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Physical and Organoleptic Characteristics and Calcium Bioaccessibility of Fortified Sweet Potato Noodles

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Abstract

Low bone density, or osteoporosis, can be caused by insufficient calcium in the body. A strategy for solving a calcium deficit is food fortification. Because sweet potatoes have a good nutrition profile, using them to manufacture noodle fortification with calcium will enhance the amount of calcium that people intake. Fortification of sweet potato noodles with calcium may have an impact on their quality. In this study, the effect of the type and amount of calcium salt on the characteristics of sweet potato noodles was investigated. Two calcium salts (calcium carbonate and calcium citrate) and two salt concentrations (20 and 30% RDA) were used to fortify sweet potato noodles. The physical parameters of sweet potato noodles were determined by measuring color, texture, and cooking loss. Sensory assessment with a hedonic test and calcium bioaccessibility analysis using a dialysis membrane was conducted. The results showed that calcium fortification did not reduce the physical and sensory quality of sweet potato noodles. The physical changes that occurred were an increase in brightness intensity and yellow color. However, this did not change the panelists' sensory acceptance. Calcium fortification at 20 and 30% RDA did not affect the hardness, elasticity, stickiness, elongation, and cooking loss of sweet potato noodles. Sensory evaluation showed that the sweet potato noodles with calcium fortification were acceptable to the panelists. Regarding the quality of the calcium content, the fortification process of sweet potato noodles significantly increased the calcium content. The amount of calcium in the noodles increases with increasing calcium concentration added. Calcium citrate fortification at the RDA level of 30% had the highest bioaccessibility, so it is recommended because it has the greatest benefit without reduction in physical and sensory quality.

Keywords: *bioaccessibility, fortification calcium, sensory, sweet potato noodles, texture*

Full length article **Corresponding Author*, e-mail: sedarnawati@yahoo.com Doi # https://doi.org/10.62877/92-IJCBS-24-25-19-92

1. Introduction

Calcium is a micronutrient with several important functions, including bone and tooth formation [1]. Calcium deficiency can lead to chronic conditions such as osteoporosis, which is characterized by a decrease in bone density leading to bone fragility [2]. Prevention of osteoporosis is very important and can be achieved by consuming calcium. The necessary calcium can be met by consuming calcium from food sources and supplements [1]. Calcium in food can occur naturally or through an additional process called calcium fortification. Many people will consume more calcium if their favorite foods are fortified with calcium. One of the people's favorite foods is noodles. According to the World Instant Noodle Association, global instant noodle consumption is increasing every year [3].

Noodles are usually made from wheat flour, which has gluten and is unhealthy for people with gluten intolerance. A gluten-free diet can manage patients with celiac disease. Sweet potatoes can become one of the alternatives to replace wheat flour and create various noodles free of gluten. The starch found in sweet potatoes can act as a binder to form the product's texture. The properties of sweet potato starch show great potential for application in the food industry [4]. Research on the production of broken rice flour products shows that substituting ingredients with sweet potatoes improves the physicochemical properties of the product [5]. The formation of product texture can also be aided through proper processing. Using an extruder for food processing can help starch gelatinization through heat and shear stress. The high-pressure extrusion process will produce noodles with a tight and compact structure, so the pores formed become small, reducing the release of particles during cooking [6]. Sweet potato is an important and popular source of carbohydrates in many countries, which contain several nutrients that the body needs [7, 8]. Orange sweet potatoes are high in beta-carotene, an antioxidant that maintains eye health [9, 10]. Beta-carotene can also be used as a natural food colorant [11]. Many functional foods use sweet potatoes as the main ingredient. Several studies related to the function of sweet potatoes include a combination of bangle and sweet potato on antioxidant activity [12].

