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## Effects of sprouted soybeans and ginger on soymilk quality attributes via a developed dual-powered milk pasteurizer

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### ABSTRACT

Soymilk market has achieved tremendous progress in consumption and sales due to its inexpensiveness and soymilk protein content. However, due to the present global health crisis, there is a need to further devise means of enriching the quality of soymilk. This study aimed to evaluate the effects of sprouted soybeans and ginger on soymilk quality and sensory attributes. A developed dual-powered milk pasteurizer was used to produce the soymilk. Soybeans, a mixture of soybeans and sprouted soybeans, and sprouted soybeans were interacted with peeled ginger and whole ginger rhizome using Taguchi experimental design to produce nine soymilk samples. The proximate composition, calorific value, total phenolic content and phytic acid content of the soymilk samples were determined using standard procedures. The moisture content of the soymilk samples ranged from 80.85 to 83.78%, crude protein content (7.47 – 9.54%), ash content (0.72 – 1.27%), fibre content (0.24 – 0.73%), crude fat (0.24 - 5.44%), carbohydrate content (1.29 - 6.82%) and calorific value (67.6 kcal/g - 91.58 kcal/g). The total phenolic content and phytic acid content ranged from 4.81 mg/l to 11.88 GAE mg/l and 26.77 to 41.86 mg/l, respectively. The soymilk produced from the mixture of sprouted soybeans and un-sprouted soybeans with the addition of either whole or peeled ginger significantly increased the crude protein content, ash content, calorific value and total phenolic content to 9.54%, 1.27%, 91.58 kcal/g and 11.88 GAE mg/l, respectively. In addition, it increased the overall sensory acceptability of soymilk. Conclusively, the use of sprouted soybeans and the addition of ginger should be encouraged to promote a more enriched soymilk beverage. Also, the developed dual-powered milk pasteuriser could be adopted for soymilk production.

### Introduction

Soybean (*Glycine max* L. Merrill) is cultivated in tropical, subtropical and temperate climates, and it belongs to the family of Fabaceae. Soybean can be used to produce several products such as soymilk, soybean oil, soy protein, soy flour and soy sauce (James et al., 2016; Babalola and Fajoye, 2021). Soymilk is one of the essential traditional beverages consumed widely in developing countries due to its inexpensive and convenient source of proteins

(Nadifah and Sari, 2016). Babalola and Fajoye (2021) reported that soymilk produced under optimum conditions could have moisture, protein, ash, fat, fibre, and carbohydrate that are 88.49%, 3.69%, 0.58%, 0.93%, 1.46% and 4.84%, respectively, while Oyedeji et al. (2018) reported that soymilk contains potassium, calcium and vitamins A and B. Soymilk is a perfect substitute for cow milk as it has close nutritional content, but with lower fat content than cow milk (Imran et al., 2008; Salau, 2012). Also, soymilk contains no lactose, so it can be consumed by lactose-intolerant people and it is mostly non-allergic because

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it is gluten and casein free (Deepika et al., 2017). Sprouting is a technique used in germinating seeds from legumes through water or other media. Sprouting is reported to improve the nutritional value of seeds and reduce phytic acid and flatulence causing oligosaccharides (raffinose and stachyose), thereby increasing sensory properties and protein digestibility (Ojha et al., 2014). Murugkar (2014) reported sprouting of soybean as an approach that could be used in reducing anti-nutrients in soybean and increasing mineral availability. Since soymilk has been seen as an alternative to dairy milk, there is a need to enrich the functionality of soymilk products by modifying the processing steps through the addition of an active ingredient such as ginger that contains many nutrients such as fatty oil, protein, carbohydrate, crude fibre and ash (Khan et al., 2016). Ghayur and Gilani (2005) reported that ginger is a rhizome plant containing many bioactive compounds such as phenolic, flavonoids, vitamins and carotenes, and therefore possesses health-promoting properties. Several researchers have attempted to improve the quality of conventional soymilk. For instance, Jiang et al. (2013) produce soymilk from germinated soybeans and reported that 28 h soybean germination enhances the nutritional value of soymilk compared to conventional soymilk. Oyedeji et al. (2018) optimized some selected soybean sprouting parameters to improve its quality attributes while Murugkar (2014) and Le et al. (2021) also produced soymilk from sprouted soybean. Bolarinwa et al. (2021) enriched soymilk with papaya puree and reported an increase in Vitamin A and C and micronutrients in the soymilk. However, there is a dearth of information on the effects of sprouted soybeans and the addition of ginger on the quality attributes of soymilk. Therefore, improving the production process of soymilk by sprouting of soybeans and addition of ginger might pave way for the development of enriched soymilk. Due to the incessant power supply in developing countries, a dual-powered milk pasteurizer that uses electricity and liquefied propane gas (LPG), as a power source, was developed and adopted for this study. Therefore, the objective of this study was to produce soymilk from a dual-power milk pasteurizer and to evaluate the effects of sprouted soybeans and ginger on soymilk proximate composition, calorific value, total phenolic content, phytic acid and sensory attributes.

## Materials and methods

### *Sprouting of soybean*

The soybeans of the variety TGX1951-3F were bought from a local market in Ilorin, Nigeria. The

soybeans were cleaned to remove debris and stones. They were rinsed three times with potable water and soaked overnight for 12 h at room temperature in water to soybeans ratio of 10:1 v/w. The soaked soybeans were drained, rinsed and placed in a germination chamber. The germination chamber has a perforated sieve that holds the soybeans, and the seeds were watered three times a day at 6 h intervals under the germination chamber temperature of ~29 °C. The sprouting process was done for 72 h.

