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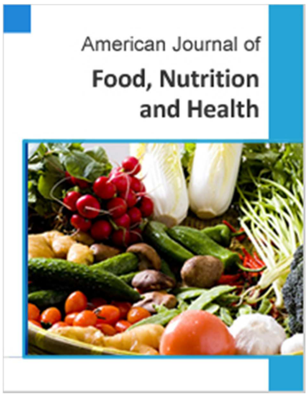

Residual Calcium Content of Sweet Potato Slices after Osmotic Pre-treatment with Salt (NaCl) Solution

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Abstract

Light yellow-flesh, matured sweet potato was used in a lab osmotic pre-treatment in sodium chloride (NaCl) solution with varying salt concentrations. The samples were subsequently dried via oven-drying. Measurements of residual calcium were taken. The dried potato slices (1 kg each of the representatives) were ashed in a muffle furnace at temperature of about 570°C for 30 mins. Solutions of the ashes were made by properly stirring with little volumes of distilled water in a beaker respectively. When the suspended solids were present in sufficient amounts to clog the nebulizer, the sample was allowed to settle and the supernatant liquid analyzed directly. The results obtained after AAS determination of calcium contents by checking absorbance against the concentration in a standard curve were analyzed using three factor design statistical analysis. Results show that potato slices of about 6mm thickness should be adopted since it yields potato products with relative higher calcium content than 2 mm and 4 mm thickness. The concentration of the salt solution should be adjusted to 10% m/v strength, as results to products with relatively higher calcium content. Where SSC of 10% m/v couldn't give product with required texture, 20% m/v could be alternative. Time of soaking should be within 20 – 40 minutes since the nutrition (Calcium) of the product is improved within this resident duration. Generally, to ensure potato products with more conserved calcium and required texture, potato slice thickness of 6 mm, salt solution concentration of about 10 to 20% m/v, and soaking time within 20 – 40 minutes should be adopted during pretreatment processing.

1. Introduction

The sweet potato (*Ipomoea batatas*) is a dicotyledonous plant that belongs to the morning glory family *Convolvulaceae*. Its large, starchy, sweet-tasting, tuberous roots are a root vegetable [11]. In some parts of the English-speaking world, sweet potatoes are locally known by other names such as kumara, but people usually confuse it with yam due to their similar appearances [16]. The young leaves and shoots are sometimes eaten as greens. The sweet potato is only distantly related to the potato (*Solanum tuberosum*) and does not belong to the nightshade family Solanaceae, but that family is part of the same taxonomic order as sweet potatoes, the Solanales. The plant is a herbaceous perennial vine, bearing alternate heart-shaped or palmate lobed leaves and medium-sized sympetalous flowers. The edible tuberous root is long and tapered, with a smooth skin whose color ranges between yellow, orange, red, brown, purple, and beige.

Its flesh ranges from beige through white, red, pink, violet, yellow, orange, and purple. Sweet potato cultivars with white or pale yellow flesh are less sweet and moist than those with red, pink or orange flesh [16].

Raw sweet potato is good source of calcium (30 mg/100 g) and other nutrients such as simple and complex carbohydrates, dietary fiber and beta-carotene (a pro-vitamin A carotenoid), while having moderate contents of other micronutrients, including vitamin B_5, vitamin B_6 and manganese [38]. When cooked by baking, small variable changes in micronutrient density occur to include a higher content of vitamin C at 24% of the Daily Value per 100 g serving. Sodium chloride (and its solution) is sometimes used as a cheap and safe drying aid because of its hygroscopic and osmotic properties, making salting and osmotic pretreatment with salt solution effective methods of food preservation and drying aid historically; the salt draws water out through osmotic pressure, improving the sensory and keeping qualities of the final products. Even though more effective desiccants and drying agents are available, few are safe for humans to ingest.

During drying process, before putting in oven for drying, sweet potatoes are subjected to pretreatment techniques, like osmotic pretreatment with salt (NaCl) solution, to improve the sensory and keeping qualities of the potato products. Most industrial, local, and traditionally processed fried/dried potato chips sellers soak sliced potato in salt solution for considerable duration as pretreatment step prior to frying/drying. These pretreatment techniques may affect the nutritional value of the end products. During osmotic pretreatment, since the cell membrane responsible for osmotic transport is not perfectly selective, solutes present in the cells (organic acids, reducing sugars, minerals, flavors and pigment compounds) can also be leached into the osmotic solution, which affect the chemical, organoleptic, and nutritional characteristics of the product.

