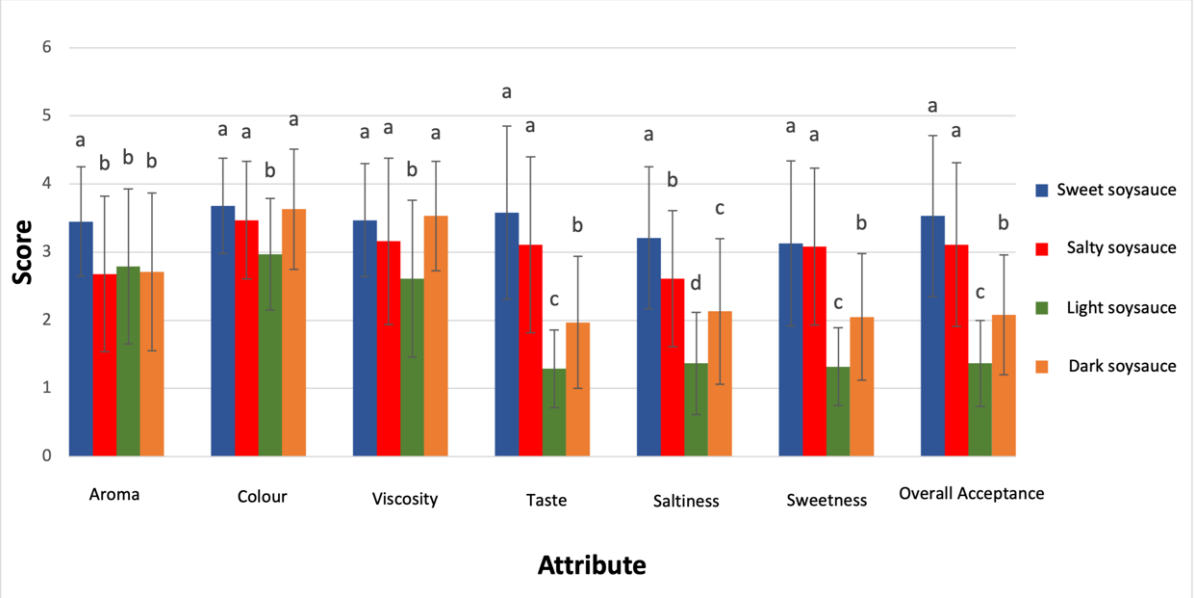

Figure 2. The preference scores for samples of sweet soy sauce, salty soy sauce, light soy sauce and dark soy sauce. (Average values with different alphabets have a significant difference ($p < 0.05$)).

For the average colour score, the light soy sauce sample was significantly ($p < 0.05$) lowest (2.97) compared to other soy sauces. According to Batenburg et al. (2006), the dark and reddish colour of soy sauce has a positive correlation with the liking score for consumers. Appearance also affects expectation of taste and quality of food before it is tasted (Wadhera & Capaldi-Phillips 2014). The appearance of a food is one of the important factors that influence consumer acceptance of the food (Wongthahan, Sae-Eaw & Prinyawiwatkul 2020). The colour liking score for commercial soy sauce that has a darker colour is the highest (Ginting & Tarmizi 2021).

Light soy sauce samples had the lowest average viscosity score (2.61) significantly ($p < 0.05$) compared to other types of soy sauce samples. The resulting texture in the mouth is one of the factors that influence the consumer's choice of a food product (Foster 2011). According to Boleng Kiliroong et al. (2021), consumers tend to associate a light soy sauce texture or low viscosity with low soy sauce quality. Commercial soy sauce, which has the lowest viscosity in the analysis results, has the lowest liking score for the viscosity attribute (Ginting & Tarmizi 2021).