### *Preparation of ginger*

Fresh ginger rhizomes (*Zingiber officinale*) were washed thoroughly with water and separated into two portions. The exocarp of one portion was peeled using a sharp knife, while the other was left as whole ginger. The two portions were grinded separately, kept in a clean container and placed in a refrigerator until further use.

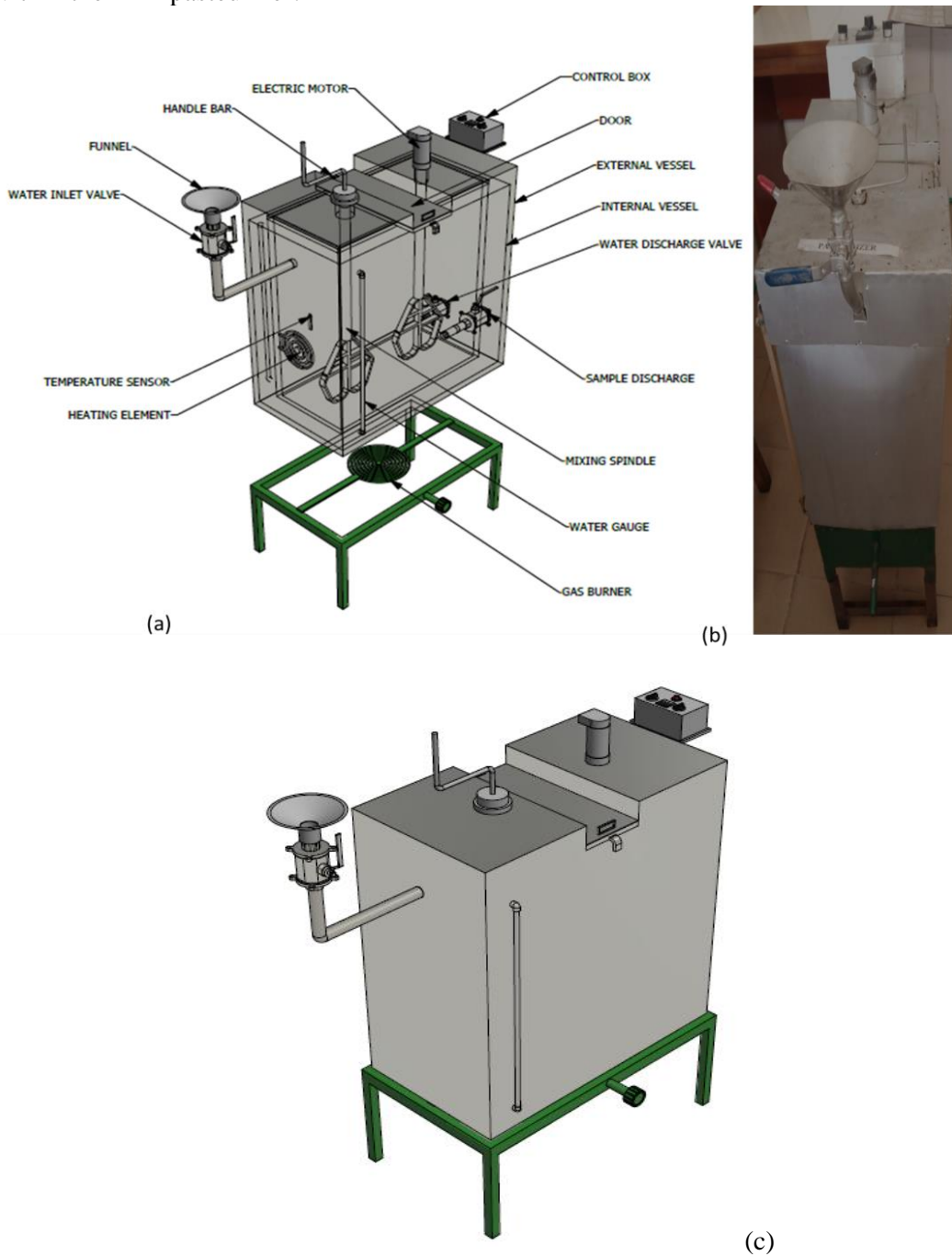
### *Description of developed dual-powered milk pasteurizer*

Figure 1 shows the isometric view, exploded and pictorial view of the developed dual-powered milk pasteurizer. The pasteurizer works on the principle of heat transfer and the theory of liquid mixing. Heat transfer is the movement of thermal energy from a region of higher temperature to a region of lower temperature. However, the heat transfer that applies to this milk pasteurizer is conduction mode of heat transfer. The pasteurizer is made up of a hand stirrer (handlebar) and an electric-powered stirrer. The handlebar was designed to serve as an alternative, basically on the stirrer in case of a power outage, while the electric motor-powered stirrer was designed to achieve a homogenous mixture of the product. The milk pasteurizer has an opening cover and exit valves that aid in easy cleaning of the pasteurizer. The internal vessel of the pasteurizer was designed to hold the milk products and it was constructed with AISI 304 stainless steel, while the external vessel was designed to hold water that serves as the heating medium for the internal vessel through conduction mode of heat transfer from the heating element or liquefied propane gas (LPG) combustion from the gas burner. Within the internal vessel, there is a temperature sensor that senses the temperature of the product within the internal vessel to send a signal to the temperature controller so as not to exceed the preset temperature. The funnel passage was designed in form of an inverted hollow cone and it serves to convey water to the external vessel. The water inlet valve allows and prevents

water into the external vessel while the discharge valve controls the collection of the end product. The water gauge is used to determine the water level in the external vessel. The standing frame serves as support to the pasteurizer for lifting it above the ground level. The gas burner was incorporated to produce a controlled flame that was generated from the LPG. The control box contains an on and off power switch, electric motor stirrer switch and temperature controller that regulates the temperature within the milk pasteurizer.