Developing gluten-free noodle variants using sweet potatoes will help improve the texture and nutrition. The nutritional value of sweet potato noodles can be improved by adding more nutrients, one of which is calcium fortification. Several factors to consider when choosing a fortifier include the effect on sensory quality, interaction with other food components, and the bioavailability [13]. Calcium carbonate and calcium citrate are two fortifying agents commonly used in the food industry. Several studies have shown that the addition of calcium salts affects consumer acceptance [14]. Calcium ions can create calcium-starch and calcium-protein complexes to form a more solid and compact product structure. Fortification should maintain the physical and sensory quality of sweet potato noodle products. However, good sweet potato noodles need a firm, elastic texture, and good sensory properties. Therefore, this research aimed to analyze the effect of calcium salt type (calcium carbonate and calcium citrate) and salt concentrations at 20 and 30% RDA (Recommended Dietary Allowance) on the characteristics of sweet potato noodles (physical, sensory, and calcium bioaccessibility).

2. Materials and methods

2.1 Materials

The main ingredients for noodle processing were orange sweet potato *(Ipomoea batatas)* and sago starch *(Metroxylon sp.)*. The fortification was done with calcium carbonate and calcium citrate (Shanghai Chemical Industry Park, China). Sweet potato flour production stages were peeling, washing, draining, slicing with a thickness of 2 mm using a Slicer (Geprüfte Sicherheit, Jerman), and drying using a Cabinet Dryer (Terara Seisakusho C. Ltd. No 4-60SP, Jepang) at 50 °C for 6 hours. Dried sweet potato slices were crushed using a Pin Disc Mill (FFC 23 Agrowindo-Maksindo, Indonesia) and sifted through an 80-mesh sieve [11].

2.2 Production of calcium-fortified sweet potato noodles

Sweet potato noodles were produced using a Single-Screw Extruder (Forming-Cooking Extruder, Scientific Laboratory Single Screw Extruder type LE 25-30/C, Labtech Engineering Co. Ltd., Thailand) with a screw speed was 130 rpm and barrel extrusion temperature was 95 °C [15].

Sweet potato flour (85%) was mixed with sago flour (15%), then added calcium salt. Sweet potato noodles were processed as in Figure 1 [15]. The types of calcium added were calcium carbonate and calcium citrate. Each calcium salt was added at two levels, 20 and 30% RDA (1000 mg/day). Calcium was added by mixing it into the dry dough gradually until it was completely homogeneous. Calcium was added to 1/5 of the dry dough and then homogenized. After the mixture of calcium and dry dough was homogeneous, another 1/5 of the dry dough was added and homogenized again. This step continued to be repeated until all the dry dough was mixed.

2.3 Analysis of physical properties

2.3.1 Color of sweet potato noodles

The Hunter method was used to measure the color of sweet potato noodles with a Chromameter (CR-A33D, Konica Minolta, Japan). This measurement will produce the values of ‘L’, ’a’, and ‘b’. The ‘L’ value will indicate the brightness, the ‘a’ value will indicate the chromatic color of red and green, and the ‘b’ value will indicate the blue and yellow [16].

2.3.2 Textural properties of sweet potato noodles

A Texture Analyzer (Stable Micro-System TA-XT2i, Inggris) was used to analyze the texture properties of sweet potato noodles. The hardness, elasticity, and stickiness of noodles were measured using a cylindrical probe with a diameter of 35 mm. Measurements were done by boiling the sweet potato noodles for 5 minutes and draining them for 5 minutes. Elongation measurements were conducted by wrapping noodles around the probe with a distance between the probes of 2 cm [16].

2.3.3 Cooking loss of sweet potato noodles

Samples of sweet potato noodles were boiled for 5 minutes and then drained. Next, it was dried in an oven at 105°C until it reached constant weight. The noodle cooking loss was determined by comparing the dry weight of sweet potato noodles before boiling with the dry weight of the sample after boiling [17].

2.4 Sensory test

The hedonic test was used in five attributes: color, aroma, taste, texture, and overall, each was assessed on a scale from 1 (dislike very much) to 7 (like very much). A sensory test was conducted with 55 panelists, and the samples were given sequentially [18].

2.5 Calcium content of sweet potato noodles

Calcium content was analyzed by atomic absorption spectrophotometry (AAS). Calcium measurements were carried out on dried sweet potato noodles, boiled sweet potato noodles (cooking for 5 minutes), and water left over from boiling sweet potato noodles [18].

