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# Effects of the Functional Properties of Corn, Cassava and Potato Starches on the Physical, Sensory and Whey Separation Properties of Soy Yoghurt

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**Abstract**
Yoghurt is a probiotic food produced from the action of acid-forming bacteria on milk and consumed due to its many nutritional and health benefits. Stabilizers play a key role in yoghurt production. Starch stabilizers were produced from a yellow variety of maize grains, TMS 419 cassava roots and orange-flesh potatoes. Soymilk was processed from soybeans using the hot water extraction method at the ratio of 250 g:1 litre. Three different yoghurt samples were produced from the soymilk fermentation at 44°C for 10 hours using the stabilizers without flavour. The corn-stabilized, cassava-stabilized and potato-stabilized yoghurts were coded XOX, YOY and ZOZ respectively. The functional properties of the starches and their effects on the physical, sensory and whey separation properties of soy yoghurts were evaluated. There was variation in the evaluated functional properties of the starches with cassava starch standing out. There was a significant difference ($p<0.05$) in the physical properties of the soy yoghurt samples. The cassava-stabilized soy yoghurt had the highest acidity (4.66 pH) and total solid content (18.03%) but the least titratable acidity value (0.42%). The potato-stabilized yoghurt was the least acidic (4.92 pH) but had the highest total titratable acidity value (0.51%). The corn-stabilized yoghurt had the least total solid content (17.49%). ZOZ had the highest score for all the sensory parameters evaluated, followed by XOX. No significant difference existed ($p>0.05$) in their appearance, mouthfeel and sweetness, while significant difference existed in their sourness, texture, after-taste and general acceptability. ZOZ had the highest acceptability of $7.95 \pm 1.10$, followed by XOX with $6.65 \pm 1.53$. YOY did not exhibit syneresis while XOX and ZOZ separated at the serum: water ratio of 70:40ml and 70:30ml, respectively. This research upholds that cassava starch is a reliable stabilizer in soy-yoghurt production.

***Keywords: Soy yoghurt, functional foods, probiotic, lactic acid, starches***

## Introduction

Yoghurt is made by adding a culture of acid-forming bacteria to milk that is usually homogenized, pasteurized and fermented (Olakunle, 2012; Kamble and Kokate, 2015). A sufficient quantity of lactic acid is produced when the milk coagulates and this coagulated milk is called yoghurt (Aswal *et al*., 2012). Fermented products are a significant part of many indigenous diets (Opara *et al*., 2013). Yoghurt is the most fermented milk product worldwide; it originated from countries around the Mediterranean Sea and the Balkans (Staff, 1998) and by the early nomadic herdsman, especially in Asia, Southern and Eastern Europe (Opara *et al*., 2013). Yoghurt is a product of lactic acid fermentation of milk by the action of a starter culture containing *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* (Da Silva *et al*., 2013; Opara *et al*., 2013; Chipurura *et al*., 2014; Ersan and Kurdal, 2014; Trikoomdun and Leenanon, 2016; Jayeola *et al*., 2010) with a final pH value of 3.8-4.6. The product is then cooled to 5°C for packaging. Yoghurt is characterized as a smooth viscous gel with a specific taste of sharp acid and green apple flavour (Hossain *et al*., 2012) and a typical flavour (sour taste) which is attributable to the production of lactic acids, acetaldehyde, acetic acid and diacetyl from carbohydrate by fermenting organisms (Jayeola *et al*., 2010).

Yoghurt is an increasingly popular cultured dairy product in most countries (Matter *et al*., 2016). Yoghurt is considered a healthy food because of its benefits, including high protein and calcium content (Mckinley, 2005), improves nutrient absorption and digestion, restores the balance of bacteria in the gut to hinder constipation, abdominal cramps, asthma, allergies, lactose and gluten intolerance (Abdel and Darclir, 2009); lowers blood pressure, provides immunity and strengthens body's defence mechanism, etcetera (Aswal *et al*., 2012). Van de Water and Naiyanetra (2008) buttressed the health-promoting properties of live lactic acid bacteria (LAB) in yoghurt to include: protection against gastrointestinal upsets; enhanced digestion of lactose by maldigestion; decreased risk of cancer; lowering of blood cholesterol; improvement of immune response and helping the body to assimilate protein, calcium and Iron. The high nutrient value of yoghurt makes it prone to microbial spoilage. However, the lactic acid formed during fermentation confers a preservative effect (Ezeonu *et al*., 2016). The flavour, texture and aroma of yoghurt vary depending on the country of origin as well as other factors including raw materials formulation and production process. Whether produced from raw or fabricated milk, yoghurt has similar physical, chemical, sensory, and microbiological properties. These properties are essential and must be preserved during storage. (Igbabul *et al*., 2014).