### Experimental design

Soybeans, sprouted soybeans, and a mixture of soybeans and sprouted soybeans were interacted with no ginger (control), peeled ginger and whole ginger rhizome using Taguchi orthogonal array design to generate nine (9) different combinations as shown in Table 1. The combinations were used to produce nine soymilk samples and their quality attributes were evaluated.



**Figure 1.** The developed dual-powered milk pasteurizer  
 (a) Exploded view (b) Pictorial view (c) Isometric view

### Soymilk preparation

Figure 2 shows the flowchart used for the production of soymilk produced from sprouted and un-sprouted soybeans with the addition of ginger. For the soymilk production, 3000 g of soybeans, a mixture of 1500 g of soybeans and 1500 g of sprouted soybeans and 3000 g of sprouted soybeans were used, respectively. For the un-sprouted soymilk, the soybeans were soaked for 12 h. The water was discarded, and then the soy marinade was washed back and boiled for 5 mins to increase the rate of exfoliating the hull. The dehulled soybeans were mixed with water at different ratios of 1 to 9 v/w. The mixture was then blended using a blender (Model ST4PN: Germany), and the grinding was terminated when smooth slurries were obtained. For the sprouted soybeans, the soybean was sprouted before the dehulling, boiling and grinding process, and for the mixed (50% sprouted and 50% un-sprouted soybeans) soymilk, 50% of the soybean were sprouted, and another 50% were soaked for 24 h, after which they were mixed, then dehulled, boiled and then grounded. The slurries were filtered separately through a mesh screen to separate the solution of milk from soybean dregs. The milk solution was boiled in the developed milk pasteurizer (Figure 1) at 100 °C for 20 min. 150 g of finely ground ginger, 2.5 g of ground cloves and 750 g of sugar were added to the soymilk solution at 100 °C, while for the soymilk samples that do not require ginger, 2.5 g of ground cloves and 750 g of sugar were added to the soymilk solution. The clove

served as a natural preservative (Kabiru et al., 2012). The cooked soymilk samples were filtered to remove the ginger and cloves residue, poured while hot in glass jar and kept in a refrigerator at 4 °C.

### Reagents and chemicals

Folin-Ciocalteu reagent and phytic acid were supplied by Biofare research laboratory (Ilorin, Nigeria). Other chemicals and reagents used were of analytical grade and also supplied by Biofare research laboratory (Ilorin, Nigeria).

### Determination of quality attributes

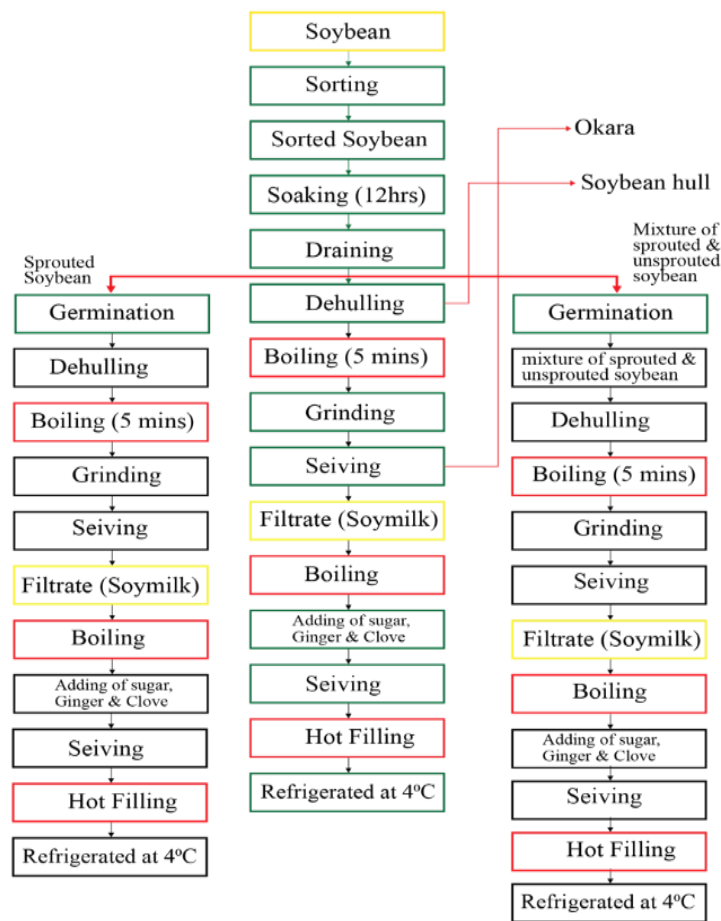
#### Proximate composition

Approximately 10 g of soymilk was weighed into a pre-weighed crucible and dried in a hot air oven at 100 °C for 15 h. The dried residue was weighed after cooling in a desiccator to determine the moisture content. The dried residue was burned in a muffle furnace at 550 °C for 12 h to determine the ash content. Crude protein content was determined by the Kjeldahl method using a conversion factor of 6.25. Crude fat content was measured by weight after alkaline hydrolysis coupled with solvent extraction (ether and petroleum ether). The carbohydrate content was calculated by subtracting the moisture, protein, fat, fibre and ash content from the total mass (Imran et al., 2010; AOAC, 2010; Jiang et al., 2013).