2.6 Calcium bioaccessibility (in vitro)

Two sample solutions were prepared, adjusted to pH 2 using HCL, added 1 ml of pepsin suspension, and incubated at 37 °C for 2 hours. Sample solutions were added with 5 ml of bile pancreatin (Sigma p-170 pancreatin and Sigma B8631 bile extract) and incubated for 2 hours. One of the solutions was titrated with NaOH until it reached a pH of 7 so that the $NaHCO_3$ requirement could be calculated. Put the $NaHCO_3$ solution into the dialysis membrane, then soak it in the other sample solution. Bioaccessibility value was calculated by comparing the mineral content in the dialysate and the total minerals in the sample [19].

2.7. Research design

The research design was completely randomized design, with type and calcium level as the factors, data was presented as an average value. Statistical analysis was conducted with SPSS V.25 to determine the difference between treatments; the Duncan test was done at a 95% confidence level ($P<0.05$).

3. Results and Discussions

3.1 Physical properties of sweet potato noodles

3.1.1 Sweet potato noodle color

Color measurement helps to control product quality by providing quantitative information on noodle color intensity [20]. Color analysis of sweet potato noodles shows that sweet potato noodles had a little bright color (L: 35.25-38.41) and the presence of red (a: 16.86-17.93) and yellow elements (b: 14.31-20.26). The low brightness of sweet potato noodles can occur from a browning reaction [21]. The appearance of red and yellow color intensity can occur due to the presence of beta-carotene pigments from orange sweet potato and the Maillard reaction during noodle processing [22].

Fortification of calcium significantly affected the color of sweet potato noodles (Table 1). Fortified sweet potato noodles had a brighter (L) and yellow (b) appearance. These results are in line with other research that showed an increase in brightness in puffed rice extrudates and noodle products after calcium fortification (Janve dan Singhal 2018). Another study that produced similar results was Grasso et al. (2024), fortification increases the brightness of cheese products but is inversely proportional to the yellowing level measurement results, the research of Grasso et al. (2024), cheese supplemented with calcium decreased the yellow color Grasso et al. (2024). Another study that conducted similar research was by Lin et al. (2023), fortification with calcium citrate and carbonate increased the brightness of noodles. In this study, it was explained that fortification with calcium citrate and calcium carbonate increased the pH of raw noodles which affected the color of the noodles [25]. Adding calcium to the sweet potato noodle dough will affect the pH, affecting the color [14]. The calcium fortification will prevent the *Maillard* reaction during the processing, Ca^{2+} ions bind to amino acids, thus inhibiting the reaction between amino acids and reducing sugars. Calcium can help to minimize the quantity of free water in the environment. The brightness and yellow color of the fortified noodles were more maintained compared to the control, and there was no difference in the color of noodles between calcium carbonate and calcium citrate fortification.

3.1.2 Sweet potato noodles texture

The hardness, stickiness, elasticity, and elongation of fortified sweet potato noodles were not significantly different ($p > 0.05$) compared with the control (Figure 2). Hardness is the force required to deform the sample. Then, the elasticity value indicates how much a product may return to its initial state after getting force on the first push. Sweet potato noodles fortified with calcium had a higher hardness and elasticity than the control, but this difference is not significant ($p > 0.05$). This could be due to the low calcium salt amount added to the noodle dough, so its effect on the texture was not detected significantly. These results are linear with research by Janve and Singhal (2018) which showed the type of calcium salt in the noodle fortification process did not significantly affect the hardness of the noodles. In the study, the main factor affecting noodle hardness was the length of boiling time. However, different results when applied to puffed rice extrudates showed the addition of calcium decreased the hardness value (Janve dan Singhal 2018). Another study by Grasso et al. (2024) shows that the type of calcium salt does not significantly affect the addition of cheese hardness Grasso et al. (2024). This is in line with this study which showed no significant difference between sweet potato noodles fortified with calcium citrate and noodles fortified with calcium carbonate. The level of elasticity of the noodles is affected by the starch gelatinization process, which involves the granules binding to other components and maintaining the product elasticity [26].

Good noodles have low-value stickiness. Calcium-fortified sweet potato noodles have a lower average stickiness value, but it is not significant ($p > 0.05$) compared with the control. Calcium strengthens the bond, but the insignificant in this research is due to the addition of calcium to the product in too small amounts. Therefore, changes in bond strength due to the presence of calcium were not significantly detected. Imperfect gelatinization of starch can cause the bonding power between particles to weaken [27].