The use of raw cow milk in yoghurt manufacture comes with the risk of having high bacteria count, antibiotics, sanitizing chemicals, mastitis, milk colostrums and bacteriophage contamination (Haj *et al*., 2007). There is a need to utilize another alternative with lesser risk for yoghurt production. The animal fat and cholesterol from the milk of animal sources used in dairy products have both been linked with modern diseases of affluence which include: type 2 diabetes, asthma, coronary heart disease, cerebrovascular disease, obesity, hypertension, cancer and many others (Igbabul *et al*., 2014). Some researchers have therefore produced yoghurt with different types of raw materials other than cow milk including corn supplemented with probiotics (Trikoomdun and Leenanon, 2016); goat milk with a water-soluble soy extract (Da Silva *et al*., 2013); soybeans (Olakunle, 2012); coconut-cake (Ndife *et al*., 2014); commercial probiotic culture (Ersan and Kurdal, 2014); baobab pulp (Chipurura *et al*., 2014); cocoa powder (Jayeola *et al*., 2010). Yoghurt has also been produced using different fruit pulps of papaya and cactus pear (Matter *et al*., 2016). Opara *et al.* (2013) produced soy yoghurt by fermentation of soymilk with *Lactobacillus* isolated from nunu (a Nigerian indigenous fermented cow milk), while Kamble and Kokate (2015) produced fruit yoghurt using apple, pineapple, strawberry, grapes and pomegranates with a mixture of buffalo and cow milk. Olorunnisomo *et al.* (2015) compared the influence of corn starch, milk powder and baobab fruit pulp as stabilizers in yoghurt made from zebu milk. Their findings showed that corn starch stabilizer decreased the yoghurt's fats and protein content, and improved its sensory acceptance though with a coliform count range of $0.1\text{-}2.4'10^2$. The viscosity of yoghurt is almost wholly dependent on the protein content of the constituent milk (Penna *et al*., 2006). The viscosity of soy yoghurt competes favourably with the viscosity of yoghurt from cow milk due to their very close protein contents (Gandhi *et al*., 2008).

Potato has a vast potential to improve food security and income generation (Okonkwo *et al*., 2008). It has high vitamin, mineral and energy content than most carbohydrate foods. It is a nutritional staple food that is rich in B-carotenes, vitamin $B_2$ and vitamin C (Iheagwara and Umunnakwe, 2006). Its protein is of high quality, while its carbohydrate is easily digestible. It is also a good source of Iron. Of all the industrial products that can be obtained from potatoes, potato starch is the most prominent. Potato contains 20% starch. The starch may be further modified chemically or physically to suit food applications. Maize has been used to manufacture different products such as flour, grits and starch, breakfast cereals, weaning foods or animal feeds (Enwere, 1998; Marija *et al*., 2018). Research shows that maize grains contain 65-84% starch, 12-15% moisture, 9-10% protein, 3-5% fat, 3% ash, 2-3% fibre and 410 calories of energy. Cassava starch has many remarkable characteristics, including high paste viscosity and clarity as well as high freeze-thaw stability (Nwokocha *et al*., 2009). Therefore, the main objective of this research work was to determine the effects of corn starch, cassava starch and potato starch on the physical, microbial and whey separation properties of soy yoghurt. While the specific objectives were: (i) to produce starch from corn, fresh cassava root and orange flesh potato, (ii) to produce soymilk from soybeans, (iii) to produce three different samples of soy yoghurt from the soymilk, stabilize the samples with the earlier corn, cassava and potato starches respectively, (iv) to determine the effects of the starches on the physical, microbial and whey separation properties of the soy yoghurt samples, and (v) to determine the sensory attributes of the soy yoghurt samples.

