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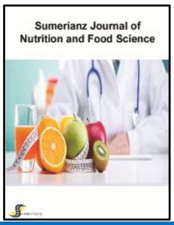

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A Study on the Quality Profiles of Pre-Digested Soymilk Stabilized With Irish Potato Starch for Ambient Storage

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Abstract

Coagulation, sedimentation and separation are major problems of home-made un-stabilized soymilk amidst the drudges in preparing it. Irish potato starch (IPS) stabilization is to improve their ambient storage stability. Soymilk prepared from 12 hours steeped and 72 hours sprouted soybeans was stabilized with 0.5%, 1%, 2% and 3% levels of IPS. Proximate, vitamin, mineral, ant-nutrient, physicochemical and functional properties of the IPS flour were evaluated using standard analytical methods. Sensory properties were evaluated by consumer preference test. Results showed that with increase in IPS stabilization levels, ash (0.85 to 0.89%), protein (3.90 to 4.15%), fibre (0.33 to 0.44%), fat (3.82 to 4.04%), carbohydrate (3.03 to 5.65%), vitamins B_1 (0.24 to 0.28 mg/100g), B_2 (0.09 to 0.12 mg/100g), B_3 (0.76 to 0.86 mg/100g), C (0.80 to 0.88 mg/100g), pro-vitamin A (3.62 to 4.14 µg/100g), calcium (24.88 to 26.67 mg/100g), phosphorous (30.79 to 31.67 mg/100g), magnesium (46.31 to 49.67 mg/100g), sodium (32.82 to 34.34 mg/100g) and iron (2.65 to 3.46 mg/100g) improved more than the control. Also improved were saponin (0.02 to 0.034 mg/100g), tannin (0.037 to 0.046 mg/100g), flavonoid (0.024 to 0.027 mg/100g), alkaloid (0.022 to 0.030 mg/100g), phenol (0.021 to 0.027 mg/100g), viscosity (4.25 to 5.39 cp), specific gravity (1.02 to 1.03), visible coagulation time (VCT) (14 to 27 d) and foam stability (0.99 to 2.00). Moisture content (MC) (88.03 to 84.72%) and pH (5.52 to 5.45) decreased lower than control. The IPS stabilization of soymilk had no significant ($p>0.05$) effect on sensory properties compared to control.
Keywords: Pre-digested; Soymilk; Irish potato starch; Stabilization; Ambient storage.

1. Introduction

Soy milk is vegetable milk produced from soybeans by soaking, grinding, boiling, and filtering. It is a stable emulsion of oil, water and protein. Its originated as a by-product of tofu (bean curds) manufacture, but was long unpopular because its oligosaccharide caused flatulence and discomfort in lactose in-intolerant adults. It became a staple food of East Asian cuisine over the last few centuries, after it was discovered that prolonged heating eliminated the flatulence-causing constituent. Improved production techniques were developed to give it a taste and consistency more closely resembling diary milk along with similar vegetable-based milks like almond and rice milk (Smita *et al.*, 2015).

High grade soybeans generally produce the best soymilk and the large seeded soybeans are considered to be the superior type (Gandhi, 2000). Soymilk flavour quality differs according to the cultivar of soybean used in its production (Smita *et al.*, 2015). The desirable sensory qualities like mouth feel (smooth but thick), color (off-white) and appearance (creamy) resembles cow's milk (Kumar *et al.*, 2003). Fresh soymilk has a very short shelf-life which limits its consumption to areas close to the production site. Thermal processing is the most common practice used to improve the microbial safety and extend the shelf-life of soymilk because it inactivates vegetative pathogen and many spoilage bacteria (Achouri *et al.*, 2007). The use of ultra-high temperature is relatively new for soymilk production. The traditional processing involves temperature of 90°C to 100°C for up to 30 min (Yuan *et al.*, 2008).

Soymilk produced from sprouted soybean has been reported to increase in protein content and reduced fat, trypsin inhibitor and phytic acid whose reduction otherwise necessitates intense heat or methods like ultra-filtration (Agrahar and Jha, 2014). As soybean sprouting is natural, non-thermal and non-chemical process, soymilk prepared from sprouted soybean is a better quality soymilk that resembles cow's milk. Besides, such soymilk has higher soymilk yield, better color characteristics, ambient storage stability and acceptable (due to the absence of beany flavour and odour) than soymilk from un-sprouted soybeans (Agrahar and Jha, 2014). Un-stabilized soymilk

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undergoes ambient storage changes due to interactions, coagulations and sedimentations that affect its physicochemical properties. Interactions and coagulation cause nutrient loss, pH changes, increase in total solids and viscosity (Okwunodulu and Nwabueze, 2019), while sedimentation causes color decrease. Sprouted soybean results in soymilk with insignificant physicochemical interactive effects (Okwunodulu *et al.*, 2015).

Oxford Advanced Learner's Dictionary defined stabilization as the process of making something physically more secure or stable. Stabilizers are additives to foods to help preserve their structure by preventing oil-water emulsion, from separating in products such as salad dressing and soymilk. Stabilizers maintain turbidity which suspends insoluble components (Specialty Mineral Incorporated SMI, 2009) and create satisfactory texture while preventing loss of odours and flavours in drinks. Some commonly used stabilizers include alginate, agar, carrageen, cellulose, gelatin, guar gum, gum Arabic, locust bean gum, pectin, starch, xanthan gum (Alan, 2011). The amount of stabilizer required for good stability depends on the amount, size and solubility of solids in the drink as well as the level of dilution before consumption. Appropriate and adequate addition of stabilizer, homogenization and protection of vitamin C improves the shelf-stability of soymilk (Agrahar and Jha, 2014).

