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Development of Chinese steamed bread with Jerusalem artichoke (*Helianthus Tuberosus* L.) tubers

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Abstract

The objective of this study is to develop a formulation of Chinese steamed bread (CSB) with Jerusalem artichoke (*Helianthus Tuberosus L.*) tuber powder with the aim to increase the nutritional value of the food product. Three formulations of CSB were developed including the 0% control, 10% and 15% w/w Jerusalem artichoke tuber powder (JAP) substitution to the total amount of wheat flour. Physicochemical properties and sensory evaluation of the bread were carried out to evaluate the quality of each formulation. Specific volume was acceptable in all formulations, but the specific volume showed potential to decrease at a higher percentage of JAP. Moisture content and water activity were not significantly different ($p<0.05$), however, both had tendencies to decrease as the higher inulin of JAP formulations could disrupt the hydration of the wheat flour. The color of the JAP formulations was reddish brown, and which corresponded to the L^* a^* b^* assessment, so it was acceptable for the sensory evaluation. For textural profile analysis, higher JAP substitution was correlated with increased in hardness, decreased resilience and cohesiveness, but improved in chewiness. The overall sensory evaluation indicates that 10% JAP was the most acceptable of all formulations including the control formulation. It can be concluded that substituting 10% JAP of the total wheat flour would be the most applicable and practical for further development.

1. Introduction

Jerusalem artichoke tuber (*Helianthus tuberosus L.*) is considered as one of the functional foods. It is a type of tuber which contains inulin, oligofructose, and fructo-oligosaccharide (FOS). Inulin, oligofructose, and FOS are non-starch carbohydrates known as fructans, and functional ingredients sharing similar characteristic to dietary fibers (Radovanovic *et al*., 2015). Inulin and oligofructose are functional ingredients since they lower the glycemic index (GI) of food and are thus reported to reduce blood glucose level in diabetic patients, lower total cholesterol, and total lipids, increase the bioavailability of minerals and act as a prebiotic which reduces the risk of intestinal infections (Niness, 1999). Fructans have potential to protect individuals from various chronic diseases. The study of the stability of one of the active compounds was studied. The degradation of inulin was not found at pH ≥ 5 at 100°C (Glibowski and Bukowska, 2011). Thus, it is potentially beneficial to develop innovative products with increased nutritional value via incorporative Jerusalem artichoke tubers.

Chinese steamed bread (CSB) is a traditional staple food in China that has become common in many Asian and Western countries (Wu *et al*., 2012). There are two types of CSB: one requires a starter dough for fermentation and the second type requires baker’s yeast to leaven the bread (Luangsakul *et al*., 2009). There are some similarities to the preparation process of Western style bread, however, the final product is steamed process not baked, which imbues differences in texture and appearance, and also a lighter color compared to Western-style baked breads (Popper *et al*., 2006).

This study focused on the development of Chinese steamed bread with the addition of Jerusalem artichoke tuber powder (JAP) replacing some wheat flour in order to develop a more nutritious food product. In addition, the physicochemical properties and the consumer acceptability of the developed products were investigated.

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2. Materials and methods

2.1 Materials for making Chinese steamed bread

The ingredients for making CSB are commercial wheat flour, yeast, water, sugar, salt, baking powder, and rice bran oil. Wheat flour used in the experiment was a type especially formulated for Chinese steamed bread, in which contains 6.67% protein. JAP was obtained from commercial farmers in Wang Nam Khiao district, Nakhon Ratchasima Province, Thailand. The Jerusalem artichoke tubers were bought from a supplier in Lopburi Province, Thailand. The Jerusalem artichoke samples were commercially dried using a commercial cabinet dryer at approximately 60°C, and ground into fine powder.

2.2 Chinese steamed bread preparation

A preliminary study of Chinese steamed bread was carried out finalize the most acceptable recipe. The best recipe in term of the overall sensory evaluation was used in the experiment.