From this research, the fortification process with calcium carbonate and calcium citrate at 20 and 30% does not decrease the texture quality of sweet potato noodles because fortified sweet potato noodles have the same texture as the control. Several factors affect the noodle texture, including ingredients and processing technique. Calcium ions can form calcium-starch and calcium-protein complexes and produce a more robust and compact structure, that affects the hardness [28]. The insignificant effect of fortification at this level indicates a good effect because it shows that the addition of calcium salt at this level does not make the noodle too hard and does not reduce the quality of the noodle. Noodles that are too hard can reduce sensory acceptance.

3.1.3 Sweet potato noodles cooking loss

Cooking losses are the amount of solids in dried noodles that dissolve into the water during cooking. The quality of the noodles improves with decreasing cooking loss values [29]. This study found that the average cooking loss value for the calcium-fortified noodles is lower than the control but not significant ($p > 0.05$) (Figure 3). Like other research, calcium fortification in rice noodles did not significantly affect cooking loss (Janve dan Singhal 2018). However, other research shows that adding calcium salt to the noodle dough can decrease the value of the cooking loss significantly [23]. That can be caused by the different amounts of calcium salt added to the noodle dough. The amount of calcium will determine the degree of influence given. Fortification with 0.25% calcium carbonate or calcium citrate decreased cooking loss [25].

3.2 Preference level (hedonic test) of sweet potato noodles

The panelist's assessments of sweet potato noodle color, aroma, taste, texture, and overall acceptability were similar (Table 2). The calcium fortification by calcium carbonate and calcium citrate at 20 and 30% RDA did not affect the panelist acceptance. This result is in line with research by Lin et al. (2023), which showed fortification of calcium citrate and calcium carbonate in noodles had no significant effect on sensory value compared to control noodles [25]. Overall, the panelists scored between 4 (medium) and 5 (like) on all the test attributes, which indicated that they could accept sweet potato noodles with calcium fortification. Another study that made noodles using wheat flour, sweet potato flour, and pumpkin flour was acceptable to the panelists [31]. One of the things that needs to be considered in the fortification process is the effect of calcium salt on product sensory. The characteristics of calcium carbonate are colorless, soapy taste, and odorless. Meanwhile, calcium citrate is colorless, has a tart taste, and is odorless [32]. Good processing and appropriate levels will reduce the detectability of these calcium salt characteristics in the product.

3.3 Calcium content of sweet potato noodles

From highest to lowest, the calcium content in sweet potato noodles was a formula with the calcium addition of 30%, 20%, and control (Table 3). Consistent with the quantity of calcium added during the fortification process. When more calcium was added during the fortification process, the calcium content of sweet potato noodles increased. Types of calcium salt did not affect the calcium content of sweet potato noodles; rather, the amount of calcium added to noodles affects the calcium content. This result was in line with other studies that show the fortification process can increase the calcium content of the product [33]. The boiling process reduces the calcium content in sweet potato noodles. Calcium can be dissolved in water, so calcium can be found in the water left over from boiling the noodles.

3.4 Calcium bioaccessibility

Dialysis membrane separates large and small molecules based on their semipermeable properties. Calcium fortification in sweet potato noodles at a 30% level did not reduce the texture and sensory quality of the noodles and had high calcium content. Therefore, calcium bioaccessibility analysis was conducted on sweet potato noodles with fortification at a 30% level. The analysis showed that the bioaccessibility of calcium in sweet potato noodles ranged from 17.215–36.626%. Calcium fortification increases the bioaccessibility value of calcium. Sweet potato noodles with 30% calcium citrate fortification had higher bioaccessibility than noodles with calcium carbonate fortification and control (Figure 4). Calcium citrate has a good solubility level; calcium citrate has a higher bioavailability than calcium from calcium carbonate [34]. The formation of a complex between calcium and citrate prevents the deposition of calcium salts during an increase in intestinal pH [35]. Citrate also plays a role in stabilizing apatite nanocrystals in bones; this is important for bone biomineralization [35].