Problems associated with home made un-stabilized soymilk production and consumption include difficulties in processing, coagulation due to interactions which leads to stability problems like sedimentation, separation and colour change during tropical ambient storage (Okwunodulu *et al.*, 2015). Soymilk from un-sprouted soybean often results in instant coagulation after sterilization. Unfortunately, attempts to preserve soymilk in rural house holds without electricity have remained a problem as most soy milk if not consumed shortly after production sediments and loose its appealing quality. This study therefore aimed at exploring the effect of stabilizing soymilk from sprouted soybean with Irish potato starches on some quality indices for ambient storage.

2. Materials and Methods

2.1. Raw Material Procurement

Soybean (*Glycine max*) (Plate 1) and Irish potato (*Solanum tuberosum*) (Plate 2) were purchased from Ubani main market, Umuahia. Empty palm bunch used for preparing plant ash was procured from a small scale oil mill in Ogbuebule in Ikwuano local Government Area, all in Abia State Nigeria.

Plate-1. Soybean

Plate-2. Irish Potato

2.2. Sample Preparation

2.2.1. Preparation of Soymilk

Soymilk was produced from sprouted soybeans according to Okwunodulu *et al.* (2017) as shown in figure 1 with slight modification. Cleaned and weighed (5.5 kg) whole soybean was soaked in clean tap water for 12 h, drained, spread on a cleaned jute sack, covered with black polyethylene and placed on a platform, few meters above the floor. The soybeans were sprinkled with water every 4 h intervals to initiate sprouting and every 6 h intervals during sprouting which lasted for 72 h (3days) at room temperature. The sprouted soybean (Plate 3) was boiled in 0.5% $NaHCO_3$ solutions for 20 minutes drained, cooled to room temperature and dehulled manually. The hulls and shoots were removed by water floatation method. The dehulled soybean cotyledons were milled in variable speed QASA kitchen blender (model QBL-18L40) with hot water (93 ºC) in a ratio of 1 Kg: 2.7 L. The slurry was sieved with a double muslin cloth, and the extract (soymilk) obtained was boiled in an open pan for 20 minutes, and allowed to cool to room temperature.

Plate-3. Sprouted soybean

2.2.2. Starch Extraction

Starch was prepared following the method described by Eke- Ejiofor (2015) as shown in figure 2 with slight modification. Fresh Irish potato roots (plate 2) were washed to remove soils and dirt, peeled using a stainless steel knife, then washed again and disintegrated with a manual grater. The resulting mash was ground, mixed with water and sieved through a double layer muslin cloth to obtain starch solutions. The starch was separated from the water by sedimentation and decantation. The wet IPS was thinly spread on an oven tray and dried at 50ºC for 24 h to obtain white, odourless and tasteless dried IPS.

Figure-1. Flow chart for production of soymilk from sprouted soybean (Okwunodulu *et al.*, 2017)

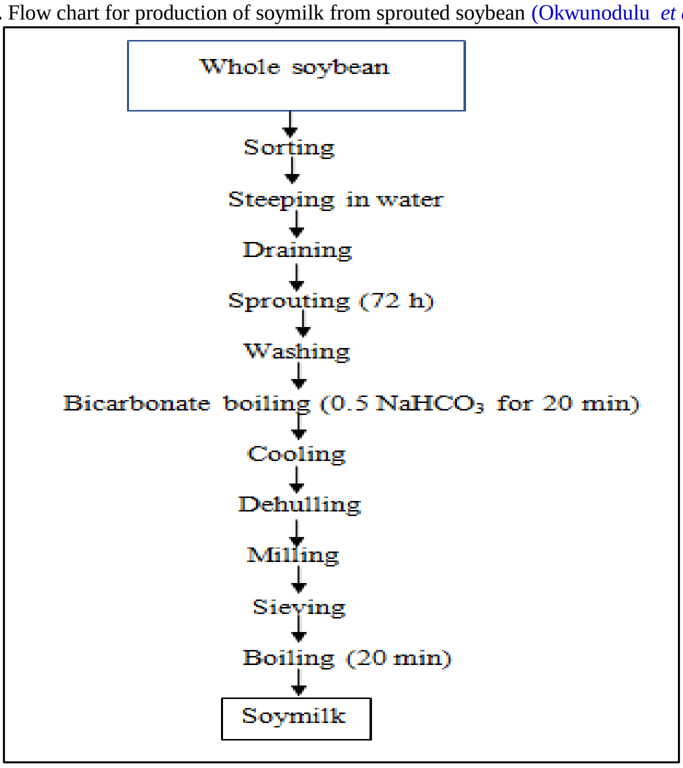
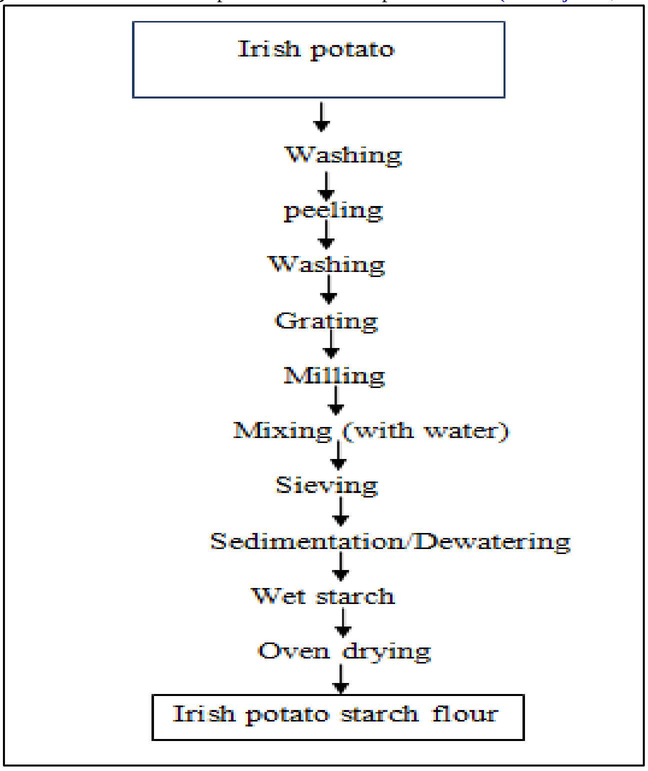