2. Materials and Methods

2.1. Source of Raw Materials

Materials were obtained from Ggaba market. The materials used for the work include sweet potato, salt (NaCl), distilled water, etc.

2.2. Sample Preparation

A whole potato was sliced into different thicknesses (2, 4 and 6 mm respectively) and Soaking solutions of different concentrations (10, 20 and 30% m/v respectively) were prepared.

2.3. Materials and Apparatus Used

Light yellow-fleshed, matured sweet potato, distilled (deionized) water, oven, stopwatch, Sodium Chloride (NaCl), soaking container, knife, sensitive weighing balance, flame photometer, etc.

Sweet potato: The potato used was light yellow-fleshed and matured. A wholesome and fresh potato was used for more accurate result.

Distilled water: Distilled water was used to avoid the presence of both non-detectable and detectable unwanted substances which may alter the result. Alternatively, deionized water may be used where distilled water is not readily available.

Stopwatch: Stopwatch was used to measure the amount of time elapsed from the point of soaking the potato slices to the required duration/time. It was used to measure soaking time.

Sodium Chloride (NaCl): The NaClwas used to effect the osmotic pre-treatment. The solution of NaCl was prepared to represent various desired levels of concentration.

Oven: The oven was used to oven-dry the samples after soaking to obtain wholesome and crispy potato slices. The drying temperature was slightly above the boiling point of water (104 to 106°C) to facilitate the process.

Soaking container: The soaking containers used should be those which do not react with the samples or the soaking solution. Containers made of stainless steel or plastic polymers are more convenient.

Knife: Knife made of stainless steel was used to peel and slice the sweet potato to the desired thickness. Any knife that may add unwanted substances to the samples was avoided.

Sensitive weighing balance: A weighing balance was used to measure out the required amount of salt (NaCl) needed to prepare different concentrations of the soaking solution.

Flame photometer: This was used to determine the calcium content of the oven-dried potato slices (mg/kg)

2.4. Procedure

The light yellow-fleshed, matured sweet potato was washed with distilled water. After which the knife was used to peel and slice the potato to the desired thickness of 2mm, 4mm, and 6mm respectively.

Salt (NaCl) solution, soaking solution, was prepared by incorporating known amount of NaCl into known volume of distilled water in the container (stainless or plastic container) to obtain different levels of soaking solution concentration (SSC); 10, 20, and 30% m/v.

The sliced potato of 2mm thickness were soaked in each of the soaking solution of various concentrations and allowed to stay for 20, 40, 80, and 100 minutes respectively. The same was repeated with sliced potato samples of 4mm and 6mm thickness respectively.

When the required time elapsed, the soaked potato samples were collected and dried via oven-drying.

At this stage, the calcium content of the potato slices (mg/kg) was determined by AAS, flame photometer.

2.5. Determination of Calcium Content

Sample preparation: The dried potato slices (1 kg each of the representatives) were ashed in a muffle furnace at temperature of about 570°C for 30 mins. Solutions of the ashes were made by properly stirring with little volumes of distilled water in a beaker respectively. When the suspended solids were present in sufficient amounts to clog the nebulizer, the sample was allowed to settle and the supernatant liquid analyzed directly.

Instrumental Parameters (General)

1. Calcium hollow cathode lamp
2. Wavelength: 422.7 nm
3. Fuel: Acetylene
4. Oxidant: Air
5. Type of flame used: Reducing

Notes

1. Phosphate, sulfate and aluminum interfere but are masked by the addition of lanthanum. Since low calcium values result if the pH of the sample is above 7, both standards and samples are prepared in dilute hydrochloric acid solution. Concentrations of magnesium greater than 1000 mg/1 also cause low calcium values. Concentrations of up to 500 mg/1 each of sodium, potassium and nitrate cause no interference.

2. Anionic chemical interferences can be expected if lanthanum is not used in samples and standards.

3. The nitrous oxide-acetylene flame will provide two to five times greater sensitivity and freedom from chemical interferences. Ionization interferences should be controlled by adding a large amount of alkali to the sample and standards. The analysis appears to be free from chemical suppressions in the nitrous oxide-acetylene flame.