The average score for taste attributes in the dark soy sauce sample (1.97) was significantly higher ($p < 0.05$) than the light soy sauce sample (1.29), while it was significantly lower ($p < 0.05$) than the sweet soy sauce sample (3.58) and salty soy sauce (3.11). According to Wongthahan, Sae-Eaw, and Prinyawiwatkul (2020), when a sample of soy sauce is tasted in the mouth, the sweet and salty tastes can be experienced simultaneously due to the sense of taste on the tongue. The sweet taste in soy sauce products has a positive correlation with the liking score for the soy sauce (Boleng Kiliroong et al. 2021).

For the average saltiness score, all four types of soy sauce have significantly different liking scores ($p < 0.05$). The liking score for saltiness (3.21) was significantly higher in the sweet soy sauce sample than in the other soy sauce samples. Soy sauce that

has a dark brown colour is associated with a salty taste, and there was a link between 'black colour' and 'dark brown colour' to a strong salty taste (Wongthahan, Sae-Eaw & Prinawiwatkul 2020). The level of saltiness in soy sauce products affects the acceptance by the panellists (Ginting & Tarmizi, 2021).

The average sweetness-liking score (3.13) for the sweet soy sauce sample and the salty score (3.08) for the soy sauce sample were nearly identical and did not differ significantly ($p > 0.05$). These findings were consistent with the total soluble solids (°Brix) results, which show that sweet soy sauce has the highest average value, followed by salty soy sauce, dark soy sauce, and light soy sauce. The sweetness of food influences its consumption (Jayasinghe et al. 2017). The flavour of sweet soy sauce was affected by the type of soybean, the flavour components produced during the fermentation process (primarily glutamic acid), as well as the type of spices and sugar added to soy sauce (Prihatiningrum & Findurina 2010; Suprapti 2005).

For overall acceptance, the scores for the sweet soy sauce sample (3.53) and the salty soy sauce sample (3.11) were significantly higher ($p < 0.05$) compared to the light soy sauce sample (1.37) and the dark soy sauce sample (2.08). In a sensory test involving regular consumers and culinary chefs, both panel groups shared similarities in terms of sensory liking for the sweetness of soy sauce (Wongthahan, Sae-Eaw & Prinyawiwatkul 2020). One of the reasons why the sweet soy sauce sample has the highest average liking value may be that the majority of subjects prefer sweet soy sauce. All subjects who participated in this sensory evaluation started consuming soy sauce since childhood. Therefore, their sense of taste was more familiar with sweet soy sauce. Although a person's taste preferences have a heritable component, they can change with age, physiological stress, and changes in dietary habits (Holt et al. 2000).

Determination of the relationship between physicochemical characteristics on consumer acceptance of soy sauce

Table 3 shows the correlation between physicochemical characteristics and sensory evaluation attributes. There is a negative correlation significantly between the aroma attribute and sodium content ($r = -0.195$, $p = 0.016$) , while the positive correlation was significant with the number of soluble solids, viscosity and colour value (L*, a* and b*)($p < 0.05$). According to a previous study, the aroma results from the heating process (Kanek, Kumazawa & Nishimura 2013). In another study, the two most important aroma compounds in soy sauce result from the Maillard reaction process (Devanthi & Gkatzionis 2019).

Table 3. Correlation between physicochemical characteristics and sensory attributes

		Sodium	pH	Total Soluble Solid	Viscosity L*	Colour		
						a*		b*
Aroma	R Value	-.195*	.066	.195*	.195*	.230**	.230**	.230**
	P value	.016	.419	.016	.016	.004	.004	.004
Colour	R Value	-.298**	.066	.257**	.257**	-.042	-.042	-.042
	P value	.000	.419	.001	.001	.609	.609	.609
Viscosity	R Value	-.296**	-.025	.222**	.222**	-.074	-.074	-.074
	P value	.000	.761	.006	.006	.364	.364	.364
Taste	R Value	-.483**	.458**	.662**	.662**	.215**	.215**	.215**
	P Value	.000	.000	.000	.000	.008	.008	.008
Saltiness	R Value	-.419**	.443**	.601**	.601**	.111	.111	.111
	P value	.000	.000	.000	.000	.172	.172	.172
Sweetness	R Value	-.507	.340**	.609**	.609**	.174*	.174*	.174*
	P value	.000	.000	.000	.000	.032	.032	.032
Overall Acceptance	R Value	-.475**	.446**	.648**	.648**	.198*	.198*	.198*
	P value	.000	.000	.000	.000	.015	.015	.015