Figure-2. Flowchart for the production of Irish potato starch (Eke- Ejiofor, 2015)



2.3. Stabilization of Soymilk

The method described by Smita *et al.* (2015) with slight modification was used for the soymilk stabilization. The soymilk bulk was divided into five batches and each batch was stabilized with 0.5, 1.0, 2.0 and 3.0% of IPS. Stabilized samples were blended, bottled, coded, sterilized at 121ºC for 5 min in an autoclave, cooled and stored for analyses (Plate 4).

Plate-4. IP1a the control, IP2a is 0.5% stabilized soymilk, IP3a is 1% stabilized soymilk, IP4a is 2% stabilized soymilk and IP5a is 3% stabilized soymilk

2.4. Analyses

2.4.1. Proximate

The method described by Onwuka (2018) was used in determining the moisture, fats, ash, protein, carbohydrate and fibre contents of the samples.

2.4.2. Vitamin

The spectrophotometer method by Onwuka (2018) was employed in determination of vitamin A, vitamin B_1(Thiamin),vitamin B_2(riboflavin) and vitamin B_3 (niacin). Vitamin C was determined by the method of Okwu and Josiah (2006).

2.4.3. Mineral

Calcium, iron and magnesium content of the soymilk were determined by complexiometric titration method of Onwuka (2018). Potassium and sodium were determined by flame photometry method described by James (1995).

2.4.4. Anti -nutrient

The gravimetric method described by Harbone (1973) was used in alkaloid determination. The method described by Association of Official Analytical Chemists (2010) was used in saponin determination. Tannin was determined by the Folin-Denis spectrophotometer method described by Pearson (1976). Flavonoid was determined by gravimetric method of Harbone (1973), and phenol was determined using the method described by Oberlease (1973).

2.4.5. Physicochemical

The pH was determined by the method described by Onwuka (2018). The method of Association of Official Analytical Chemists (2010) was employed in the viscosity determination.

2.4.6. Visible Coagulation Time (VCT)

Physical observation of the samples for an obvious sedimentation and phase separation of the samples as described by Okwunodulu *et al.* (2015) was used for the determination. The samples were examined on daily basis for visible coagulation of the samples characterized by separation into clear supernatant and clouded sediments. The appearance of these features and a slight change in colour was considered the end of the stability period of the soymilk.

2.4.7. Functional Properties Determination

Bulk density, oil and water absorption capacity, swelling index and dispersability were determined by the method described by Onwuka (2018).

3. Sensory Analysis

Sensory evaluation of the soymilk produced was carried out according to the method described by Iwe (2007). Appearance, taste, flavour, consistency and general acceptability were the attributes evaluated. The 30 semi-trained panellists were randomly selected from Michael Okpara University of Agriculture, Umudike who were presented the coded samples in same types of plates along with a bottle of water each. They were to rinse their mouths before and after tasting and score according to 9-point hedonic scale where 9 is like extremely, 5 is neither like nor dislike and 1 is dislike extremely.

4. Statistical Analyses

Data obtained from the analyses were subjected to analysis of variance (ANOVA) using split-plot method and the mean values were separated using Duncan multiple range test (SPSS 17version).

5. Results and Discussion

5.1. Proximate Composition

The results are presented in Table 2.

5.1.1. Moisture Content (MC)

Moisture content is the amount of moisture in the sample given as a percentage of the sample's original weight. The MC of the stabilized samples decreased (88.03 to 84.72%) significantly ($p<0.05$) lower than control (90.19%) with increase in IPS stabilization levels. This phenomenon could be attributed to the increasing total solids by the IPS thereby reducing the available free water for microbial activities. Soymilk MC has an inverse correlation with total solids (Okwunodulu and Nwabueze, 2019). Despite the decrease, the MC of the stabilized samples were very high which established soymilk as a high moisture foods, and would not store for a very long time under ambient storage without proper packaging, preservatives or adequate stabilization. Their higher MC will aid free flowing, easy swallowing and refreshing while increased total solids due to IPS will enhance mouth feel, acceptability and possibly longer ambient stability. Therefore, stabilization level should not be above 3% to avoid compromising acceptability, ambient stability and refreshing value.

5.1.2. Ash

Ash content is a measure of metallic content of food. In this study, it increased (0.85 to 0.89%) significantly ($p<0.05$) more than the control (0.84%) with increase in IPS stabilization levels. This was reflected in higher ash content (0.89%) of sample E (soymilk with 3% Irish potato) than that of sample B (soymilk with 0.5% Irish potato) with 0.85%. The IPS may have improved the mineral content of the stabilized soymilk samples unlike in the control. This mineral improvement is desirable due to the inherent health benefits of minerals (Eruvbetine, 2003).

5.1.3. Protein

Protein helps to build and maintain healthy muscle mass, while also supporting tendon, ligaments and other body-tissue. It also helps to prevent spikes in blood glucose, which is especially important for preventing type-2-diabetes and balancing energy (Ajani *et al.*, 2012). These health benefits are likely to improve in the stabilized soymilk samples as protein content improved significantly ($p<0.05$) with increase in IPS stabilization levels. As the improvement (3.90 to 4.15%) was significantly ($p<0.05$) higher than control (3.86%), IPS must have contributed significantly ($p<0.05$) to that. Protein also helps in the synthesis of new cell, repair worn out tissue and other substances require for healthy functioning and development of the body.