4. The 239.9 nm line may also be used. This line has a relative sensitivity of 120.

The results obtained after AAS determination of calcium contents by checking absorbance against the concentration in a standard curve are reported below.

3. Results

The data generated are shown in Table 1.

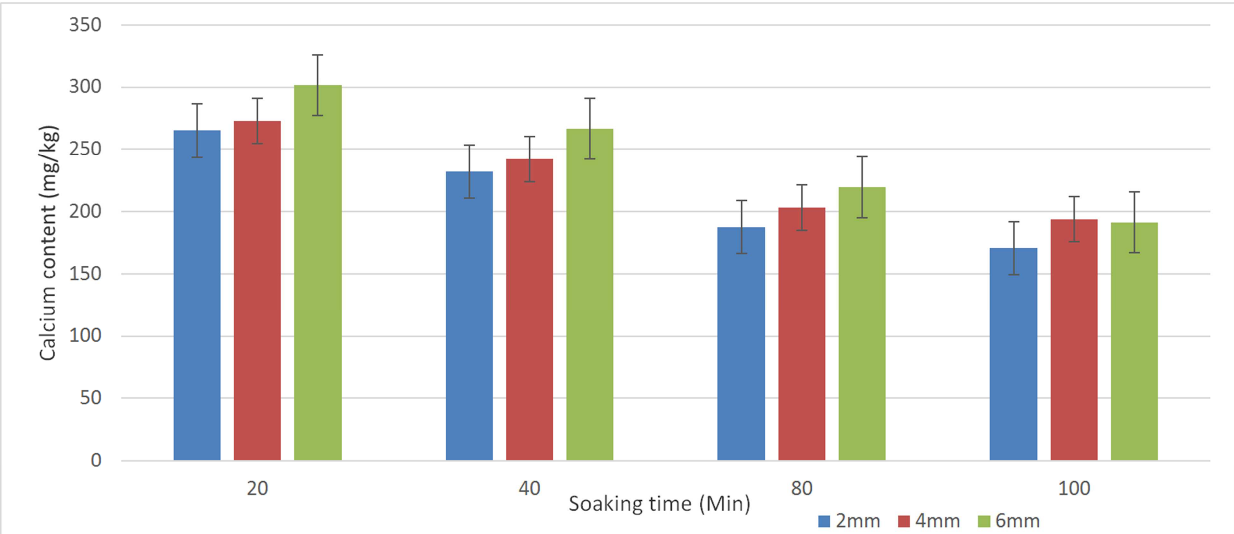

Figure 1. *Showing the variation in the calcium contents of sweet potato slices of different thicknesses soaked in 10%m/v of salt concentration with time.*