The ingredients of the most acceptable recipe were flour (55.65%), water (30.91%), sugar (8.24%), rice bran oil (2.06%), yeast (1.65%), baking powder (1.10%), and salt (0.7%). The commercial wheat flour was sifted through a 60 µm mesh sieve. Then, baking powder and salt were added to the sifted flour. Separately the sugar was dissolved in the luke-warm water (approximately 40˚C), yeast was activated in the sugar solution, and then this wet mixture was poured into the dry mixture, and rice bran oil was added. The batter was mixed using a spiral kneader of the mixing machine (Model HS-100, Hua Min Machine Honour Product, China) with a medium speed for 12 minutes until all the ingredients were smoothly integrated. It was then proofed for about 40 minutes at room temperature. Then the dough was shaped into small round balls of about 30 g and placed individually onto waxed paper. The small dough balls were proofed for another 20 minutes and steamed in a steamer.

CSB made with the mentioned ingredients was treated as a control for the experiment. For other treatments, the wheat flour was substituted with 10% JAP and 15% JAP w/w, respectively. The cooled CSB prepared by each formulation were separately packed into LDPE plastic ziplock bags and stored in the refrigerator at approximately 4˚C for approximately 16 hours for further analysis.

2.3 Physicochemical properties

For the determination of physicochemical properties and sensory evaluation, the cold CSB were re-steamed for 7 minutes. The physicochemical properties including specific volume, the ratio of height to diameter, moisture content, water activity, color measurements, and texture profile analysis of the crumb were analyzed.

2.4 Specific volume and ratio of height to diameter measurements

After cooling at room temperature, the CSB were weighed and their volumes were obtained by sesame displacement.

2.5 Moisture content and water activity

After cooling the Chinese steamed bread at room temperature for 5 minutes in the normal atmosphere, they were transferred to plastic ziplock bags and allowed to cool for 40 minutes. Samples were cut into small pieces. Then the moisture content was analyzed by infrared moisture analyzer (Sartorius Ag Gottinger, Model MA45-00023V1, Germany) and AquaLab water activity meter (Model series 4TE, Decagon Device Inc., USA). Samples were measured in triplicate.

2.6 Color measurements

Color measurements were performed by a Konica Minolta Sensing chroma meter (Model CR-400, Inc, Japan). The chromameter was attached to the surface of the sample in order to determine the measurements. The outer layer of the CSB samples was measured in triplicate at different areas of each sample, and three samples from each formulation were also measured using a Hunter Lab system.

2.7 Texture profile analysis (TPA) of the Chinese steamed breadcrumb

Chinese steamed bread were cooled for 40 minutes in plastic zip lock bags at room temperature texture profile analysis (TPA) using a Brookfield texture analyzer (Model CT3 V.14 from Brookfield Engineering Labs, Inc., USA). Three blocks (20 mm x 20 mm x 20 mm) sliced from the center of each of the three samples from each formulation were used to perform the analysis. The texture analyzer was equipped with a 10 kg load cell and a clear acrylic cylinder probe (38.1 mm diameter and 20 mm L, TA4/1000 probe, TA-RT-KI fixture). The parameters were set at a pre-test speed of 2 mm/s, a test speed of 1 mm/s, and post-test speed of 5 mm/s. The trigger force used was 5.0 g. The samples were compressed to 50% of their original height. All tests were conducted in triplicate for each sample, and the values were averaged for each texture parameter (Hardness, adhesive force, resilience, cohesiveness, springiness index, gumminess, and chewiness index).

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2.8 Sensory evaluation

The sensory evaluation of three formulations of Chinese steamed bread was conducted by 33 semi-trained panelists from Mahidol University International College, Nakhon Pathom, Thailand. The 9-point hedonic scale was used to evaluate the acceptability of each attribute for each formulation. The attributes included were aroma, taste, texture, color, and overall liking. Each category was scored numerically: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely. The flavor intensity, which combines the intensity of aroma and taste together were scored on a scale of very strong, strong, moderate, slight and absent for each formulation. For the ranking test, 1 was ranked as the most preferred, 2 as the second preferred, and 3 as the least. There were also spaces provided for the panelists to write any comments after the sensory evaluation.

CSB for sensory evaluation were steamed for 7 minutes after being taken from the refrigerator and served warm. The samples were made the day before the sensory evaluation. They were served with identical sample containers and each of the formulations were given a different random 3-digit code. The panelists were instructed to cleanse their palate with water between samples. The balanced order system was used to serve the panelist.