Table-1. Proximate compositions of soymilk stabilized with Irish potato starches (%)

Samples	Moisture	Ash	Protein	Fiber	Crude fat	Carbohydrate
Un-stabilized soymilk	$90.19^{a}\pm0.37$	$0.84^{e}\pm0.00$	$3.86^{d}\pm0.00$	$0.28^{e}\pm0.00$	$3.65^{b}\pm0.00$	$1.20^{d}\pm0.36$
0.5% stabilized soymilk	$88.03^{b}\pm0.60$	$0.85^{de}\pm0.00$	$3.90^{cd}\pm0.00$	$0.33^{de}\pm0.02$	$3.82^{ab}\pm0.00$	$3.03^{c}\pm0.66$
1% stabilized soymilk	$86.43^{c}\pm0.04$	$0.88^{abc}\pm0.00$	$3.94^{b}\pm0.02$	$0.35^{cd}\pm0.00$	$3.85^{ab}\pm0.00$	$4.61^{b}\pm0.00$
2% stabilized soymilk	$85.46^{d}\pm0.20$	$0.86^{bcde}\pm0.00$	$4.06^{ab}\pm0.00$	$0.39^{b}\pm0.01$	$3.88^{ab}\pm0.03$	$5.32^{ab}\pm0.23$
3% stabilized soymilk	$84.72^{e}\pm0.05$	$0.89^{a}\pm0.00$	$4.15^{a}\pm0.02$	$0.44^{a}\pm0.01$	$4.04^{a}\pm0.17$	$5.65^{a}\pm0.05$

Values are means of triplicate determinations ± standard deviation. Means with the same superscripts within the same column are not significantl different (P>0.05)

5.1.4. Crude Fibre

Crude fibre refers to the indigestible plant material, such as vegetables, fruits, grains, beans and legumes. Fibre has been reported to offers a variety of health benefits and is essential in reducing the risk of chronic disease such as diabetes, obesity, cardiovascular disease and intestinal diverticulitis Ajani *et al.* (2012). It acts to lower the concentration of low-density lipoprotein in the blood, possibly by binding with bile's acids (Ishiwu and Tope, 2015). With significant ($p<0.05$) increase in fibre content as the IPS stabilization level increases, stabilized soymilk may likely improve in these inherent health benefits associated with fibre. Significant ($p<0.05$) higher fibre content of all the stabilized soymilk (0.33 to 0.44%) compared to control (0.28%) implied that IPS must have been the major contributor. Therefore, IPS stabilization is a welcome fibre improvement in soymilk.

5.1.5. Crude Fat

This improved slightly (3.82 to 3.88) among stabilized samples with increase in IPS stabilization level except in sample E (soymilk stabilized with 3% Irish potato). Significant ($p<0.05$) fat improvement (4.04%) only in sample E (soymilk stabilized with 3% Irish potato) may signify that IPS had significant ($p<0.05$) fat improvement only as from 3% stabilization level. Also significant ($p<0.05$) higher fat content of stabilized samples compared to control (3.65%) implicated IPS as the primary source of fat to the stabilized soymilk samples. Eat is energy substrate, source of fat soluble vitamins and maintenance of body temperature (Amankwah *et al.*, 2009) which can only be significant ($p<0.05$) as from 3% level of IPS stabilization.

5.1.6. Carbohydrate

Carbohydrate content of the stabilized soymilk significantly ($p<0.05$) increased (3.03 to 5.65%) with increase in IPS stabilization levels. Significant ($p<0.05$) higher carbohydrate content of the stabilized samples than the control substantiated IPS as the major source. This is beneficial improvement as the stabilized soymilk samples will provide more energy when consumed than the control. Carbohydrate is the second energy substrate of food.

5.2. Vitamin Composition

The results are presented in Table 2.

5.2.1. Vitamin B_1

Vitamin B_1 (thiamine) content of the stabilized soymilk samples significantly ($p<0.05$) improved (0.24 to 0.28 mg/100 g) more than the control sample (0.12 mg/100 g) which implicated IPS as the main source. This improvement was significant ($p<0.05$) only as from 1% level of stabilization as soymilk samples stabilized with 0.5 and 1% IPS were similar. The improvement could have been more than what was obtained if not the inevitable processing loss during processing of IPS into flour. Thiamine is important for cognitive function and nervous system, red blood cell formation, sugar oxidation, optimal digestion and anti-stress among others (ProHealth, 2018).

Table-2. Vitamin compositions of soymilk stabilized with Irish potato starches

Samples	Vitamin B_1 (mg/100g)	Vitamin B_2 (mg/100g)	Vitamin B_3 (mg/100g)	Vitamin C (mg/100g)	Pro-vitamin A (µg/100g)
Un-stabilized soymilk	$0.21^{d}\pm0.01$	$0.08^{d}\pm0.00$	$0.76^{c}\pm0.01$	$0.79^{e}\pm0.01$	$3.41^{d}\pm0.01$
0.5% stabilized soymilk	$0.24^{c}\pm0.01$	$0.09^{c}\pm0.00$	$0.76^{c}\pm0.01$	$0.80^{d}\pm0.00$	$3.62^{c}\pm0.04$
1.0% stabilized soymilk	$0.24^{c}\pm0.00$	$0.10^{bc}\pm0.00$	$0.81^{b}\pm0.00$	$0.84^{c}\pm0.01$	$3.63^{c}\pm0.04$
2.0% stabilized soymilk	$0.26^{b}\pm0.01$	$0.11^{ab}\pm0.01$	$0.86^{a}\pm0.02$	$0.85^{b}\pm0.00$	$3.87^{b}\pm0.01$
3.0% stabilized soymilk	$0.28^{a}\pm0.01$	$0.12^{a}\pm0.01$	$0.86^{a}\pm0.01$	$0.88^{a}\pm0.02$	$4.14^{a}\pm0.01$

Values are mean triplicate determinations ± standard deviation. Means with the same superscripts within the same column are not significantly different (P>0.05)

5.2.2. Vitamin B_2

With increase in IPS stabilization levels, vitamin B2 (Riboflavin) of stabilized soymilk samples improved (0.09 to 0.12 mg/100g) significantly ($p<0.05$) more than the control (0.08 mg/100g). Riboflavin values obtained in this study were generally low and therefore not a good source. Despite this, the improvement which could be credited solely from IPS was very much desired as it plays a supportive role in the treatment of sickle-cell anaemia (Knapp, 2011). Its appreciable presence in food could contribute towards keeping healthy blood cells.