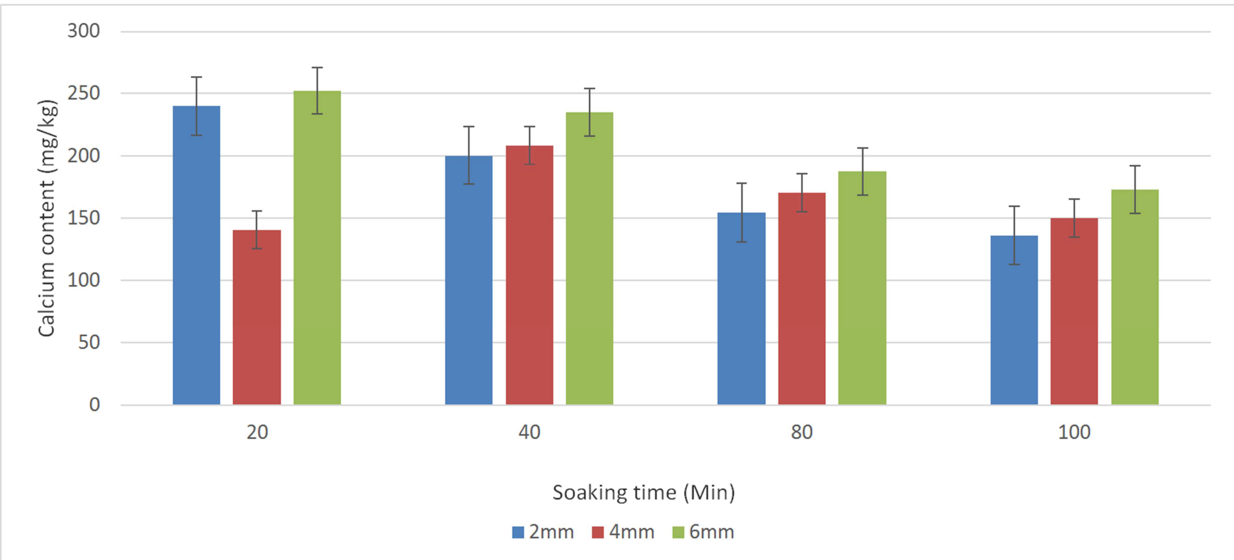

Figure 2. *Showing variation in the calcium contents of sweet potato slices of different thicknesses soaked in 20%m/v of salt concentration with time.*

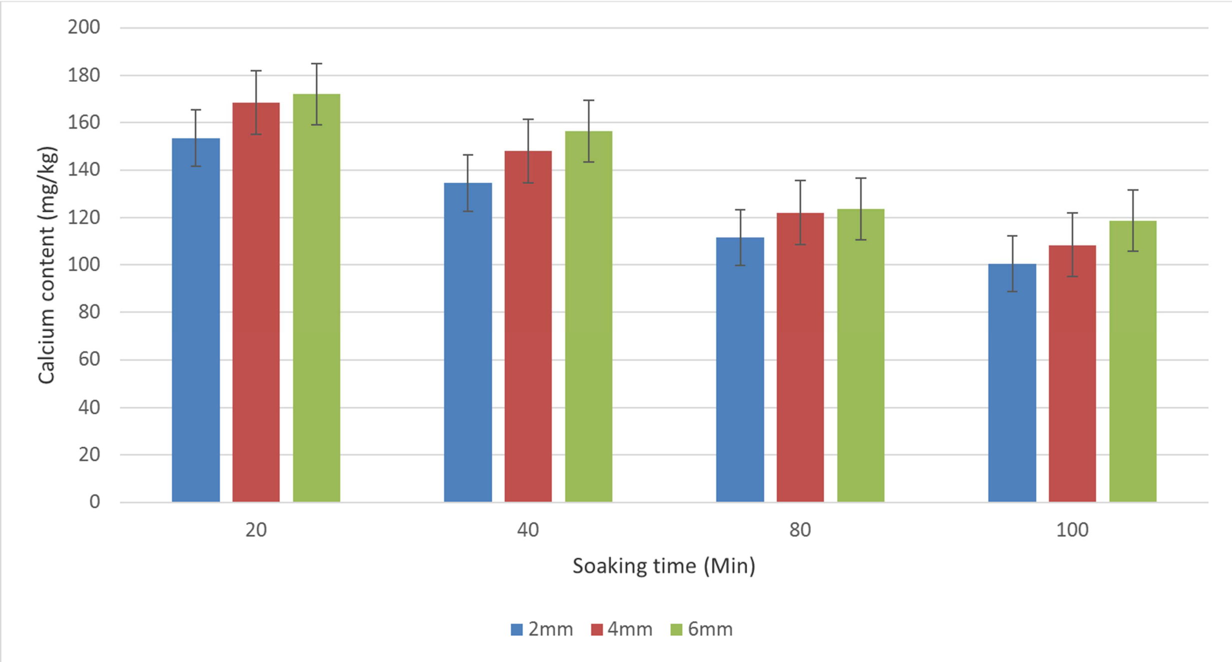

Figure 3. *Showing the variation in the calcium contents of sweet potato slices of different thicknesses soaked in 30%m/v of salt concentration with time.*

Table 1. *Calcium content of potato slices (mg/kg).*

Potato Slice Thickness, x (mm) Thickness, S (mm)	Soaking Solution Conc, C (% m/v)	Time of soaking, t (min)			
		20	40	80	100
	10	265.0	232.0	187.5	170.5
2	20	240.0	200.5	154.5	136.0
	30	153.5	134.5	111.5	100.5
	10	273.0	242.0	203.5	194.0
4	20	140.5	208.5	170.5	150.0
	30	168.5	148.0	122.0	108.5
	10	301.5	266.5	219.5	191.5
6	20	252.5	235.0	187.5	173.0
	30	172.0	156.5	123.5	118.5

4. Discussion

As seen in Table 1, when a potato slice thickness of 2mm was soaked in a 10% m/v of soaking solution for 20 minutes, the calcium content was found to be 265.0 mg/kg. When the time was extended to 40 minutes, the calcium content was 232.0 mg/kg. Extensions in soaking time to 80 minutes and 100 minutes resulted into calcium contents of 187.5mg/kg and 170.5mg/kg respectively.