2.9 Data processing and statistical analysis

All data were obtained a randomized design, and each physicochemical properties tests were done in triplicate in order to obtain means. Data values response means ± standard deviation. For sensory evaluation, a few panelists were screened out due to incomplete filling of data forms. The statistical differences of data of physicochemical properties and sensory evaluation for all three formulations were analyzed using one-way analysis of variance (ANOVA) and Duncan's new multiple range test ($p < 0.05$). For the ranking test, Wilcoxon rank sum test was used to find the statistical difference. All calculations were performed using SPSS 18.0 (SPSS Inc, Chicago, IL).

3. Results and discussion

The results of the experiments will be separately presented according to each parameter.

3.1 Physicochemical properties

The effect of different Jerusalem artichoke powder substitution on physicochemical properties including specific volume and ratio of height to diameter, moisture content, water activity and color measurement of CSB were studied.

Specific volume and ratio of height to diameter of CSB are the main parameters that determine the volume expansion and gas holding capacity of the dough. If the specific volume is high, it will give a very open grain structure, and if the specific volume is low, it will give a closed grain structure (Zhu, 2014). As for Chinese steamed bread, the ideal specific volume must be more than 2.3 mL/g which will yield the most desirable texture and oven spring, according to the quality evaluation scoring system of CSB from SBT 10139-93 launched by the Ministry of Commerce of China (Zhu, 2014).

Table 1. Effect of different JAP substitution on physicochemical properties of CSB

	Control	10% JAP	15% JAP
Specific volume (mL/g)	2.23 ± 0.21[a]	2.21 ± 0.29[a]	2.06 ± 0.20[a]
Ratio of height to diameter	0.70 ± 0.03[a]	0.67 ± 0.01[a]	0.71 ± 0.03[a]
Moisture content (%)	40.37 ± 2.73[a]	38.62 ± 0.25[a]	38.56 ± 0.46[a]
Water Activity	0.9558 ± 0.0021[a]	0.9514 ± 0.0214[a]	0.9463 ± 0.0140[a]

Data are presented with means ± standard deviation. Means with different letters are significantly at $p \leq 0.05$

The results in Table 1 show that the control formulations give mean specific volume of 2.23 mL/g which is close to the ideal specific volume, and a statistically insignificant ($p<0.05$) decrease of mean specific volumes for 10% JAP and 15% JAP with value of 2.21 and 2.06 mL/g respectively. However, the 10% JAP formulation has decreased by 0.1% as compared to the control sample, where 15% JAP has decreased by 7.6%. This indicates that 10% JAP substitution did not give an effect on the specific volume. While 15% was acceptable, it still decreased much more than expected compared to 10% considering that there was only 5% difference of substitution between the two. A decreasing trend of the specific volume can be observed. The volume expansion and the structure of the CSB were formed by the gas product from yeast and baking powder and the gluten network. The result from the experiment indicates that the JAP substitution of 10% and 15% does not significantly disturb the formation of the gluten network. However, it can be assumed that with the higher level substitution of JAP to wheat flour, the specific volume of the CSB would decrease, and provide undesirable volume and texture. This may be caused by the ash content (approximately 4%) and crude fiber (approximately 5%) in the JAP. There is evidence that

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chemicals in bran can weaken the gluten network (Jacobs *et al*., 2016). Part of bran is composed of cellulose and lignin, and these two substances also contain crude fiber (Murray, 1977), and ash. Therefore ash content and crude fiber from the JAP could disturb on the dough formation and expansion if the amount is excessively high, giving a lower specific volume.