5.2.3. Vitamin B_3

Like other vitamins, vitamin B_3 (niacin) contents of stabilized soymilk increased (0.81 to 0.86 mg/100 g) significantly ($p<0.05$) higher than control (0.76 mg/100g) as from 1% level of IPS stabilization. Though IPS is not a good source of niacin, but the improvement is associated with some health benefits. Vitamin B3 is a precursor for enzyme co-factors that assist in their work as catalyst in body metabolism. Its limited amount in these studied samples may contribute in alleviating niacin deficiency which causes pellagra (Duel and Sturtz, 2010).

5.2.4. Vitamin C

There was significant ($p<0.05$) vitamin C improvement (0.80 to 0.88 mg/100 g) in the stabilized soymilk samples with increase in IPS stabilization levels. This could be attributed to IPS as the main source. Though the improvement was significantly ($p<0.05$) higher than the control (0.79 mg/100g), the entire samples were not good vitamin C source as their values were low. The values obtained in this study were lower than 10.30 to 38.67mg/100g obtained by Sanusi *et al.* (2008).This could be attributed to inevitable vitamin C loss during IPS processing into flour. Besides, sterilization heat must have contributed too. Despite this loss, vitamin C improvement in this study is not without some health benefits. Vitamin C is a very important antioxidant, required for proper development and health of man (Knapp, 2011). Vitamin C helps in detoxification of alcohol and other harmful substance, and protects people from diabetes (Raff *et al.*, 2004), prevents fat oxidation, improves nutrient absorption and aesthetic appeal of foods(Dutch State Mines DSM, 2011).

5.2.5. Vitamin A activity (retinol)

The retinol content of IPS stabilized soymilk samples (3.62 to 4.41 µg/100g) improved significantly ($p<0.050$) more the control (3.41 µg/100g) with increasing levels of stabilization. This improvement was significant as from 1% level of stabilization. The improvement may also encompass the associated health benefits of retinol. Retinol improves vision and maintains epithelial cell functions (Akuyili *et al.*, 2003). Higher values of vitamin A is an indication of good source of essential fat-soluble vitamins whose functions include; growth maintenance, health of the eyes, maintenance of the structure/function of the cell of the skin and mucous membranes (Ihekoronye and Ngoddy, 1985).

5.3. Mineral Composition

The results are as shown in Table 3.

5.3.1. Calcium

Calcium content of the stabilized soymilk samples significantly ($p<0.05$) improved (24.88 to 27.67 mg/100 g) with increase in IPS stabilization levels more than the control (24.34 mg/100g). The IPS may have been the primary calcium source. This calcium improvement was a welcome development as calcium is very important in the building and maintenance of strong teeth and it plays a key role in our cells. Also, calcium will contribute to total solids of the soymilk and desired viscosity.

Table-3. Mineral compositions of soymilk stabilized with Irish potato starches (mg/100g)

Samples	Calcium	Potassium	Magnesium	Sodium	Iron
Un-stabilized soymilk	$24.34^{cd}\pm0.08$	$29.32^{d}\pm0.11$	$45.53^{c}\pm0.11$	$32.41^{e}\pm0.01$	$2.42^{e}\pm0.00$
0.5% stabilized soymilk	$24.88^{c}\pm0.04$	$30.79^{bc}\pm0.01$	$46.31^{b}\pm0.01$	$32.82^{d}\pm0.05$	$2.65^{d}\pm0.00$
1.0% stabilized soymilk	$25.77^{b}\pm0.04$	$31.11^{abc}\pm0.72$	$46.61^{b}\pm0.27$	$33.31^{c}\pm0.01$	$2.74^{c}\pm0.02$
2.0% stabilized soymilk	$26.53^{a}\pm0.11$	$31.33^{ab}\pm0.10$	$47.24^{a}\pm0.06$	$33.88^{b}\pm0.04$	$3.14^{b}\pm0.03$
3.0% stabilized soymilk	$26.76^{a}\pm0.06$	$31.76^{a}\pm0.06$	$47.67^{a}\pm0.02$	$34.34^{a}\pm0.08$	$3.46^{a}\pm0.01$

Values are means of triplicate determinations ± standard deviation. Means with the same superscripts within the same column are not significantly different ($P>0.05$)

5.3.2. Potassium

Potassium content of the stabilized soymilk samples significantly ($p<0.05$) increased (30.79 to 31.67 mg/100g) more than the control (29.32 mg/100g) with increase in IPS stabilization levels. The IPS may have been the major source. This improvement may likely improve the health benefit of the soymilk due to potassium. Potassium is a very important mineral for proper functioning of all human cells, tissues, and organs. Potassium helps to relief strokes, high blood pressure, kidney disorder, anxiety and stress. Potassium also enhances muscle strength, metabolism, regulate body fluid balance, needed for transmission of nerve impulses, muscle contraction and proper metabolism (Organic Facts, 2018).