When a potato slice thickness of 2mm was soaked in a 20% m/v of soaking solution for 20 minutes, the calcium content was found to be 240.0 mg/kg. When the time was extended to 40 minutes, the calcium content was 200.5mg/kg. Extension in soaking time to 80 and 100 minutes resulted into calcium contents of 154.5mg/kg and 136.0 mg/kg respectively.

When a potato slice thickness of 2mm was soaked in a 30% m/v of soaking solution for 20 minutes, the calcium content was found to be 153.5 mg/kg. When the time was extended to 40 minutes, the calcium content was 134.5mg/kg. Extending the soaking time to 80 and 100 minutes resulted into calcium contents of 111.5mg/kg and 100.5 mg/kg respectively. The longer the duration of soaking time, the lesser calcium content was found.

When a potato slice thickness of 4mm was soaked in a 10% m/v of soaking solution for 20 minutes, the calcium content was found to be 273.0 mg/kg. When the time was extended to 40 minutes, the calcium content was 242mg/kg. Extentions in soaking time to 80 minutes and 100 minutes resulted into calcium contents of 203.5mg/kg and 194.0mg/kg respectively.

When a potato slice thickness of 4mm was soaked in a 20% m/v of soaking solution for 20 minutes, the calcium content was found to be 140.5 mg/kg. When the time was extended to 40 minutes, the calcium content was 208.5. Extentions in soaking time to 80 minutes and 100 minutes resulted into calcium contents of 170.5mg/kg and 150.0mg/kg respectively.

When a potato slice thickness of 4mm was soaked in a 30% m/v of soaking solution for 20 minutes, the calcium content was found to be 168.5 mg/kg. When the time was extended to 40 minutes, the calcium content was 148.0mg/kg. Extensions in soaking time to 80 minutes and 100 minutes resulted into calcium contents of 122.0mg/kg and 108.5mg/kg respectively. The longer the 4mm potato slice was soaked, the less calcium content was found.

When a potato slice thickness of 6mm was soaked in a 10% m/v of soaking solution for 20 minutes, the calcium content was found to be 301.5 mg/kg. When the time was extended to 40 minutes, the calcium content was 266.5mg/kg. Extensions in soaking time to 80 minutes and 100 minutes resulted into calcium contents of 219.5mg/kg and 191.5mg/kg respectively.

When a potato slice thickness of 6mm was soaked in a 20% m/v of soaking solution for 20 minutes, the calcium content was found to be 252.5 mg/kg. When the time was extended to 40 minutes, the calcium content was 235.0mg/kg. Extensions in soaking time to 80 minutes and 100 minutes resulted into calcium contents of 187.5mg/kg and 173.0mg/kg respectively.

When a potato slice thickness of 6mm was soaked in a 30% m/v of soaking solution for 20 minutes, the calcium content was found to be 172.0 mg/kg. When the time was extended to 40 minutes, the calcium content was 156.5mg/kg. Extensions in soaking time to 80 minutes and 100 minutes resulted into calcium contents of 123.5mg/kg and 118.5mg/kg respectively. The longer the 6mm potato slice was soaked, the less calcium content was found.

Given the various soaking solution concentrations and time of soaking, it was found out that the 6mm potato slice contained much more calcium than any of the other thicknesses. As can be seen in Table 1, the thicker the potato slices, the higher the level of calcium retained. With regards to the soaking time, it was found out that a duration of 20 minutes would produce a potato product of a higher calcium content than when the other durations were considered. Referring to the soaking solution concentration, the 10% m/v of the soaking solution was found out to produce a potato product of a higher calcium content than when the other concentrations were considered.