As for height to diameter ratio (Table 1), there was no statistically significant difference between the values, but if the level of replacement of JAP is high, it can be assumed that the height to diameter ratio will be lower because crude fiber and ash will disturb the rising of the dough. It has been found that increasing JAP will increase dietary fiber content and decrease gluten content which can cause inability to keep the dough structure as well. (Gedrovica and Karklina, 2011)

For the moisture content and water activity of the CSB, water is an essential ingredient for gluten development, since the protein needs to be hydrated to form cross-links or disulfide bonds between glutenin and gliadin (Crosby *et al.,* 2012). Table 1 shows no significant differences at the level of 0.05 among all formulations for moisture content and water activity. However, despite the statistical analysis, there was an observed trend that both moisture content and water activity decreased inversely to the level of JAP substitution. Comparing with the control, moisture content decreased 4.33% for 10% JAP, and 4.48% for 15% JAP, and water activity decreased 0.46% for 10% JAP and 0.99% for 15% JAP, respectively

Based on the results, the moisture content and water activity decreased as the level of JAP substitution increased. Even though there were no significant differences at the level of 0.05, the decreasing in moisture content and water activity with more JAP content was found in other study with 0, 10, 20, 30, 40, 50, and 100% JAP substitution to wheat flour in bread dough, thus this correlation was not a coincidence (Gedrovica and Karklina, 2011).

The decreasing in moisture content could possibly be due to the formation of inulin (from JAP) as a barrier around the starch granules which allowed less water to interact with protein to form the gluten network, leading to less water absorption in the wheat flour and making it harder for the matrix to form. As for water activity, with more JAP substitution, it is possible that it will decrease because inulin is a water soluble dietary fiber, so there could be less unbound water in the CSB.

3.2 Physical appearance

The differences in color, illustrated in Table 2 shows that for L* value, the number decreased with higher percentages of JAP substitution. This means that the color became darker as the level of JAP substitution increased (all significant differences at the level of 0.05). For a* value, the control had a slight greenish color, but the formulations with JAP substitution had a reddish color. According to the result, the reddish color intensified at higher percentages of JAP in the CSB (all significant difference at the level of 0.05 for a*). For b* value, the color of all formulations was yellowish. There was an observable trend that with higher levels of JAP, the sample became more yellow (all significant differences at the level of 0.05). For ΔEab* values, it shows that there were statistically significant differences between the total color difference of all three formulations. Thus, there is a possibility that the colour difference could be detected among all three formulations by human eyes.

Table 2. Color measurements of CSB with different level of JAP substitution

	Control	10% JAP	15% JAP
L*	82.28 ± 0.94^{a}	65.98 ± 1.12^{b}	62.81 ± 0.66^{c}
a*	- 1.02 ± 0.09^{a}	2.88 ± 0.34^{b}	3.78 ± 0.23^{c}
b*	13.78 ± 0.96^{a}	23.76 ± 1.03^{b}	24.70 ± 0.69^{c}
ΔEab*		19.63 ± 1.00^{b}	22.84 ± 0.52^{c}

Data are presented with means ± standard deviation. Means with different letters are significantly at $p \leq 0.05$

Figure 1. Photograph of three formulations of CSB as substitution with JAP

The appearance of the with JAP at different concentrations are shown in Figure 1. The sizes are not much different. The control formulation was the least dense and 15% JAP is the densest, and 10% was in between. From the observation, 15% was also firmer, and harder to deform. The color of 15% JAP was slightly darker than 10% JAP.

3.3 Textural profile analysis of Chinese steamed breadcrumb

The results of Textural profile analysis (TPA), are shown in Table 3. Hardness, gumminess, and chewiness indices are textural parameters that show increasing values as more JAP was added in the formulation with statistically significant differences between all three formulations. Vice versa, resilience shows a decreasing

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value as more JAP was added in the formulation with the statistically significant difference between all three formulations. For the cohesiveness and springiness indices, both show a decreasing trend, but not all the values within the parameter were significantly different at the level of 0.05. For adhesive force, there was no trend established and all values were not statistically different at the level of 0.05.

The hardness of CSB increased with increased amount of JAP substitution which lowered the steamed bread quality. This may be caused by the decreased moisture content and the increased dietary fiber and ash content. There was 114.9% increase from the control formulation to 15% JAP formulation, and 52.4% increase from control to 10% JAP. Also, the stabilizing property of inulin in JAP could also make the crumb firmer and contributed to increased hardness.