*Correlation significant at 0.05 (2-tailed)

**Correlation significant at 0.01 (2-tailed)

There was a negative correlation significantly between the sodium content and the colour attribute score evaluated by the subject ($r = -0.298$, $p < 0.001$). Results from Table 2 showed that sweet soy sauce has the lowest sodium content. Figure 2 shows that the average liking score for sweet soy sauce was the highest for the colour attribute. For total soluble solids and viscosity, a positive correlation was observed, which was significant in relation to the colour attribute ($r = 0.257$, $p = 0.001$) . When the brightness value increases, the score for liking the colour attribute also increases (Wongthahan, Sae-Eaw & Prinyawiwatkul 2020).

For the relationship between the soy sauce viscosity liking score assessed by the subject and the physicochemical characteristics, a negative correlation exists between the attribute and the sodium content, which is significant ($r = -0.296$, $p < 0.001$) . Total dissolved solids and viscosity showed a positive correlation that was significantly associated with the preference score for viscosity ($r = 0.222$, $p = 0.006$) . According to a study conducted by Imamura (2016), the viscosity was likely caused by the high solid content in the soy sauce. In another study, most panellists preferred soy sauce, which has a very viscous texture (Boleng Kiliroong et al. 2021).

A significant correlation was found between the liking score for the taste attribute and all the physicochemical characteristics studied ($p < 0.05$) . According to a study conducted by Boleng Kiliroong et al. (2021), the majority of panelists who participated in the sensory evaluation preferred the sweetness of soy sauce. Three factors influence taste attributes: aroma, taste, and mouth stimulation, which are also affected by hot or cold temperatures (Boleng Kiliroong et al. 2021).

There was a negative correlation between the sodium content and the preference score for the salinity attribute significantly ($r = -.0419$, $p < 0.001$) . The results of the study were contrary to the study conducted by Wongthahan, Sae-Eaw, and Prinyawiwatkul (2020) where a high percentage of salt content further increases the consumer acceptance score. There was a significant positive correlation between the salinity attribute score with pH ($r = 0.443$, $p < 0.001$), total soluble solids and viscosity ($r = 0.601$, $p < 0.001$).

Additionally, the sweetness attribute exhibits a significant correlation with all the evaluated physicochemical characteristics ($p < 0.05$). A high pH value can be observed for soy sauce that has a high content of total soluble solids (Guidi & Gloria 2012). This is evident because there is a positive correlation between the sweetness attribute with both pH characteristics and total dissolved solids in soy sauce.

For the overall acceptance of soy sauce by the subject, there was a significant correlation between the attribute and all physicochemical characteristics ($p < 0.05$). According to Wongthahan, Sae-Eaw and Prinyawiwatkul (2020), the overall acceptance score was more influenced by the liking score for taste and saltiness. Further studies are needed to investigate the proximate analysis of MSG content and sugar content in soy sauce, to determine more clearly whether the addition of MSG affects the sodium content. Complete nutrient information can be included to assist in studies involving soy sauce formulations

CONCLUSION

This study provides insights into the physicochemical characteristics, sodium content, and sensory acceptance of selected commercial soy sauces without sodium labelling in Malaysia. Most of the physicochemical characteristics of soy sauce have significant differences except for the pH value. Sodium content in soy sauce without caramel was significantly higher than that in soy sauce with caramel. Soy sauce with caramel was also more viscous than without caramel. For overall consumer acceptance, sweet soy sauce received the highest consumer acceptance, followed by salty, dark, and light soy sauce. These findings underscore the importance of transparent sodium labelling to enable consumers to make informed choices and support regulatory implementation in Malaysia.

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