## *Materials and Methods*

### *Collection of Raw Materials*

Fresh cassava roots (TMS 419) and orange flesh potatoes were obtained from the National Root Crops Research Institute, Umudike, while dried yellow maize grains, soybean (*Glycine max*), glucose D (sweetener), sodium bicarbonate and freeze-dried yogourmet starter culture were obtained from Ubani Main Market, all in Umuahia, Abia State, Nigeria. All reagents used were of analytical grade from Oxoid Ltd, Hampshire, England. The processing activities were carried out in the Food Processing Laboratory of the Department of Food Science and Technology, Michael Okpara University of Agriculture Umudike, Abia State, Nigeria.

### *Production of Cassava, Maize and Potato Starch*

The method of Abbas *et al.* (2010) was modified and used to produce cassava starch, maize starch and potato starch. The fresh cassava roots were peeled, washed and finely grated into a slurry state using Nissan Diesel Engine model S50. The starch was filtered from the fibre and then collected by sedimentation after 1 hour. The wet starch was then drained and dried overnight in an electric oven at 85°C until adequately dried. The hard starch cake was crushed manually with a rolling pin before sieving with a 350μm sieve and packaged in high-density polyethene material.

Maize grains were sorted, washed and soaked in clean water for about 4 hours to soften the endosperm. The soaking water was changed at each hour interval. This was to avoid impacting any undesirable odour to the eventual starch to be obtained. The soaked grains were then wet-milled into a slurry and sieved using a muslin cloth to remove the fibre and retain the starch. The starch was allowed to settle for 1 hour and the supernatant was decanted. The wet starch was then drained and dried overnight in an electric oven at 85°C until adequately dried. The hard starch cake was crushed manually with a rolling pin before sieving with a 350µm sieve and packaging in high-density polyethene material. The potato roots were sorted, washed to remove sand particles, peeled, washed again, and manually shredded into tiny uniform sizes before grating using Nissan Diesel Engine model S50. The starch was filtered from the fibre by sieving with a muslin cloth. The mixture was allowed to sediment for 1 hour, after which the supernatant was discarded. The wet starch was then drained and dried overnight in an electric oven at 85°C until adequately dried. The potato starch cakes were crushed manually with a rolling pin before sieving with a 350µm sieve and packaged in high-density polyethene material.

***Production of Soymilk***

The method of Olorunnisomo *et al.* (2015) was slightly modified and used *to produce* plain soymilk. 1.5kg of soybean was used to obtain 6 litres of soymilk at a soybean: water ratio of 1:4. Hot extraction method was used in soymilk production. The soybeans (1.5kg) were sorted, cleaned, transferred directly into boiling water containing 0.5% sodium bicarbonate and boiled for 10 minutes. It was then manually dehulled and wet-milled with 6 litres of hot water using a Kenwood BL 440 electric blender. Little quantity was blended at a time to achieve thorough blending so as to enhance milk extraction. The slurry was sieved using a double-folded muslin cloth. The mashy residue called okara was discarded while the soymilk (filtrate) was pasteurized for 20 minutes at 85°C. It was then cooled immediately to 45°C and transferred into a sterilized container.

***Production of Soy Yoghurt***

The method of Belewu (2005) was adopted with slight modifications in the production of soy yoghurt. Pasteurized soymilk was divided into three portions of 2 litres each. Each portion was used to produce soy yoghurt using the earlier produced maize, cassava and potato stabilizers. The soy yoghurts stabilized with corn starch, cassava starch and potato starch were coded as XOX, YOY and ZOZ respectively. For each sample, 60g of sweetener (Glucose D), which equals 10% of the soymilk, was gradually dissolved into the soymilk by first dissolving some portion of the sweetener with some quantity of the soymilk at a time in a beaker before carefully transferring it into the entire lot (soymilk) in the container. Then, the same step was taken in mixing 2g of the stabilizers, which equals 1% of the soymilk, into their respective soymilk samples (XOX, YOY and ZOZ). The soymilk samples were separately and thoroughly homogenized by blending at a higher speed using the electric blender. The homogenization was to help break down the globules, which will enable the starter culture to effect a thorough fermentation process. The homogenized soymilk samples were pasteurized at 81°C for 20 minutes before cooling to 42°C. The manufacturer's guideline was adhered to in inoculating the starter culture. Yogourmet (freeze-dried yoghurt starter culture) was used. 10g (2 sachets) of the starter culture was dissolved in each homogenized 2 litres of soymilk using the same method used in dissolving the sweetener. The sample in each container was carefully and thoroughly shaken to mix very well. It was covered very well and incubated at 44°C for 8 hours to allow fermentation to take place, after which it was refrigerated to stop the fermentation process.