**Table 1.** Taguchi experimental design outline for the effects of sprouted soybean and ginger on the quality attributes of soymilk

Experimental runs	Soybean	Ginger
1	U	N
2	U	WG
3	U	PG
4	S	N
5	S	WG
6	S	PG
7	MUS	N
8	MUS	WG
9	MUS	PG

where U is un-sprouted soybeans, S is 100% sprouted soybeans and MUS is the mixture of 50% sprouted and 50% un-sprouted soybeans, while N, WG and PG mean no ginger addition, whole ginger addition and peeled ginger addition, respectively.



**Figure 2.** Flow chart for production of soymilk produced from sprouted and un-sprouted soybeans with the addition of ginger

*Calorie value determination*

Calorie value was determined using Ezeonu et al. (2016) method. The method involves multiplying % carbohydrate content by 4%, protein content by 4% and fat content by 9% as shown in Equation 1. The energy was measured in kilo-calories/100 g (Kcal/100 g).

$$\text{Calorific value}=(\%CP \times 4)+(\%CFT \times 9)+(\%CHO \times 4) \quad (1)$$

where CP is the of percentage crude protein, CFT is the percentage of crude fat and CHO is the percentage of carbohydrate

*Total phenolic content (TPC)*

The total phenolic contents of the soymilk samples were determined using the method described by Jiang et al. (2013). Acidic acetone was used as an extraction solvent to extract total phenolic contents from freeze-dried soymilk. Dry powder of 0.5 g was extracted twice with 5 mL of acidic acetone at ratios 70-acetone: 29-water: 0.5-acetic acid. Folin-Ciocalteu assay using gallic acid (GA) as the external standard was used to determine the TPCs. The mixture solution prepared from sample extracts (50 μL), distilled water (3950 μL), Folin-Ciocalteu’s reagent (250 μL) and 7% Na<sub>2</sub>CO<sub>3</sub> (750 μL) was vortexed and allowed to stand for 2 h. The absorbance was measured using a UV-visible spectrophotometer (TU-1901, Beijing Purkinje General Instrument Co., Ltd., Beijing, China) against a reagent blank at 765 nm. The TPC was determined from the gallic acid calibration curve and expressed as milligrams of gallic acid

equivalents per gram of freeze-dried soymilk (mg GAE/g).

#### *Phytic acid content determination*

Phytic acid contents in the soymilk samples were extracted following the method described by Jiang et al. (2013) and Lai et al. (2013). Ten (10) mL petroleum ether was used to defat 0.5 g of freeze-dried soymilk. The residues were then collected for 14 h using 10 mL of 2.4% HCL in an orbit shaker. The supernatant was collected for analysis after centrifugation. The amount of phytic acid in the sample was determined using a colorimetric assay. One (1) mL Wade Reagent (0.03%  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$  + 0.3% sulfosalicylic acid) was thoroughly combined with 0.1 mL of the sample extract and diluted to 3 ml with distilled water. The phytic acid content was measured using a phytic acid standard calibration curve and expressed in milligrams of phytic acid (PA) per gram of freeze-dried soymilk (mg/g).

#### *Sensory evaluation*

Sensory evaluation was conducted to determine consumers responses and to discern the best type of soymilk. This was done on soymilk that had been stored for 24 h at 4 °C for proper flavour development. Sensory attributes of the samples were evaluated by 15 semi-trained panelists who are conversant with soymilk. The colour, taste, flavour, texture and overall acceptability were the sensory attributes that were evaluated. Soymilk samples were served at room temperature (27 °C) in coded plastic disposable cups. Water was given to the panelists for palate cleansing between samples. Panelists were presented with 30 ml of each of the nine (9) soymilk samples. Nine (9) points hedonic scale was used to determine the responses of panelists for each attribute, where “9” represents extremely like and “1” represents extremely dislike.

#### *Statistical analysis*

All the soymilk samples were conducted in duplicate, and the results were expressed as the mean  $\pm$  standard deviation. Analysis of variance (ANOVA) of the data was performed using the SPSS package (SPSS 20.0, SPSS Inc., Chicago, IL, USA). Duncan multiple tests with a confidence interval of 95% were used to determine significant differences between means.

## **Results and discussion**

### Proximate composition of soymilk

#### Moisture content

Table 2 shows the effect of sprouted soybean and ginger on the proximate composition of soymilk. It was observed that the moisture content ranged from 80.85% to 83.78%. The highest moisture content was found in soymilk produced from un-sprouted soybeans with no ginger (83.78%) while soymilk produced from sprouted soybean and peeled ginger was observed to have the lowest moisture content (80.85%). A holistic look at the trend in the moisture content revealed a decreasing trend in the moisture content of soymilk produced from un-sprouted soybeans to soymilk produced from sprouted soybeans, which could be attributed to the sprouting process and the addition of ginger. Sprouting causes the exfoliation of soybean skin and reduces its water retention capacity, so there is a possibility that sprouting influences the moisture content of soymilk. A decreasing trend in the moisture content was observed when whole ginger and peeled ginger were added to the soymilk produced from either sprouted soybean or a mixture of 50% un-sprouted soybeans and 50% sprouted soybeans. The moisture content obtained were lower than 89.20% to 93.21% reported by Ugochi et al. (2015), but higher than 69.38 to 72.65% reported by Folorunsho et al. (2015). The observed reduction in the moisture content could be attributed to the differences in the total solid content of the soymilk samples. Partial coagulation of protein could also influence the moisture content of soymilk samples. The specific impact of ginger inclusion and sprouting on moisture content has not been explicitly established in the literature. However, this study agreed with established thought in the literature that the metabolic reaction of sprouting could cause the reduction in the moisture content and does not rule out the possibility of ginger addition influencing the moisture content.

Therefore, soymilk samples with lower moisture contents are expected to have a longer shelf life and be less prone to microbial growth and proliferation and thus could positively impact its storage stability.