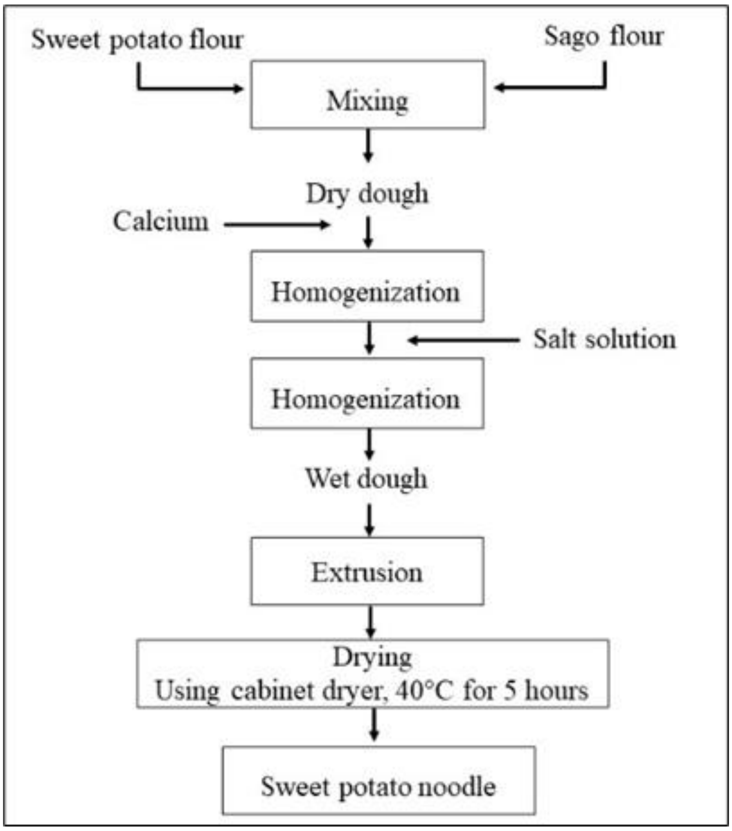

Figure 1. Sweet potato noodles process

Table 1: The color of sweet potato noodles

Sample	L	a	b
Control noodle	35.25 ± 0.295[a]	16.86 ± 1.335[a]	14.31 ± 1.481[a]
Noodle calcium carbonate 20%	37.38 ± 1.304[b]	18.39 ± 0.164[b]	19.10 ± 0.334[b]
Noodle calcium carbonate 30%	37.85 ± 0.916[b]	17.92 ± 0.683[ab]	18.26 ± 1.135[b]
Noodle calcium citrate 20%	38.12 ± 0.335[b]	17.93 ± 0.094[ab]	17.86 ± 0.838[b]
Noodle calcium citrate 30%	38.41 ± 1.407[b]	17.86 ± 0.353[ab]	20.26 ± 1.334[b]

Note: value = mean±SD, n = 3 *data in one column with different superscripts are significantly different (P< 0.05).