Statement of the problem: The data for calcium content of potato slices (mg/kg) were fitted in a PST × SSC × TS (i.e. A(3) × B(3) × C(4)) factorial design as shown in table 2.

NOTE: PST – Potato Slice Thickness: SSC – Soaking Solution Concentration: and TS – Time of Soaking.

Table 2. *Calculation of totals, means, and SD for PST, SSC and TS.*

A (PST) (mm)	B (SSC)% m/v	C (TS), t (min)				TOTAL	MEAN ± SD
		20	40	80	100		
$a_1 = 2$	$b_1 = 10$	265.00	232.00	187.50	170.50	855.00	173.83 ± 50.00
	$b_2 = 20$	240.00	200.50	154.50	136.00	731.00	
	$b_3 = 30$	153.50	134.50	111.50	100.50	500.00	
	TOTAL	658.50	567.00	453.50	407.00	2086.00	
$a_2 = 4$	$b_1 = 10$	273.00	242.00	203.50	194.00	912.50	177.42 ± 46.69
	$b_2 = 20$	140.50	208.50	170.50	150.00	669.50	
	$b_3 = 30$	168.50	148.00	122.00	108.50	547.00	
	TOTAL	582.00	598.50	496.00	452.50	2129.00	
$a_3 = 6$	$b_1 = 10$	301.50	266.50	219.50	191.50	979.00	199.79 ± 54.17
	$b_2 = 20$	252.50	235.00	187.50	173.00	848.00	
	$b_3 = 30$	172.00	156.50	123.50	118.50	570.50	
	TOTAL	726.00	658.00	530.50	483.00	2397.50	
TOTAL	$b_1 = 10$	839.50	740.50	610.50	556.00	2746.50	228.88 ± 39.36
	$b_2 = 20$	633.00	644.00	512.50	459.50	2248.50	187.38 ± 38.41
	$b_3 = 30$	494.00	439.00	357.00	327.50	1617.50	134.79 ± 23.24
	TOTAL	1966.50	1823.50	1480.00	1342.50	6612.50	183.68 ± 51.68
	MEAN± SD	218.50± 56.38	202.28± 43.65	164.44± 36.57	149.17± 33.27		

The data were subjected to three-way ANOVA after which advice were given to the processor as per PST, SSC and TS to be adopted and why, at 95% level of confidence.

Table 3. *ANOVA table.*

Source of Variation	DF (n-1)	SS	MS	F_{cal}	F_{tab} (5%)
PST (A)	2	4749.2635	2374.6318	8.0389	3.8900
SSC (B)	2	53355.7218	26677.8609	90.3137	3.8900
TS (C)	3	28187.9649	9395.9883	31.8086	3.4900
A×B	4	1931.5282	482.8821	1.6347	3.2600
A×C	6	2101.8476	350.3079	1.1859	3.0000
B×C	6	2259.0560	376.5093	1.2746	3.0000
Error	12	3544.6940	295.3912		
Total	35	96130.0760			

$$\text{CF} = \left(\sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{k=1}^{c} \text{yijk}\right)^2 / n_A \times n_B \times n_C = T^2 / n_A \times n_B \times n_C = 1{,}214{,}587.6740$$

$n_A = 3$, $n_B = 3$, $n_C = 4$, $n_A \times n_B \times n_C = 36$, $n_A \times n_B = 9$, $n_A \times n_C = 12$, $n_B \times n_C = 12$

$$\text{SST} = \left(\sum_{i=1}^{3}\sum_{j=1}^{3}\sum_{k=1}^{4} \text{yijk}\right)^2 - \text{CF}$$

$$\text{SSA} = \sum_{i=1}^{3} T^2{}_i / n_B \times n_C - \text{CF}$$

$$SSB = \sum_{K=1}^{3} T^2{}_k / n_A \times n_C - CF$$

$$SSC = \sum_{J=1}^{4} T^2{}_j / n_A \times n_B - CF$$

$$SS\ (A \times B) = \sum_{i=1}^{3} \sum_{k=1}^{3} T^2{}_{ik} / n_C - SSA - SSC - CF$$

$$SS\ (A \times C) = \sum_{i=1}^{3} \sum_{j=1}^{4} T^2{}_{iJ} / n_C - SSA - SSC - CF$$

$$SS\ (B \times C) = \sum_{k=1}^{3} \sum_{j=1}^{4} T^2{}_{ik} / n_C - SSB - SSC - CF$$

$$SSE = SST - SSA - SSB - SSC - SS\ (A\times B) - SS\ (A\times C) - SS\ (B\times C)$$

For PST (mm), SSC (% m/v), and TS (min), F_{cal} is greater than F_{tab}

The variation in residual calcium content (mg.kg db) of potato slices due to A, B, and C are very highly significant.