#### *Crude protein*

The crude protein content obtained ranged from 7.47% to 9.54%. The highest protein content (9.54%) was observed in soymilk produced from a mixture of 50% sprouted soybeans and 50% un-sprouted soybeans, and with whole ginger inclusion. Although, there was no significant difference in the crude protein content of the soymilk that has ginger and without ginger, but the soymilk must be produced from a mixture of 50%



sprouted soybeans and 50% un-sprouted soybeans. The least crude protein content (7.47%) was observed in soymilk produced from un-sprouted soybean with no ginger. Sprouting was observed to influence the crude protein content of the soymilk produced from sprouted soybeans. This result correlates with the findings of Murugkar (2014), that soymilk prepared from sprouted soybeans was richer in crude protein than the one prepared from un-sprouted soybeans. Oyedeji et al. (2018) also established the same findings with soymilk protein values that ranged between 1.3% and 2.26%. However, the crude protein contents obtained in this study were higher when compared with 3.9 to 4.1% and 1.3 to 2.26% reported by Murugkar (2014) and Oyedeji et al. (2018), respectively. Murugkar (2014) confirmed that the metabolic breakdown of the nutrients due to sprouting increased the protein content of soymilk. It is also important to stress that ginger inclusion could contribute to the increase in the protein content of soymilk samples. Ajayi et al. (2013) reported that ginger has certain levels of protein that ranged between 11.65% and 12.05%, and this might have a significant effect on the overall protein content of the soymilk samples.

#### *Ash content*

The ash content of the soymilk samples ranged from 0.72% to 1.27%. The soymilk sample with the highest ash content was produced from the mixture of 50% sprouted soybeans and 50% un-sprouted soybeans with peeled ginger. The soymilk sample with the lowest ash content was produced from un-sprouted soybeans with no ginger. The differences in the ash content could be a result of the differences in the dry matter of the samples (Sanusi et al., 2022). It could also be attributed to the sprouting of the soybean and the inclusion of ginger in the soymilk samples. The ash contents of the soymilk samples were higher than 0.01% to 0.88% reported by Folorunsho et al. (2015) and Ugochi et al. (2015), respectively. The implication of this finding enables a convenient assertion that the ash content of soymilk samples can be increased with the sprouting of soybeans and ginger inclusion.

#### *Crude fibre*

The crude fibre of the soymilk samples ranged from 0.24% to 0.73%. Soymilk with the highest crude fibre (0.73%) was produced from the mixture of 50% sprouted soybeans and 50% un-sprouted soybeans with peeled ginger. The soymilk with the lowest crude fibre (0.24%) was produced from un-sprouted soybeans. Correlating the findings made in this study

with those established in other works revealed that the results obtained were higher than those reported by Ugochi et al. (2015) and Obi (2014), who recorded values that ranged from 0.081% to 0.087% and 0.13% - 0.33%, respectively. Sprouting could have contributed to this disparity, but it is not plausible enough to assume that this might be the only cause of the high crude fibre content. However, it is convenient to assert that the high differential increase may be due to the effect of sprouting and ginger in the soymilk.

#### *Crude fat*

Soymilk is known to be naturally low in saturated fat, and it is cholesterol-free. It contains Omega-3-fatty acids, which are healthy fats that the body itself cannot form. The soymilk sample with the highest fat content (5.44%) was produced from sprouted soybeans with the addition of whole ginger. The soymilk with the lowest crude fat content (0.24%) was produced from sprouted soybeans. This result corroborates with the findings in the literature that sprouting reduces the fat content of soymilk. For instance, in the study conducted by Folorunso et al. (2015) and Ugochi et al. (2015), low crude fat content in soymilk produced from sprouted soybeans ranged from 1.87 to 3.12% and 1.98 to 2.18%, respectively. The reduction in the fat content in soymilk could be attributed to the catabolic activities that occur in the soybean's cotyledon during sprouting (Murugkar, 2014). In the specific context of the findings made in this study, a plausible explanation that could be given for the high-fat content in samples B and E could be attributed to the fact that whole ginger was added. The high-fat content of ginger had been reported by Ajayi et al. (2013). Therefore, it is safe to theorize that the addition of ginger into the soymilk contributed to the fat content of the soymilk samples.

#### *Carbohydrate content*

Soymilk is usually taken as a substitute by lactose-intolerant people due to the absence of lactose traditionally found in cow's milk. Carbohydrate is known as the body's primary source of energy. In soymilk, it is made up of sugar and fibre (Liu, 2008). The carbohydrate content of the soymilk samples ranged from 1.29% to 6.82%. The soymilk with the highest carbohydrate content (6.82%) was produced from the mixture of 50% sprouted soybeans and 50% un-sprouted soybeans with no ginger addition, while the lowest (1.29%) was produced from sprouted soybeans with whole ginger addition. There were no significant differences in the carbohydrate content of samples B, D and F, respectively. A general holistic

look at the trend in the carbohydrate content revealed an inconsistent decreasing trend in the carbohydrate content of the soymilk samples. Hence, the result obtained was correlated with some of the findings in closely related works. The soymilk samples' carbohydrate contents were lower compared to those reported by Folorunso et al. (2015), whose carbohydrate contents ranged from 10.81% - 15.16%. Liu (2008) also reported values in the range of 0.8 - 11.7%, which were within the values obtained in this study.