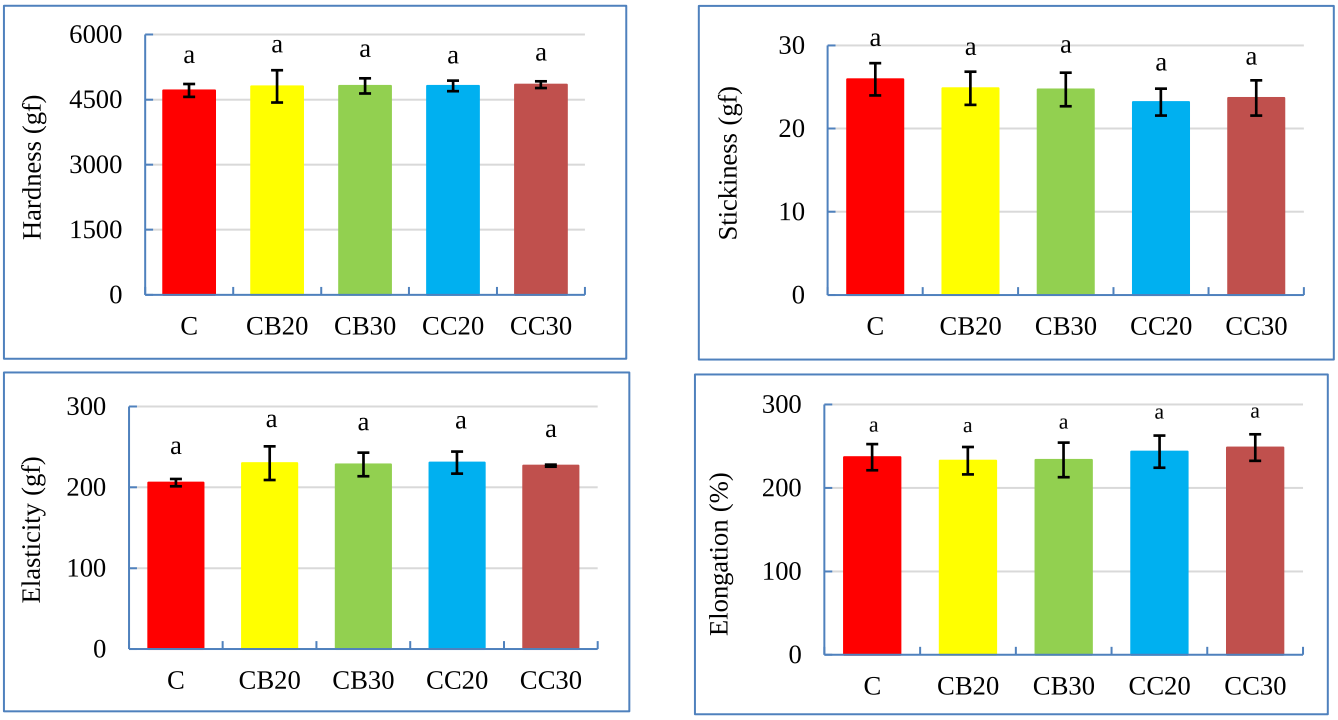

Figure 2. Texture characteristics of sweet potato noodles

Note: value = mean ± SD, n = 3, * data with different superscripts are significantly different (P < 0.05). C = Control noodle, CB20 = Noodle calcium carbonate 20%, CB30 = Noodle calcium carbonate 30%, CC20 = Noodle calcium citrate 20%, CC30 = Noodle calcium citrate 30%.

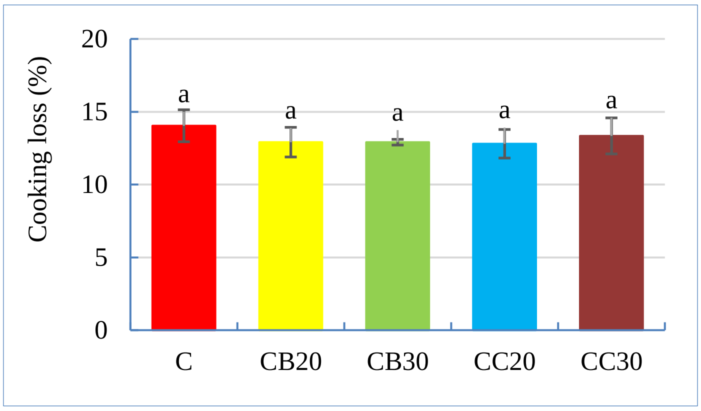

Figure 3. The cooking loss of sweet potato noodles

Note: value = mean ± SD, n = 3, * data with different superscripts are significantly different (P < 0.05). C = Control noodle, CB20 = Noodle calcium carbonate 20%, CB30 = Noodle calcium carbonate 30%, CC20 = Noodle calcium citrate 20%, CC30 = Noodle calcium citrate 30%.

Table 2: Hedonic test of sweet potato noodles

Sample	Color	Aroma	Taste	Texture	Overall
Control noodle	4.6 ± 1.27[a]	4.6 ± 1.00[a]	4.5 ± 1.20[a]	4.7 ± 1.08[a]	4.7 ± 0.93[a]
Noodle calcium carbonate 20%	4.6 ± 1.17[a]	4.5 ± 1.10[a]	4.5 ± 1.12[a]	4.7 ± 1.11[a]	4.6 ± 0.92[a]
Noodle calcium carbonate 30%	4.8 ± 0.92[a]	4.7 ± 0.93[a]	4.7 ± 1.03[a]	4.5 ± 1.29[a]	4.6 ± 0.99[a]
Noodle calcium citrate 20%	4.8 ± 1.07[a]	4.7 ± 0.93[a]	4.7 ± 0.88[a]	4.8 ± 1.07[a]	4.9 ± 0.74[a]
Noodle calcium citrate 30%	5.0 ± 0.96[a]	4.7 ± 0.96[a]	4.7 ± 1.19[a]	4.8 ± 1.19[a]	4.8 ± 1.17[a]

Note: value = mean±SD, n = 55 *data in one column with different superscripts are significantly different (P< 0.05).