***Functional Analysis of the Starch Stabilizers***

***Water Absorption Capacity***

The method described by Onwuka (2018) was used in determining the water absorption capacity of the stabilizers used. One gram (1g) of the sample was weighed (W) into a graduated 15ml centrifuge tube and 10ml distilled water was added. The sample was later mixed thoroughly and allowed to stand for 30 minutes at room temperature before centrifuging at 2000rpm for 30 minutes. The volume of free water (the supernatant) was read directly from the graduated centrifuge tube. Water and oil absorption capacity was calculated as:

$$\text{WAC} = 1 + \frac{(V1 - V2)}{W} \text{ml/g}$$

Where: $V_1$ = Initial volume of water before centrifugation (ml), $V_2$ = Final volume of water after centrifugation (ml), W = Weight of sample (g)

***Gelation Temperature***

The method described by Onwuka (2018) was employed in determining the gelation temperature of the starches. The mixture was heated in a boiling bath with continuous stirring. The temperature was recorded 30 seconds after gelation was noticed.

***Bulk Density***

The method of Onwuka (2005) was also used. 10.0g of flour sample was weighed into a graduated cylinder and its volume was recorded. After then, the bottom of the cylinder was tapped gently at the top of the laboratory table several times until there was no further diminution of the sample level after filling to the 10ml mark. Bulk density was then determined as:

$$\text{Bulk density (g/ml)} = \frac{\text{weight of the sample (g)}}{\text{volume of the sample (ml)}}$$

***Determination of Total Solids***

The Total Solid was determined as described by AOAC (2005). 3.0g of the sample was weighed into a dry Petri dish of known weight (W). The total portion was pre-dried for 25 minutes in a steam bath and then dried for 3 hours at 100°C in a forced draft air oven. The Total Solid sample is the weight of the dried sample residue and was calculated as follows:

$$\% \text{ Total Solid} = \frac{W2 - W1}{W1 - W} \times 100$$

Where: W = Weight of the dish (g), $W_1$ = Weight of dish and sample test portion (g), $W_2$ = Weight of dish and dry sample(g).

***Whey Separation Analysis***

The whey separation potential of the soy yoghurt samples was determined using the gravity separation method of Ahmed and Sahar (2014). One hundred millilitres of each sample were poured into a graduated measuring cylinder and placed on an undisturbed shelf at room temperature. Separation of the serum fluid from the gel matrix was visually measured for a period of 5 days.

***Sensory Evaluation***

Sensory Evaluation was carried out according to the method described by Iwe (2002) using a nine-point hedonic scale. 9 represents the highest score (Like Extremely), while 1 represents the lowest score (Dislike Extremely). Three coded soy yoghurt samples were served to 20 semi-trained panelists who were randomly selected students of the Department of Food Science and Technology, Michael Okpara University of Agriculture Umudike. The panellists were instructed to independently indicate their level of preference for the samples evaluated. The sensory attributes of the soy yoghurt samples evaluated were colour, mouthfeel, sweetness, sour, after-taste, texture and general acceptability.

***Determination of pH and Titratable Acidity***

A Hanna digital pH meter was used. The meter was switched on and allowed to equilibrate for about 15 minutes and calibrated with pH 4.0 and pH 7.0 buffer solutions before the measurement. The pH meter's electrode was rinsed with distilled water. The electrode and temperature probe was dipped into each soy yoghurt sample and was allowed to display. The displayed pH value for each sample was recorded.

Titratable acidity (TA) of the samples was evaluated by titration using 0.1N sodium hydroxide, as listed for yoghurt in the Standard Methods for the Examination of Dairy Products (Chukwuma et al., 2016). The first permanent pink colour obtained indicated the endpoint. The titratable acidity was expressed as per cent lactic acid.