*Calorie value content of soymilk*

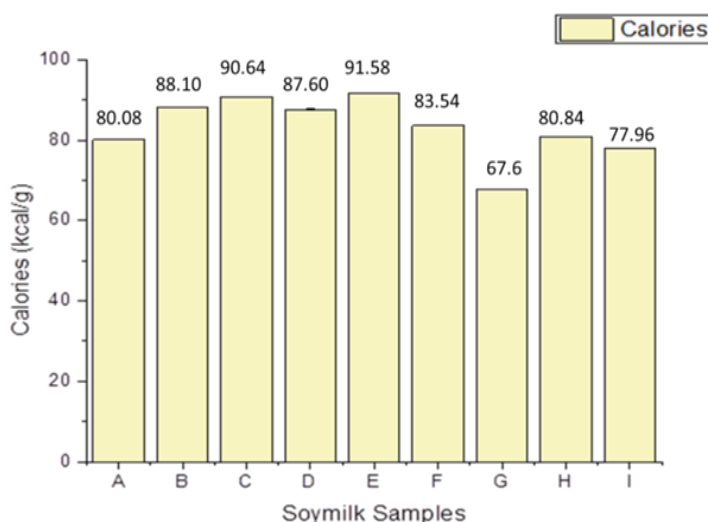
Assessment of energy value, otherwise called calorie content, is a vital food quality parameter in beverage production. Figure 3 shows the calorie values of the

soymilk samples produced. It has been established that an average man needs as much as 2500 kcal supply of energy daily to maintain a healthy body weight (Babatunde et al., 2010). Beverages such as soymilk can be used as energy supplements, which could be one of the reasons behind the increasing popularity of soymilk consumption across the globe. The soymilk samples produced were found to contain an appreciable number of calories. The highest calorie content (91.58 kcal/g) observed in sample E was produced from sprouted soybeans with the addition of whole ginger, while the lowest (67.6 kcal/g) was observed in sample G and it was produced from the mixture of 50% sprouted soybeans and 50% un-sprouted soybeans with no ginger addition.

**Table 2.** Effect of sprouted soybeans and ginger on proximate composition of soymilk

Soymilk samples	Soybean	Ginger	Moisture content (%)	Ash (%)	Crude Fibre (%)	Crude Fat (%)	Crude Protein (%)	Carbohydrate (%)
A	U	N	83.78±0.11 <sup>a</sup>	0.72±0.06 <sup>c</sup>	0.24±0.00 <sup>c</sup>	4.00±0.28 <sup>d</sup>	7.47±0.02 <sup>g</sup>	3.55±0.26 <sup>c</sup>
B	U	WG	83.52±0.00 <sup>a</sup>	0.88±0.14 <sup>bc</sup>	0.48±0.05 <sup>b</sup>	5.34±0.00 <sup>a</sup>	8.14±0.01 <sup>e</sup>	1.87±0.15 <sup>e</sup>
C	U	PG	83.11±0.64 <sup>ab</sup>	1.19±0.00 <sup>a</sup>	0.50±0.00 <sup>b</sup>	4.16±0.00 <sup>d</sup>	7.64±0.00 <sup>f</sup>	5.66±0.00 <sup>b</sup>
D	S	N	82.67±0.17 <sup>b</sup>	1.26±0.13 <sup>a</sup>	0.47±0.00 <sup>b</sup>	0.24±0.00 <sup>g</sup>	8.59±0.01 <sup>d</sup>	1.97±0.04 <sup>e</sup>
E	S	WG	82.30±0.12 <sup>b</sup>	0.89±0.07 <sup>bc</sup>	0.67±0.00 <sup>a</sup>	5.44±0.00 <sup>a</sup>	9.41±0.02 <sup>b</sup>	1.29±0.07 <sup>f</sup>
F	S	PG	80.85±0.00 <sup>c</sup>	0.95±0.04 <sup>b</sup>	0.53±0.00 <sup>b</sup>	4.46±0.00 <sup>c</sup>	9.01±0.02 <sup>c</sup>	1.84±0.14 <sup>e</sup>
G	MUS	N	82.54±0.96 <sup>b</sup>	0.86±0.08 <sup>bc</sup>	0.50±0.76 <sup>b</sup>	5.04±0.00 <sup>b</sup>	9.54±0.02 <sup>a</sup>	6.82±0.21 <sup>a</sup>
H	MUS	WG	82.43±0.00 <sup>b</sup>	0.96±0.12 <sup>b</sup>	0.15±0.12 <sup>c</sup>	3.00±0.00 <sup>f</sup>	9.54±0.01 <sup>a</sup>	3.92±0.11 <sup>c</sup>
I	MUS	PG	82.57±0.19 <sup>b</sup>	1.27±0.05 <sup>a</sup>	0.73±0.05 <sup>a</sup>	3.24±0.00 <sup>e</sup>	9.42±0.02 <sup>b</sup>	2.78±0.34 <sup>d</sup>

\*U, S and MUS mean un-sprouted soybeans, 100% sprouted soybeans and a mixture of 50% sprouted and 50% un-sprouted soybeans, while N, WG and PG mean no ginger addition, whole ginger addition and peeled ginger addition, respectively. \*Values with different letters as subscripts have significant differences along the same column (p≤0.05).



**Figure 3.** Effect of sprouted soybeans and ginger on calorie value of soymilk

A is the un-sprouted soybeans with no ginger, B is the un-sprouted soybeans with whole ginger, C is the un-sprouted soybeans with peeled ginger, D is the sprouted soybeans with no ginger, E is the sprouted soybeans with whole ginger, F is the sprouted soybeans with peeled ginger soymilk, G is mixed (50% sprouted soybeans and 50% un-sprouted soybeans) with no ginger, H is the mixed (50% sprouted soybeans and 50% un-sprouted soybeans) with whole ginger and I is the mixed (50% sprouted soybeans and 50% un-sprouted soybeans) with peeled ginger

\*Values with the same letters as subscripts along the same column have no significant difference (P≥0.05).