5.3.3. Magnesium

With increase in IPS stabilization levels, magnesium content of the stabilized soymilk samples (46.31-47.67 mg/100g) improved more than the control (45.53 mg/100g). However, this improvement was only significant (p<0.05) at stabilization levels of 1 and 3% as soymilk samples stabilized with 0.5 and 1% and that that between 2 and 3%were similar. This may mean low magnesium content of IPS. This magnesium improvement obtained in this study may reflect in the health benefits of the soy milk. Magnesium regulates diverse body biochemical reactions like protein synthesis, muscle and nerve function, blood glucose control, and blood pressure regulation (Aydin *et al.*, 2010). It contributes to the structural development of bone and is required for the synthesis of DNA, RNA and the antioxidant glutathione.

5.3.4. Sodium

Sodium content of the stabilized soymilk samples (32.82 to 34.34 mg/100g) was significantly enhanced more than the control (32.41 mg/100g) probably due to IPS as the major source. This enhancement is concentration dependent for effective health benefits. Low sodium diet has been reported to be beneficial in the prevention of high blood pressure (Onwuka, 2018). Sodium also is critical in nervous system function, muscular contraction, nerve functions and maintenance of body fluid balance (Gomez-Candela *et al.*, 2011).

5.3.5. Iron

Iron content of the stabilized soymilk samples also improved significantly (p<0.05) with increase in IPS stabilization levels. This iron increase (2.65 to 3.46 mg/100g) which was higher than the control sample (2.42 mg/100g) justified IPS as the primary source in the soymilk. The improvement is of beneficial effect. Iron is required for haemoglobin production (Office of Dietary Supplements ODS, 2007), helps our muscles to store and use oxygen and is part of many proteins and enzymes (Wessling-Resnick, 2014). Though iron values obtained in this study were low, consumption of 520 to 679 ml of the soymilk sample will meet the RDI of 10 to 18 mg/d (Office of Dietary Supplements ODS, 2007) which make these samples good iron source.

5.4. Anti-Nutrient Composition

The results are presented in Table 4.

5.4.1. Saponins

Beyond the safe limit of 5 to 10 mg/kg in food (Ndie and Okaka, 2018), saponin reduces nutrient bioavailability, decreases enzyme activity, protein zinc and iron digestibility (Liener, 2003; Sun *et al.*, 2009). Saponin content of the stabilized soymilk samples increased (0.020 to 0.034 mg/kg) significantly (p<0.05) with increase in IPS stabilization levels. Though the increase was higher than the control (0.017 mg/kg), all the saponin values of the entire sample were lower than the recommended safe limit. Therefore, they are safe for human consumption without adverse health effect such as protein indigestibility and impairment of intestinal enzyme action.

5.4.2. Tannin

Significant (p<0.05) tannin content increase (0.037 to 0.046 mg/100g) more than the control (0.035 mg/100g) with increase in IPS stabilization level increase exposed IPS as the major source. Tannin is heat stable astringent bitter plant polyphenolic compound which high concentration inhibits protein digestibility by either binding or precipitates proteins and various other organic compounds like amino acids and alkaloids (Popova and Mihaylova, 2019). Tannin inhibits digestive enzyme (trypsin, chemotrypsin, amylase and lipase) activities, interferes with dietary iron absorption and increase fecal nitrogen (Ferrell and Thorington, 2006). Fortunately, tannin content of the entire soymilk samples obtained in this study were considerably lower than 120 mg/kg safe limit (Ndie and Okaka, 2018) and therefore will have insignificant (p>0.05) adverse effect on consumers.

Table-4. Anti-nutrient composition of soymilk stabilized with Irish potato starches (mg/100g)

Samples	Saponin	Tannin	Flavonoid	Alkaloids	Phenols
Un-stabilized soymilk	0.017^{e}±0.00	0.036^{e}±0.00	0.022^{e}±0.00	0.019^{c}±0.00	0.019^{d}±0.00
0.5% stabilized soymilk	0.020^{d}±0.60	0.037^{d}±0.00	0.024^{d}±0.00	0.023^{b}±0.00	0.021^{bc}±0.00
1.0% stabilized soymilk	0.024^{c}±0.04	0.041^{c}±0.00	0.025^{c}±0.00	0.023^{b}±0.00	0.023^{b}±0.00
2.0% stabilized soymilk	0.028^{b}±0.20	0.043^{b}±0.00	0.026^{b}±0.00	0.025^{b}±0.00	0.023^{b}±0.00
3.0% stabilized soymilk	0.034^{a}±0.05	0.046^{a}±0.00	0.027^{a}±0.00	0.030^{a}±0.00	0.027^{a}±0.00

Values are means of triplicate determinations ± standard deviation Means with the same superscripts within the same column are not significantly different (P>0.05)

5.4.3. Flavonoid

Like other anti-nutrients, flavonoid content of stabilized soymilk samples increased (0.024 to 0.027 mg/100g) significantly (p<0.05) more than the control (0/022 mg/100g) with increase in IPS stabilization levels. Despite the increase, all the flavonoid content of the entire samples were very low and may have little or no adverse effect on health and therefore IPS fortified soymilk is safe for human consumption.

5.4.4. Alkaloid

Alkaloid content of stabilized soymilk samples increased (0.022 to 0.03 mg/100g) with significant ($p<0.05$) effect only at 3% level of IPS stabilization. This may mean that the alkaloid content of Irish potato was very low that it could have a significant ($p<0.05$) influence only as from 3% level of stabilization. Though the increase was significantly ($p<0.05$) higher than the control (0.019 mg/100g), alkaloid levels of the entire samples were considerably low and therefore safe for human consumption.

5.4.5. Phenol

Phenol content of the stabilized soymilk samples also increased with significant ($p<0.05$) effect as IPS levels of stabilization increased which saw IPS as the primary source. The values of the stabilized soymilk are higher than the control sample (0.019 mg/100g), However, the values obtained in this study are considerably lower than the safe limit.