Table 3. Texture profile analysis of CSB with different level of JAP substitution

	Control	10% JAP	15% JAP
Hardness (N)	4.64 ± 0.22[a]	7.07 ± 0.32[b]	9.97 ± 0.61[c]
Adhesive force (N)	0.08 ± 0.05[a]	0.04 ± 0.06[a]	0.09 ± 0.11[a]
Resilience	0.54 ± 0.03[a]	0.46 ±0.04[b]	0.39 ± 0.05[c]
Cohesiveness	0.84 ± 0.06[a]	0.77 ± 0.09[ab]	0.73 ± 0.11[b]
Springiness Index	0.91 ± 0.02[a]	0.90 ± 0.01[b]	0.88 ± 0.02[b]
Gumminess	3.88 ± 0.27[a]	5.43 ± 0.61[b]	7.34 ± 1.40[c]
Chewiness Index (N)	3.56 ± 0.29[a]	4.89 ± 0.59[b]	6.46 ± 1.32[c]

Data are presented with means ± standard deviation. Means with different letters are significantly at p≤0.05

The results (Table 3) show that gumminess and chewiness index of 15% JAP increased from the control by 89.2% and 81.5% respectively, and this could caused by the ability of inulin to form gel during the dough formation (Milani and Maleki, 2012) and eventually created a more chewy texture by causing a thick dough structure, which improved the CSB quality as chewiness is a desirable characteristic according to quality evaluation scoring system from SBT 10139-93 (Zhu, 2014).

Since the gluten network that gives the elasticity of the CSB was weakened by the declination of hydration process and disturbance from dietary fiber and ash in JAP, the elasticity decreased, so it is reasonable that resilience, springiness index, and cohesiveness decreased also as the result expressed. Comparing 15% JAP with the control, the resilience, springiness index and cohesiveness decreased by 27%, 3.3%, and 13.1% respectively.

As for adhesive force, which is the maximum force required to separate teeth after biting the sample, Table 2 shows no trend and no statistically significant difference at the level 0.05, so it can conclude that JAP substitution to wheat flour up to 15% does not have an effect on the CSB adhesiveness in this experiment.

3.4 Sensory evaluation

Sensory evaluation was composed of three parts which are the 9-point hedonic scale, flavor intensity, and ranking. The sensory evaluation of the acceptability of attributes from the different JAP substitution by 9-point hedonic scale is shown in Figure 2. For most attributes other than color, 10% JAP substitution had the highest score, with the score range from 6.55-7.17 which falls in the 'like moderately' category. This indicates that 10% Jerusalem artichoke powder substitution to wheat flour was the most acceptable for panelists. At 15% JAP substitution, the score values ranged from 6.45-6.76. Even though it is slightly lower than 10% JAP, it is still a good score, and the acceptability is not much different from 10% because these were not significantly different at the level of 0.05 for all attributes. The control had the highest score for the color attribute of 7.34, but for the rest of the attributes, it was the formulation with the lowest values of 5.31-6.00.

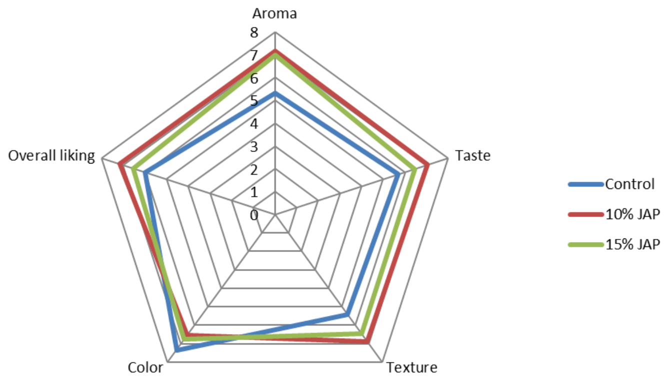

Figure 2. Sensory evaluation on attributes of CSB on different level of JAP substitution by 9-point hedonic scale.

Besides color all other attributes including aroma, taste, texture, and overall liking show the same trend; 10% JAP gained the highest scores, followed by 15% JAP and control, respectively.