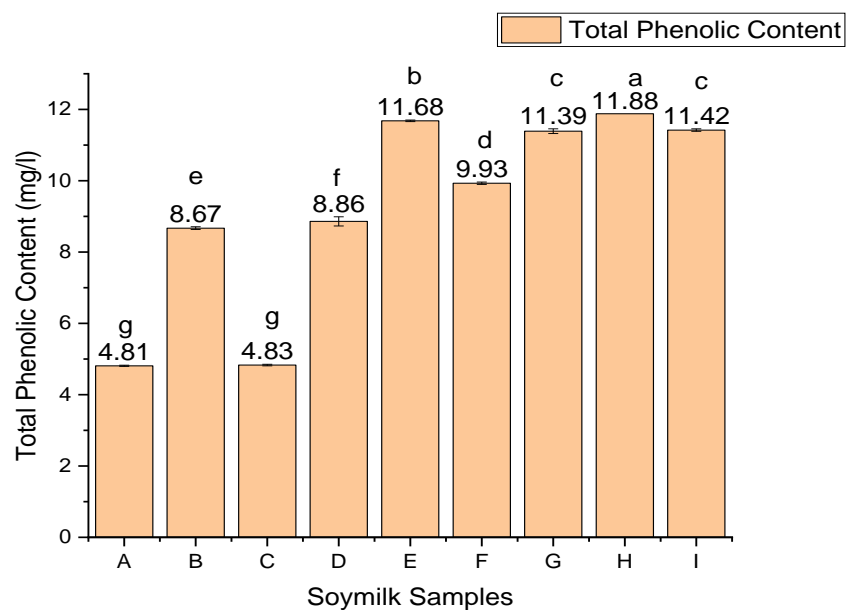


The calorie content of the soymilk samples produced under different influences of sprouting and ginger was found to be higher than those reported by Hajirostamloo and Mahastie (2009), who reported that the calorie value of soymilk is 76 kcal/g. Etiosa et al. (2018) reported a lower calorie content (46.9 kcal/g), while Folorunso et al. (2015) reported a higher calorie content that ranged from 114.35±8.91 kcal/g to 132±4.47 kcal/g. The soymilk samples with the addition of either whole ginger or peeled ginger were observed to have higher calorie content than the samples that are free of ginger.

#### *Effect of sprouted soybeans and ginger on total phenolic content of soymilk*

Total phenolic components contribute to the nutritional profile and benefit of beverages due to their ability to scavenge free radicals. Some of the advantages of total phenolic content include its potential in acting as anti-ageing, anti-inflammatory, anti-oxidant and anti-proliferative agent in the body system. This same chemical entity has also been said to mitigate the development of long-term diabetes complications (Ma and Huang, 2014). Hence, Figure 4 shows the effect of sprouted soybeans and ginger on total phenolic content of soymilk samples. An increase in the total phenolic content of soymilk samples was observed in those produced from sprouted soybeans with the addition of whole ginger. As observed in Figure 4, total phenolic content was higher in soymilk

produced from sprouted soybeans and a mixture of 50% un-sprouted and 50% sprouted soybeans with the addition of ginger. The total phenolic content of the samples ranged between 4.81 and 11.88 GAE mg/l. The soymilk with the highest value of total phenolic content (11.88 GAE mg/l) was produced from the mixture of sprouted and un-sprouted soybeans with the addition of whole ginger. The soymilk samples with the lowest total phenolic content were produced in samples A and C with no significant difference at  $p \geq 0.05$ , while other soymilk samples have a distinctively significant difference. The increase in the total phenolic content can be attributed to sprouting, as it has been reported to play an essential role in increasing phenolic content of soybeans. For instance, Jiang et al. (2013) reported that the phenolic content of soymilk ranged between 2.41 GAE mg/l and 4.30 GAE mg/l and this is lower than those observed in this study. Ma and Huang (2014) also reported an increase in total phenolic contents that ranged between 3.94 GAE mg/l and 5.52 GAE mg/l. Jiang et al. (2013) reported that the sprouting process increases phenolic compounds in soybeans because of the bio-synthesis and bio-accumulation of total phenolic compounds as a protective mechanism to survive under stressful environmental conditions. In addition, it was observed that the addition of ginger, either as whole or peeled, played an important role in the increment of total phenolic content.