5.5. Physicochemical Properties

The results are presented in Table 5.

5.5.1. Viscosity

Increase in IPS stabilization increased (4.25 to 53.39 cp) significantly ($p<0.05$) the viscosity of soymilk samples more than the control (4.21 cp).The viscosity increase maybe attributed to increase in total solid content of soymilk by the IPS which is a function of viscosity (Okwunodulu and Nwabueze, 2019). Viscosity is the measure of mouth feel, consistency and soymilk acceptability, while stabilization decides smoothness and ambient stability. The more viscous the soymilk is, the lesser the acceptability and shelf-stability. Thus, stabilization levels that result in maximum stability and acceptability are most preferred.

Table-5. Physicochemical properties of Irish potato starch stabilized soymilk

Samples	Viscosity (cp)	pH	Specific gravity	VCT (days)	Foam stability (s)
Un-stabilized soymilk	$4.21^{e}\pm0.01$	$5.60^{a}\pm0.01$	$1.02^{ab}\pm0.00$	$19.00^{d}\pm0.00$	$0.50^{c}\pm0.01$
0.5% stabilized soymilk	$4.25^{d}\pm0.00$	$5.52^{b}\pm0.01$	$1.02^{ab}\pm0.00$	$27.00^{a}\pm0.70$	$2.00^{a}\pm0.01$
1.0% stabilized soymilk	$4.29^{c}\pm0.02$	$5.50^{c}\pm0.01$	$1.02^{ab}\pm0.00$	$23.50^{b}\pm0.70$	$2.00^{a}\pm0.01$
2.0% stabilized soymilk	$4.85^{b}\pm0.00$	$5.48^{d}\pm0.01$	$1.03^{a}\pm0.00$	$21.50^{c}\pm0.70$	$0.99^{b}\pm0.01$
3.0% stabilized soymilk	$5.39^{a}\pm0.01$	$5.45^{e}\pm0.00$	$1.03^{a}\pm0.00$	$14.50^{e}\pm0.70$	$0.99^{b}\pm0.01$

Values are means of triplicate determinations ± standard deviation. Means with the same superscripts within the same column are not significantly different ($P>0.05$). VCT is visible coagulation time

5.5.2. pH

The pH of the stabilized soymilk samples decreased significantly ($p<0.05$) from 5.52 to 5.45 cp with increasing levels (0.5% to 3.0%) of IPS lower than control (5.60 cp). This pH decrease justified the report of Ihekoronye and Ngoddy (1985) that carbohydrate decreases pH. The pH of the control was lower than 6.66 reported by Okwunodulu and Okwunodulu (2016) which may be attributed to soybean variety and processing method employed. The pH reduction (tending to acidity) in this study is not encouraging as it may result in coagulation, sedimentation and reduced acceptability. Higher pH values (pH>4) are indication of low acidity favour ambient stability (Okwunodulu and Okwunodulu, 2016).

5.5.3. Specific Gravity

Specific gravity (SG) of the stabilized soymilk samples increased with increase in IPS stabilization levels. The increase was only significant ($p<0.05$) as from 1% level of stabilization. Low SG is ideal as it depicts acceptable consistency.

5.5.4. Visible Coagulation Time (VCT)

This is the time lag (stability period) taken by the stabilized samples to show visible coagulation. The VCT of the stabilized samples decreased significantly ($p<0.05$) with increase in IPS stabilization levels but more than the control (19 days) except in sample stabilized with 3% IPS. This mat mean the 3% IPS may have supplemented the total solids of soymilk more than the medium viscosity can carry thereby leading to coagulation, sedimentation and separation. This was justified by the maximum VCT (27 d) obtained in sample stabilized with 0.5% IPS and least (14 d) in sample stabilized with 3% IPS. Therefore, it could be inferred that IPS stabilization of soymilk produces the best results at lower levels (0.5 to 2%). The stabilized samples could have been stable for more than the days recorded if the pH had been more that what was obtained. Low pH had been reported to initiate coagulation (Okwunodulu and Okwunodulu, 2016).

5.5.5. Foam Stability (FS)

This is the ability of soymilk protein to stabilize against the gravitational and mechanical stress. The FS values of stabilized soymilk samples decreased (2.0 to 0.99 s) with increase in IPS stabilization levels but higher than the control (0.5 s). Maximum FS (2 s) was obtained at stabilization levels of 0.5% and 1.0% which have no significant ($p>0.05$) difference. However, the FS levels of the entire samples were considerably low which could be attributed to the disintegration of the protein component of the soybean which played an important role in the formation of foam network. The decrease was no desired as FS is an index of freshness and acceptability of soymilk most especially at higher IPS stabilization levels.

5.6. Functional Composition of Irish Potato Starch

The results are presented in Table 6.

5.6.1. Bulk Density (BD)

This is defined as the mass per unit volume of a substance which is a function of food product porosity. It is an important determinant in designing and requirement of packaging materials, as it reveals their load carrying capacity (Onimawo and Akubor, 2005). The BD of IPS sample (0.65 g/ml) is lower than 0.92 to 0.97 g/ml for corn starch/soybean flour blends and 0.94 to 0.98g/ml for sorghum/African yam bean blends reported by Okoye *et al.* (2017). Low BD obtained from IPS would be advantageous (Amandikwa, 2012) as high BD will adversely affect the consistency and mouth feel of the stabilized soymilk which is the major determining factor in their acceptability.