For sensory evaluation on the texture of CSB, the panelists prefer 10% JAP substitution most as being 'liked moderately' and control formulation the least. This also indicates that by sensory test, the texture of the 10% and 15% JAP formulations were not statistically different from each other. For the sensory test, the CSB was served immediately after it was steamed (not more

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than 5-10 minutes delay), so the warm CSB could have a softer texture or lower hardness value compared to the value of hardness obtained from TPA. They were cooled prior to TPA a much longer period of 40 minutes, so CSB was no longer warm and not as soft. In addition, the inulin from JAP that comes in contact with water may form a gelling property and give a better texture that is more preferred by panelists, which corresponds to the result from TPA that gumminess and chewiness improved. The study that investigated the influence of JAP in bread dough also confirms that adding 10% JAP to wheat flour causes the thick dough structure and also a stabilizing property which was most desirable compared to the other percentage of JAP substitution (Gedrovica and Karklina, 2011)

For aroma and taste, the 10% JAP also received the highest score of all formulations categorized as 'liked moderately,' 15% JAP was not statistically different from 10% JAP, and the control was last being categorized between 'neither like nor dislike' and 'like slightly.' For the aroma of control formulation, it was described by the panelist as having a weird and somewhat unpleasant aroma. This could possibly be due to the complex interactions of flavor and aromatic compounds in the CSB and the LDPE plastic ziplock bag that was used as packaging while stored in the refrigerator since the unattractive aroma appeared only after it was stored in the plastic bag. The strong flavor of JAP seems to have covered up the odor, causing the formulations with JAP to become more preferred to the panelist instead. There could be an occurrence of oxygen permeation from the environment, migration of plastic bag's monomers, or loss of aroma due to absorption of the aromatic compound into the plastic packaging (Van Willige *et al*., 2000), which caused an off-flavor CSB for the control samples. The unpleasant aroma in control formulation could also affect the perception of the taste of the CSB by panelists and lower its rating score.

According to the panelists, JAP has a unique herb flavor that is acceptable and enhanced the flavor of the plain steamed bread. Based on the paper, analysis of essential oils in Jerusalem artichoke leaves and tubers by GC-MS, it indicates that (-)-β-bisabolene was the major essential oil found in the JA tuber, and that these compounds give out woody, fruity, balsamic, astringent and green flavors or odors (Helmi *et al.,* 2014). Moreover, even though the amount of salt put in the three formulations were equal, many panelists commented that the 15% JAP was salty. This could be due to a compound in JAP that enhanced the saltiness in the CSB. The flavor intensity test result confirmed that panelists were able to detect the higher concentration of JAP level in CSB and that they still preferred the flavor of 10% JAP more than 15% which could be too intense.

The original white color of the control formulation was most liked by the panelists, however, it was not statistically different from 10% and 15% JAP. The color of formulations with JAP was judged acceptable by the panelists, who categorized it between 'like slightly' and 'like moderately'. The reddish-brown color of the CSB with JAP substitution could otherwise be perceived as a healthy food product.

For overall liking in the hedonic scale, the panelists preferred 10% JAP, however, there were no statistical differences from the control formulation and 15% JAP formulation. The result of the hedonic scale corresponds to the ranking test result (Figure 2), where the most preferred from the ranking was also 10% JAP substitution followed by 15%, and the least was the control formulation. Nevertheless, the rating score of both 10% and 15% JAP were acceptable by the panelists and have promising potential to launch as new products.

4. Conclusion

In conclusion, from all assessments based on results from all physicochemical and sensory evaluations, 10% JAP substitution to wheat flour was acceptable in all properties and even improved textural properties of the CSB.

The specific volume of 10% JAP substitution to wheat flour comparing to control shows that there were no significant differences at the level of 0.05, as it does not disturb the expansion of the dough. The water content in 10% JAP and 15% JAP only slightly decreased and does not have a major impact on the dough formation.

According to TPA texture analysis, there were differences among different substitutions of JAP. The crude fiber and ash content lowered the quality by increasing the hardness, decreasing the resilience, and cohesiveness of the CSB, but improved in chewiness and gumminess by the gelling property of inulin. As for the sensory evaluation in terms of texture, the panelists preferred the texture of 10% JAP more than the control formulation and 15% JAP.