***Statistical Analysis***

Data obtained were expressed as the mean ± standard deviation (SD). The data obtained were subjected to Analysis of Variance (ANOVA) using SPSS software version 15, while mean treatments were separated using Duncan Multiple Range Test (DMRT) at a 95% confidence level ($p>0.05$). A Completely Randomized Design (CRD) was adopted as the experimental design for the study, as illustrated by Hinkelmann and Kempthrone (2008).

**Results and Discussion**

The results of the functional properties of starches used for soy yoghurt stabilization are presented in Table 1. Based on the result, the bulk density of the starch samples ranged from 0.63 in potato starch to 0.68 in corn starch. Cassava starch had a bulk density of 0.65. There was a significant difference ($p<0.05$) between corn starch and the other two samples. Cassava starch and potato starch showed no significant difference ($p>0.05$). The water absorption capacity (WAC) of the starches ranged from 1.62 in potato starch to 1.75 in corn starch. The WAC value for cassava starch was 1.74. There was no significant difference ($p>0.05$) between corn starch and cassava starch, while there was a significant difference ($p<0.05$) between potato starch and the other two starch samples. The water absorption capacity in commercial starches is vital to some food products' quality and texture because it stabilizes them against effects such as syneresis. The oil absorption capacity (OAC) of the starches ranged from 0.99 in potato starch to 1.13 in cassava starch. Corn starch had an OAC of 1.02. The OAC value for cassava starch was significantly different ($p<0.05$) from corn starch and potato starch. There was no significant difference ($p>0.05$) between corn starch and potato starch. Oil absorption capacity is attributed mainly to the physical entrapment of oils. It indicates the rate at which the proteins bind to fat in food formulations (Singh *et al*., 2005). Potato starch had the highest gelation temperature of 70$^{o}$C, followed by corn starch at 66.5$^{o}$C, while cassava starch had the lowest gelation temperature value of 64.00. There was a significant difference ($p<0.05$) in the gelation temperature values among the samples. The pH values of the samples range from 6.03 to 6.22. Cassava starch had the highest pH value of 6.22, followed by corn starch with 6.11, while potato starch had the lowest value of 6.03. Cassava starch was significantly different ($p<0.05$) from corn starch and potato starch but corn starch and potato starch did not show any significant difference ($p>0.05$) between themselves. The solubility index (SI) values of the samples range from 0.81 in corn starch to 1.26 in cassava starch, while potato starch had a SI value of 1.11. There was a significant difference ($p<0.05$) in the SI values among the starch samples. The solubility power (SP) values of the samples range from 9.25 to 10.55. It followed the same trend obtained under the SI parameter. Cassava starch had the highest SP value of 10.55, followed by potato starch with 9.85, while corn starch had the lowest value of 9.25. There was a significant difference ($p<0.05$) in the SP values among the samples. The functional properties of starch stabilizers play a key role in the physical, sensory and whey separation properties of yoghurts produced using them.

The results of the physical properties of soy yoghurt samples stabilized with corn, cassava and potato starch stabilizers are presented in Table 2.

From the result, the total titratable acidity of the samples ranged from 0.42% in cassava-stabilized soy yoghurt to

0.51% in potato-stabilized soy yoghurt. Corn-stabilized soy yoghurt had a total titratable acidity level of 0.47%. There was a significant difference ($p<0.05$) between the soy yoghurt samples. The total solids of the soy yoghurt samples ranged from 17.49% in corn-stabilized soy yoghurt to 18.03% in cassava-stabilized soy yoghurt. Potato-stabilized soy yoghurt had a total solid content of 17.87%. There was a significant difference ($p<0.05$) between the three samples. Muhammed *et al*. (2005) had earlier reported a closer total solid of 17.11%. The result of the pH of the different soy yoghurt samples indicates that there was a significant difference ($p<0.05$) in the acidic level among the three soy yoghurt samples. Cassava-stabilized soy yoghurt has the highest acidic value of 4.66, followed by corn-stabilized soy yoghurt with 4.86, while potato-stabilized soy yoghurt has the most negligible acidic value of 4.92. Sample ZOZ had the highest pH and TTA values and this can be related it its starch stabilizer having the highest gelation temperature value but least values for bulk density, OAC and WAC. Elsayed *et al.* (2020) in their research obtained the values (TS: 20.64% - 21.99%; pH: 3.94 - 4.68; TTA: 0.65-1.14). The TS and TTA values were lower than that of Elsayed *et al.* (2020) but our pH value was slightly higher than theirs. However, the difference is that Elsayed *et al.* (2020) flavoured their yoghurt samples with fruits and stored at -5°C for up to 21 days. These values were closely related to what Abdel-Galeele *et al.* (2013) obtained.