The means will be separated using Fisher's LSD procedure for multiple comparison test:

$$LSD\ (CCV)_{0.05} = LSD(DF_E)_{0.05} = t(DF_E) \times \sqrt{(2 \times MSE / n_A \times n_B \times n_C)}$$

$$LSD\ (A, PST) = t(12)_{0.05} \times \sqrt{(2 \times MSE / n_B \times n_C) = 2.179 \times \sqrt{(2 \times 295.3912/12)}}$$

LSD (A) = 15.2891

$$LSD\ (B, SSC) = t(12)_{0.05} \times \sqrt{(2 \times MSE / n_A \times n_C) = 2.179 \times \sqrt{(2 \times 295.3912/12)}}$$

LSD (B) = 15.2891

$$LSD\ (C, TS) = t(12)_{0.05} \times \sqrt{(2 \times MSE / n_A \times n_B) = 2.179 \times \sqrt{(2 \times 295.3912/9)}}$$

LSD (C) = 17.6543

Table 4. *Separation of the means.*

A (PST), mm	
$a_1 = 2$	173.83 ± 50.00^a
$a_2 = 4$	177.42 ± 46.69^a
$a_3 = 6$	199.79 ± 54.17^b
LSD(p = 0.05)	15.2891
B (SSC)% m/v	
$b_1 = 10$	228.88 ± 39.36^a
$b_2 = 20$	187.38 ± 38.41^b
$b_3 = 30$	134.79 ± 23.24^c
LSD(p = 0.05)	15.2891
C (TS), min	
$c_1 = 20$	218.50 ± 56.38^a
$c_2 = 40$	202.28 ± 43.65^b
$c_3 = 80$	164.44 ± 36.57^c
$c_4 = 100$	149.17 ± 33.27^c
LSD (p = 0.05)	17.6543

4.1. Advice to Processors and Industrial Chemists

1. Potato slices of about 6mm thickness should be adopted since it yields potato products with relative higher calcium content than 2 mm and 4 mm thickness.
2. The concentration of the salt solution should be adjusted to 10% m/v strength, as it results to products with relatively higher calcium content. Where SSC of 10% m/v couldn't give product with required texture, 20% m/v could be alternative.
3. Time of soaking should be within 20 – 40 minutes since the calcium content of the product is improved within this resident duration.

4.2. What Processors Should Do

Generally, to ensure potato products with more conserved calcium content (and, perhaps, other significant elements and compounds), potato slice thickness of 6 mm, salt solution concentration of about 10 to 20% m/v, and soaking time within 20 – 40 minutes should be adopted during pretreatment processing.

5. Conclusion

During pretreatment for drying process, sweet potatoes are subjected to pretreatment techniques, like osmotic pretreatment with salt (NaCl) solution, to improve the sensory and keeping qualities of the potato products. Most local and traditionally processed fried/dried potato chips sellers soak sliced potato in salt solution for considerable duration as pretreatment step prior to frying/drying. These pretreatment techniques usually affect the nutritional value of the end products.

Water removal during osmotic treatment is based on the natural and non-destructive phenomenon of osmosis across cell membranes. The driving force for the diffusion of water from the tissue into the solution is provided by the higher osmotic pressure of the hyper-tonic solution, such as salt solution. The diffusion of water is accompanied by the simultaneous counter diffusion of solutes from the osmotic solution into the tissue. Since the cell membrane responsible for osmotic transport is not perfectly selective, solutes present in the cells (organic acids, reducing sugars, minerals, flavors and pigment compounds) can also be leached into the osmotic solution, which affect the organoleptic and nutritional characteristics of the product.

However, to ensure potato products with more conserved nutrients (calcium) and required texture, potato slice thickness of 6 mm, salt solution concentration of about 10 to 20% m/v, and soaking time within 20 – 40 minutes should be adopted during the pretreatment process.

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