The color difference was obvious based on the results from the chromameter, and showed the differences between treatments and control. However, there were no significant differences at the level of 0.05 between all formulations.

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As for the sensory evaluation as a whole, 10% JAP substitution was the most preferred by the panelists, but not statistically different from 15% JAP.

Overall, 10% JAP substitution to the wheat flour had the most desirable physicochemical properties, and it was the most acceptable in the sensory evaluation. Therefore, 10% JAP to the wheat flour has high potential to be applicable in CSB without disrupting the original desirable properties of CSB and has the potential for development into a product with higher nutritional value. Future work can be done on the analysis of the active compounds of JAP in Chinese steamed bread for further investigation.

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References

Crosby, G. and Editors of America's Test Kitchen. (2012). The Science of Good Cooking. USA: American's Test Kitchen.

Gedrovica, I. and Karklina, D. (2011). Influence of Jerusalem artichoke powder on dough rheological properties. Proceedings of the 6th Baltic Conference on Food Science and Technology "Innovations for Food Science and Production" "FOODBALT-2011", May 5 - 6, 2011, p. 7–12. Jelgava, Latvia.

Glibowski, P. and Bukowska, A. (2011). The effect of pH, temperature and heating time on inulin chemical stability. *Acta Scientiarum Polonorum. Technologia Alimentaria*, 10(2), 189-196.

Helmi, Z., Al Azzam, K.M., Tsymbalista, Y., Abo Ghazleh, R.A., Shaibah, H. and Aboul-Enein, H. (2014). Analysis of essential oil in Jerusalem artichoke (*Helianthus tuberosus* L.) leaves and tubers by gas chromatography-mass spectrometry. *Advanced Pharmaceutical Bulletin*, 4 (2), 521-526. https://doi.org/10.5681/apb.2014.077

Jacobs, P.J., Bogaerts, S., Hemdane, S., Delcour, J.A. and Courtin, C.M. (2016). Impact of wheat bran hydration properties as affected by toasting and degree of milling on optimal dough development in bread making. *Journal of Agricultural and Food Chemistry*, 64(18), 3636-3644. https://doi.org/10.1021/acs.jafc.5b05958

Luangsakul, N., Keeratipibul, S., Jindamorakot, S. and Tanasupawat, S. (2009). Lactic acid bacteria and yeasts isolated from the starter doughs for Chinese steamed buns in Thailand. *LWT - Food Science and Technology*, 42(8), 1404-1412. https://doi.org/10.1016/j.lwt.2009.03.007

Murray, R. (1977). Dietary fiber. New York: MSS Information Corp.

Niness, K.R. (1999). Inulin and oligofructose: what are they? *The Journal of Nutrition*, 129(7), 1402S–1406S.

Popper, L., Schäfer, W. and Freund, W. (2006). Future of flour: A compendium of flour improvement. Bergen/Dumme, Germany: Agrimedia.

Radovanovic, A., Stojceska, V., Plunkett, A., Jankovic, S., Milovanovic, D. and Cupara, S. (2015). The use of dry Jerusalem artichoke as a functional nutrient in developing extruded food with low glycaemic index. *Food Chemistry*, 177, 81-88. https://doi.org/10.1016/j.foodchem.2014.12.096

Van Willige, R.W., Linssen, J.P. and Voragen, A.G. (2000). Influence of food matrix on absorption of flavour compounds by linear low-density polyethylene: proteins and carbohydrates. *Journal of the Science of Food and Agriculture*, 80(12), 1779-1789. https://doi.org/10.1002/1097-0010(20000915)80:12<1779::aid-jsfa726>3.0.co;2-f

Wu, C., Liu, R., Huang, W., Rayas-Duarte, P., Wang, F. and Yao, Y. (2012). Effect of sourdough fermentation on the quality of Chinese Northern-style steamed breads. *Journal of Cereal Science*, 56 (2), 127-133. https://doi.org/10.1016/j.jcs.2012.03.007

Zhu, F. (2014). Influence of ingredients and chemical components on the quality of Chinese steamed bread. *Food Chemistry*, 163, 154-162. https://doi.org/10.1016/j.foodchem.2014.04.067

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