Table 3: Calcium content of sweet potato noodles

Sample	Dry noodle calcium content (mg/100g)	Boiled noodle calcium content (mg/100g)	Water calcium content (mg/100g)
Control noodle	15.458 ± 1.1216[a]	11.452 ± 0.5647[a]	3.231 ± 0.4990[a]
Noodle calcium carbonate 20%	230.933 ± 4.3011[b]	188.505 ± 1.7766[b]	12.640 ± 0.1304[c]
Noodle calcium carbonate 30%	340.739 ± 9.3953[c]	307.991 ± 14.6863[d]	14.090 ± 1.3153[c]
Noodle calcium citrate 20%	236.015 ± 5.5670[b]	206.132 ± 9.0107[c]	10.968 ± 0.8286[b]
Noodle calcium citrate 30%	345.258 ± 2.9249[c]	320.209 ± 3.0061[d]	12.699 ± 0.9673[c]

Note: value = mean±SD, n= 3 *data in one column with different superscripts are significantly different (P<0.05).

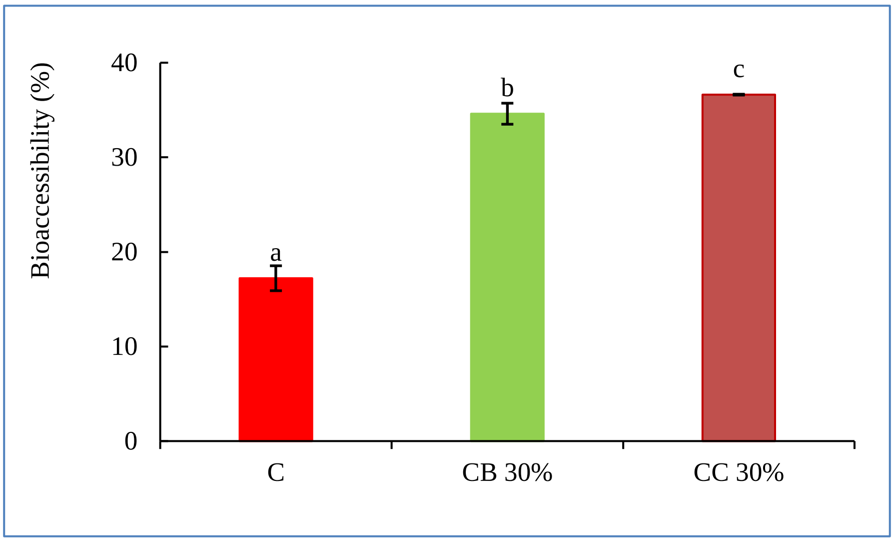

Figure 4. Calcium bioaccessibility of sweet potato noodles

Note: value = mean ± SD, n = 3, * data with different superscripts are significantly different (P < 0.05). C = Control noodle, CB30 = Noodle calcium carbonate 30%, CC30 = Noodle calcium citrate 30%.

4. Conclusions

Calcium fortification in sweet potato noodles significantly ($p < 0.05$) increased the brightness and yellow intensity and had no significant ($p > 0.05$) effect on the level of hardness, elasticity, stickiness, elongation, and cooking loss. Calcium fortification also had no significant impact ($p > 0.05$) on the sensory test. Calcium fortification of 30% RDA produces a higher calcium content without decreasing the physical and sensory characteristics of sweet potato noodles. Overall, calcium-fortified sweet potato noodles were acceptable to the panelists. Calcium citrate fortification at a 30% RDA level on sweet potato noodles has the highest calcium bioaccessibility and was acceptable to the panelists.

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