Table-6. Functional properties of Irish potato starch

Samples	Bulk Density	Solubility (%)	Swelling index (%)	D (%)	LGC	WAC (g/g)	OAC (g/g)
IPS	0.65±0.00	14.84±0.08	3.74±0.02	84.67±0.10	6.00±0.00	3.25±0.01	2.17±0.00

Values are means of triplicate determinations ± standard deviations. Means within the same column are not significantly P>0.05 different. IPS is Irish potato starch. D is dispersibility, LGC is least gelation capacity, WAC is water absorption capacity and OAC is oil absorption capacity

5.6.2. Solubility

The IPS had low solubility of 14.84% which is not a disadvantage in this study as the heat of sterilization will enhance their solubility. The more soluble the starch granules, the more the medium viscosity the more the soymilk solids are evenly dispersed and evenly suspended, and the better the ambient stability (Okwunodulu and Abasiekong, 2015).

5.6.3. Swelling Index

Swelling index is a measure of how much water a food material can absorb which is dependent on carbohydrate content. Swelling index of 3.74% from IPS is desirable as higher values will bind most of the soymilk free water thereby increase the viscosity beyond desirable limit. This will in turn reduce the soymilk MC and acceptability more.

5.6.4. Dispersibility

This is a measure of how much IPS is dispersed evenly in a medium. Dispersibility value of 84.67% obtained is encouraging as it will improve consistency and stability of the stabilized soymilk which is the primary aim of stabilization.

5.6.5. Least Gelation Capacity

This is the least protein concentration required to form self supporting gel by food. Least gelation capacity of 6.00 from IPS is an indication of ability to gel easily (Onimawo and Egbekun, 1998) which signifies better consistency, mouth feel and acceptability.

5.6.6. Water Absorption Capacity (WAC)

This is the ability of food material to absorb water and has an inverse relationship with MC Hoover (2001). Therefore, low WAC IPS value of 3.25 g/g is an indication of high MC of stabilized soymilk and increase the soymilk medium viscosity and ambient stability. The low WAC of IPS could be attributed to destruction of the macromolecular matrix that entraps large volume of water during processing (Chen and Lin, 2002).

5.6.7. Oil Absorption Capacity (OAC)

This is the ability of food material to absorb oil which helps to improve the mouth feel and retains flavour (Egan *et al*., 1981). Low OAC (2.31g/g) of IPS implied that the oil content of the stabilized soymilk samples will not be adversely affected by the IP. Soymilk oil helps to boost energy, mouth fell and flavour of soymilk.

5.7. Sensory Characteristics

The results are as shown in Table 7.

5.7.1. Flavour

The IPS stabilization levels had no significant (p>0.05) flavour variations on the entire soymilk samples except in sample stabilized with 2% IPS which was scored highest (7.28). These results suggest that, 2.0 stabilized soymilk has a flavour that was liked moderately than other samples which were slightly liked.

Table-7. Sensory scores of soymilk stabilized Irish potato starch

Samples	Flavour	Appearance	Consistency	Aroma	Acceptability
Un-stabilized soymilk	6.32^{ab}±2.85	7.60^{a}±1.76	7.36^{a}±1.58	7.64^{a}±1.60	7.48^{a}±1.58
0.5% stabilized soymilk	6.52^{ab}±1.66	7.60^{a}±1.35	7.56^{a}±1.36	7.20^{a}±1.56	7.16^{ab}±1.18
1.0% stabilized soymilk	6.12^{ab}±1.92	7.44^{ab}±1.33	7.52^{a}±1.30	6.72^{a}±1.90	6.64^{ab}±1.82
2.0% stabilized soymilk	7.28^{a}±1.49	8.04^{a}±1.02	7.72^{a}±1.17	7.28^{a}±1.28	7.20^{ab}±1.76
3.0% stabilized soymilk	6.40^{ab}±1.63	6.52^{bc}±1.98	6.80^{ab}±1.92	6.48^{a}±2.40	6.28^{b}±2.07

Values are means of triplicate determinations ± standard deviation. Means with the same superscripts within the same column are not significantly different (P>0.05)

5.7.2. Appearance

There was no significant (p>0.05) variation in appearance in the entire samples except in samples stabilized with 1 and 3% IPS. Sample stabilized with 2% was scored highest (8.04) while that stabilized with 3% IPS was scored the least (6.25). Therefore, 2.0% stabilized soymilk was liked very much by the panellist followed by that stabilized with 0.5% and control which were similar.

5.7.3. Consistency

The IPS stabilization had no significant (p>0.05) effect on the consistency of the entire soymilk samples except in sample stabilized with 3% IPS which was the least scored (6.80). Despite the similarity, sample stabilized with 2% IPS was scores highest (7.72). The results revealed that, the consistency of 3.0% stabilized soymilk was like slightly, while the consistency of the other samples was like moderately.

5.7.4. Aroma

There is no significant (p>0.05) impact of IPS stabilization on the aroma of stabilized soymilk samples. Despite the similarity, the aroma of the control sample was scored higher (7.64) than all the stabilized samples (6.48 to 7.28). Sample stabilized with 2% IPS had the highest score while that with 3% IPS had the least.

5.7.5. General Acceptability

The IPS stabilization decreased (7.20 to 6.28) general acceptability of the stabilized soymilk samples lower than the control (7.48). But samples stabilized with 0.5, 1 and 2% IPS were score the highest while that of 3% was the least (6.28). Stabilized samples with 1 and 3% IPS were slightly liked while other samples were moderately like with 2% IPS stabilized sample having the highest score (7.20) followed by 0.5% IPS stabilized sample. The higher score obtained in the un-stabilized soymilk could be attributed to the familiarity of consumers with consumption of plain soymilk.

6. Conclusion

The present study revealed that increase in Irish potato starch stabilization levels on pre-digested soymilk had better proximate, mineral and vitamin compositions with appreciable low anti-nutrient composition than the un-stabilized soymilk. Physicochemical properties also revealed increase in viscosity and specific gravity but decreased pH while shelf-stability, foam stability and acceptability were higher than un-stabilized soymilk at lower Irish potato starch stabilization levels of 0.5 to 2.0%.

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