The result of the sensory analysis of soy yoghurt samples is presented in Table 3. The result showed no significant difference in the appearance of the samples ($P>0.05$). However, potato-stabilized soy yoghurt had the highest mean score of 7.50, followed by corn-stabilized soy yoghurt (7.05) and then cassava-stabilized soy yoghurt (6.90). The lack of significant difference in the appearance of the samples showed that the percentage of the starch stabilizers used (1%) could not alter the appearance of the finished product although some of the starches (corn and potato starches) contained some colour pigments. The preference in terms of appearance decreased from potato-stabilized soy yoghurt to corn-stabilized soy yoghurt and then cassava-stabilized soy yoghurt. This also reveals that the more the colour pigment in the stabilizer, the creamier the appearance of the yoghurt and hence, its consumer acceptability based on appearance. The result of the mouthfeel also followed the same trend of appearance. There was no significant difference in mouthfeel among the three samples. Their mean scores also increased from cassava-stabilized soy yoghurt (6.30) to corn-stabilized soy yoghurt (6.35), while potato-stabilized soy yoghurt had the highest mean score of 6.85. This result showed that the stabilizers used for the soy yoghurt played their role very well in binding the constituents of the product. Oladipo *et al*. (2014) hinted that fat content imparts both flavour and mouthfeel. In terms of sweetness, potato-stabilized soy yoghurt had the highest mean score of 6.25, followed by corn-stabilized soy yoghurt with 6.05, while cassava-stabilized soy yoghurt had the least mean score of 5.50. Though there was no significant difference among them ($p>0.05$), the slight variation in their mean scores could be attributed to the carbohydrate composition of each of the stabilizers used. This is because it constitutes another source of sweetening to the product. In terms of the sourness of the products, it was observed that there was a significant difference ($p<0.05$) among the three samples. Potato-stabilized soy yoghurt had the highest mean score of 6.85, followed by corn-stabilized soy yoghurt with 5.75, while cassava-stabilized soy yoghurt had the least mean score of 5.15. There was no significant difference ($p>0.05$) between corn-stabilized soy yoghurt and cassava-stabilized soy yoghurt as well as between corn-stabilized soy yoghurt and potato-stabilized soy yoghurt. A significant difference ($p<0.05$) existed between cassava-stabilized soy yoghurt and potato-stabilized soy yoghurt. The difference in sourness could be a result of the varying carbohydrate contents of the samples. In terms of texture, there was a significant difference ($p<0.05$) among the samples. Potato-stabilized soy yoghurt had the highest mean score of 7.55, followed by cassava-stabilized soy yoghurt with a mean score of 5.30. Corn-stabilized soy yoghurt had the lowest-ever mean score of 4.80. Potato-stabilized soy yoghurt significantly differed ($p<0.05$) from both corn-stabilized soy yoghurt and cassava-stabilized soy yoghurt, while corn-stabilized soy yoghurt and cassava-stabilized soy yoghurt were not significantly different between themselves ($p>0.05$). The texture of the samples indicates the stabilizers used in the products.

The after-taste characteristics of the samples followed the same trend as their texture characteristics. Potato-stabilized soy yoghurt had the highest mean score of 7.20, while corn-stabilized soy yoghurt and YOY had the same mean score of 6.10. Potato-stabilized soy yoghurt was significantly different ($p<0.05$) from corn-stabilized soy yoghurt and cassava-stabilized soy yoghurt, while corn-stabilized soy yoghurt and cassava-stabilized soy yoghurt had no significant difference ($p>0.05$) between themselves. This trend could be attributed to the texture of the samples. This is because a more viscous and sweet product has a higher capacity to align in the taste buds for a longer time. This retains its taste in the mouth (after-taste) for a long time after being consumed. The general acceptability of the samples followed the same pattern with viscosity and after-taste. Generally Potato-stabilized soy yoghurt (ZOZ) performed had the best sensory parameter than other samples. It had the highest mean score of 7.95 and is significantly different ($p<0.05$) from corn-stabilized soy yoghurt and cassava-stabilized soy yoghurt. However, the sensory values of ZOZ were compared very well with the values obtained by Chaitali *et al.* (2019). For appearance, ZOZ had 7.50 ±1.36 while Chaitali *et al.* (2019) had obtained between 7.2 ± 0.68 – 8.80 ± 0.66; for texture, ZOZ had 7.55 ±1.00 while Chaitali *et al.* (2019) had obtained between 7.9 ± 0.45 – 8.2 ± 0.25; for mouthfeel, ZOZ had 6.85 ±1.93 while Chaitali *et al.* (2019) had obtained between 7.8 ± 0.28 – 8.7 ± 0.35; for general acceptability, ZOZ had 7.95 ±1.10 while Chaitali *et al.* (2019) had obtained between 8.10 ± 0.14 –

8.50 ± 0.24.

***Whey Separation Analysis of Soy Yoghurt Stabilized with Corn, Cassava and Potato Starch Stabilizers***

The result of the serum (whey) separation analysis of the soy yoghurt samples is shown in Table 4. After five days of undisturbed storage in a graduated measuring cylinder on a shelf at room temperature, the cassava-stabilized soy yoghurt did not show any separation while corn-stabilized soy yoghurt and potato-stabilized soy yoghurt separated at the serum: water ratio of 60:40ml and 70:30ml respectively. The whey floated in potato-stabilized soy yoghurt while it sank in corn-stabilized soy yoghurt. The separated water in potato-stabilized soy yoghurt was very clear while it was cloudy in corn-stabilized soy yoghurt. This showed that cassava starch had the greatest yoghurt binding capacity, followed by potato starch, while corn starch showed the least yoghurt binding capacity. The lack of whey separation in corn-stabilized soy yoghurt may indicate a sufficient amount of negatively-charged hydrocolloid to provide repulsion on the positively-charged protein molecules of the yoghurt, thereby stabilizing the matrix (Chukwuma, 2016). The separation observed may have been affected by the fact that the stabilizers were added before the fermentation of the soy yoghurt samples. Some research works posit that the addition of stabilizers before yoghurt fermentation increases the chances of whey separation and other defects. The report by Chaitali *et al.* (2019) showed that the water-holding capacity of the binder in any mixture varies inversely with its syneresis potential. In this case, the stabilizers act as binders. The values obtained here (30% - 40% separation) were closely related to the syneresis values obtained by Chaitali *et al.* (2019) which ranged between 25.245 and 46.01%.

**Conclusion**

The physical properties of yoghurt samples depend on the functional properties of the stabilizer used in its production. From this research findings, corn starch, cassava starch and potato starch can adequately be used to stabilize soy yoghurts. There were marked differences in the functional properties of the starches used. The cassava starch-stabilized soy yoghurt had the highest total solids and acidity and also showed the highest binding potential by its absence of separation after 5-day storage. Corn starch-stabilized soy yoghurt and potato starch-stabilized soy yoghurt samples showed serum: whey separation ratios of 60ml:30ml and 70ml:30ml respectively. From the result obtained in this research, it is recommended that yoghurt producers should consider utilizing these locally available, cheaper, and safer starches as reliable stabilizers in yoghurt production. In this research, the stabilizers were used at 1%. The effects of using higher percentages of these stabilizers should be further evaluated. The effects of blending these stabilizers for possibly better results should also be evaluated and compared directly with yoghurts stabilized with animal-based stabilizers.

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**Table I: Results of functional properties of starches used for soy yoghurt stabilization**

| Sample | BD (g/ml) | WAC (g/g) | OAC (g/g) | G. TEMPT.(ºC) | pH | SI (%) | SP (%) |
|---|---|---|---|---|---|---|---|
| XOXs | $0.68^{a}$+0.0071 | $1.75^{a}$+0.0071 | $1.02^{b}$+0.0283 | $66.50^{b}$+0.5000 | $6.11^{b}$+0.0050 | $0.81^{c}$+0.0141 | $9.25^{c}$+0.0500 |
| YOYs | $0.65^{b}$+0.0071 | $1.74^{a}$+0.0071 | $1.13^{a}$+0.0141 | $64.00^{c}$+0.0000 | $6.22^{a}$+0.0200 | $1.26^{a}$+0.0071 | $10.55^{a}$+0.0500 |
| ZOZs | $0.63^{b}$+0.0071 | $1.62^{b}$+0.0000 | $0.99^{b}$+0.0354 | $70.00^{a}$+0.0000 | $6.03^{b}$+0.0300 | $1.11^{b}$+0.0141 | $9.85^{b}$+0.0500 |

***Values are means ± standard deviation of duplicate determinations. Means followed by the same superscript in a column denote values that are not significantly different at (P >0.05)***

***KEY:*** *XOXs = Corn starch. YOYs = Cassava starch. ZOZs = Potato starch. BD = Bulk Density. WAC = Water Absorption Capacity. OAC = Oil Absorption Capacity. G. TEMPT. = Gelation Temperature. SI = Swelling Index. SP = Solubility Power.*

**Table 2: Results of physical properties of soy yoghurt samples stabilized with corn, cassava and potato stabilizers**

| Sample | %TTA | %TS | pH |
|---|---|---|---|
| XOX | $0.47^{b}$+0.0071 | $17.49^{c}$+0.0071 | $4.86^{b}$+0.0000 |
| YOY | $0.42^{c}$+0.0071 | $18.03^{a}$+0.0212 | $4.66^{c}$+0.0071 |
| ZOZ | $0.51^{a}$+0.0071 | $17.87^{b}$+0.0071 | $4.92^{a}$+0.021 |

***Values are means ± standard deviation of duplicate determinations. Means followed by the same superscript in a column denote values that are not significantly different at (P >0.05)***

***KEY:****XOX =Soy yoghurt stabilized with corn starch. YOY = Soy yoghurt stabilized with cassava starch. ZOZ =Soy yoghurt stabilized with potato starch. TS = Total Solids. TTA = Total Titratable Acidity*

**Table 3: Result of sensory properties of soy yoghurt stabilized with corn, cassava and potato stabilizers**

| Sample | Appearance | Mouthfeel | Sweet | Sour | Texture | After Taste | General acceptability |
|---|---|---|---|---|---|---|---|
| XOX | $7.05^{a}$+1.05 | $6.35^{a}$+1.57 | $6.05^{a}$+1.70 | $5.75^{ab}$+2.00 | $4.80^{b}$+1.58 | $6.10^{b}$+1.25 | $6.65^{b}$+1.05 |
| YOY | $6.90^{a}$+1.65 | $6.30^{a}$+1.42 | $5.50^{a}$+1.88 | $5.15^{b}$+1.87 | $5.30^{b}$+1.98 | $6.10^{b}$+1.71 | $6.30^{b}$+1.69 |
| ZOZ | $7.50^{a}$+1.36 | $6.85^{a}$+1.93 | $6.25^{a}$+1.62 | $6.85^{a}$+1.73 | $7.55^{a}$+1.00 | $7.20^{a}$+1.11 | $7.95^{a}$+1.10 |

***Values are means ± standard deviation of duplicate determinations. Means followed by the same superscript in a column denote values that are not significantly different at (P >0.05)***

***KEY:*** *XOX =Soy yoghurt stabilized with corn starch. YOY = Soy yoghurt stabilized with cassava starch. ZOZ =Soy yoghurt stabilized with potato starch.*

**Table 4: Result of whey Separation Results of Soy Yoghurt Samples Stabilized with Different Stabilizers**

| Samples | Whey: Serum Ratio | |
|---|---|---|
| | Day 1 | Day 5 |
| XOX | 100ml : 0ml | 60ml : 40ml |
| YOY | 100ml : 0ml | 100ml : 0ml |
| ZOZ | 100ml : 0ml | 70ml : 30ml |

***KEY:*** *XOX =Soy yoghurt stabilized with corn starch. YOY = Soy yoghurt stabilized with cassava starch. ZOZ = Soy yoghurt stabilized with potato starch*