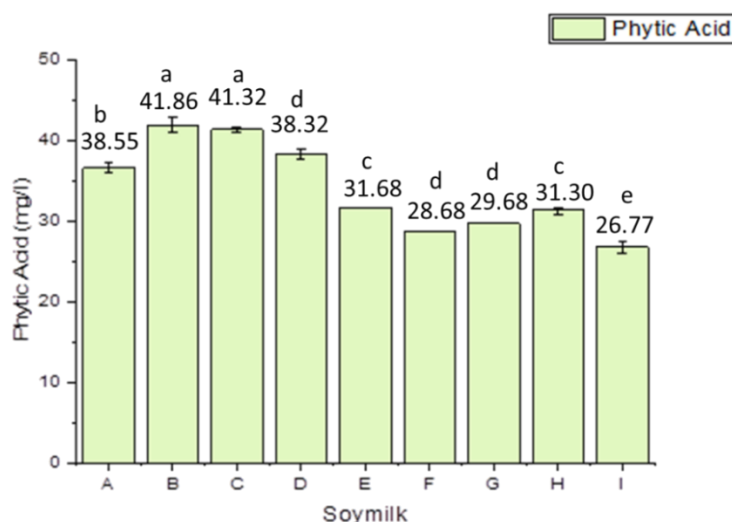


**Figure 4.** Effect of sprouted soybeans and ginger on total phenolic content of soymilk

### Effect of sprouted soybeans and ginger on phytic acid content of soymilk

The effect of sprouted soybeans and ginger on the phytic acid content of soymilk is presented in Figure 5. Phytic acid in food is known as an anti-nutrient, but it is also known to have health benefits when found in food. Oboh (2006) reported that it serves as an antioxidant that can help prevent cancer. The phytic acid content in the soymilk samples was between 26.77 mg/l and 41.86 mg/l. The soymilk sample with the highest phytic acid content was observed in soymilk produced from un-sprouted soybeans with the addition of whole ginger (41.86 mg/l), while the least phytic acid content was produced from the mixture of 50% un-sprouted soybeans and 50% sprouted soybeans with the addition of peeled ginger (26.77 mg/l). This result is in line with the work conducted by Oyedeji et al. (2018) (29 mg/l – 39 mg/l), in which the effect of sprouting on phytic acid content of soymilk

was assessed and found to decrease significantly. Murugkar (2014) explained that the reduction in the phytic acid content of soymilk could be explained in terms of the activity of phytase released during sprouting. In the specific context of this study, the increment in phytic content is significantly higher than those in the work of Murugkar (2014) (16 mg/l – 27 mg/l), which may be attributed to the addition of whole and peeled ginger. Ajayi et al. (2013) reported a distinguished level of phytic acid presence in ginger. Nevertheless, it is essential to note that the high phytic acid content, which may be considered an anti-nutrient, is not a reason to avoid consuming soymilk with ginger as long as it is within the permissible range for consumption. Lönnerdal et al. (1999) reported that the phytic acid in soymilk within 60 mg/l is referred to as low-phytate soymilk and is safe for consumption. Therefore, the soymilk samples produced are still within an acceptable range.



**Figure 5.** Effect of sprouted soybeans and ginger on phytic acid content of soymilk

A is the un-sprouted soybeans with no ginger, B is the un-sprouted soybeans with whole ginger, C is the un-sprouted soybeans with peeled ginger, D is the sprouted soybeans with no ginger, E is the sprouted soybeans with whole ginger, F is the sprouted soybeans with peeled ginger soymilk, G is mixed (50% sprouted soybeans and 50% un-sprouted soybeans) with no ginger, H is the mixed (50% sprouted soybeans and 50% un-sprouted soybeans) with whole ginger and I is the mixed (50% sprouted soybeans and 50% un-sprouted soybeans) with peeled ginger

\*Values with the same letters as subscripts along the same column have no significant difference ( $P \geq 0.05$ ).

### Sensory attributes of the soymilk samples

The mean score for the sensory attributes of the soymilk samples was presented in Table 3. The mean score of the colour of the soymilk samples ranged from 6.60 to 7.47. Sample H, produced from the mixture of 50% sprouted soybeans and 50% un-sprouted soybeans with the addition of whole ginger had the highest colour likeness from the panelist, while the

sample D (sprouted soybeans with no ginger) had the least. Soymilk samples with ginger addition were more preferred in terms of colour. The soymilk sample that had the highest likeness for taste was observed in sample I (7.93), which was produced from the mixture of 50% sprouted soybeans and 50% un-sprouted soybeans with the addition of peeled ginger, while sample D (6.87), that was produced from sprouted soybeans with no ginger, had the least taste. The

soymilk sample with the highest likeness for flavour was observed in sample I (8.00) produced from the mixture of 50% sprouted soybeans and 50% un-sprouted soybeans with the addition of peeled ginger, while the least (6.00) was observed in sample A when produced from un-sprouted soybeans with no ginger inclusion. To ascertain the panelists' preference for

texture, it ranged from 6.67 to 7.73 with sample H having the highest value, while the least was observed in sample D. The overall acceptability of the soymilk samples ranged from 7.20 to 8.20 with sample H having the highest overall acceptability, while sample D had the least overall acceptability.

**Table 3.** Sensory attributes of the Soymilk Samples

Soy milk Samples	Soybeans	Ginger	Colour	Taste	Flavour	Texture	Overall acceptability
A	U	0	6.73 ± 0.79 <sup>cd</sup>	7.87 ± 0.74 <sup>bcd</sup>	6.00 ± 1.19 <sup>d</sup>	7.07 ± 0.88 <sup>abc</sup>	7.27 ± 0.59 <sup>b</sup>
B	U	1	6.80 ± 0.68 <sup>bcd</sup>	7.67 ± 0.61 <sup>cd</sup>	6.80 ± 1.01 <sup>bc</sup>	7.40 ± 0.74 <sup>ab</sup>	7.53 ± 0.83 <sup>ab</sup>
C	U	2	7.07 ± 0.79 <sup>abcd</sup>	7.40 ± 0.91 <sup>d</sup>	6.53 ± 0.92 <sup>cd</sup>	7.06 ± 0.88 <sup>abc</sup>	7.67 ± 0.98 <sup>ab</sup>
D	S	0	6.60 ± 0.83 <sup>d</sup>	6.87 ± 0.74 <sup>e</sup>	7.40 ± 0.91 <sup>ab</sup>	6.67 ± 1.11 <sup>bc</sup>	7.20 ± 1.21 <sup>b</sup>
E	S	1	7.33 ± 0.82 <sup>abc</sup>	7.20 ± 1.15 <sup>bc</sup>	7.40 ± 1.06 <sup>ab</sup>	7.07 ± 1.22 <sup>abc</sup>	8.07 ± 0.59 <sup>ab</sup>
F	S	2	6.80 ± 0.78 <sup>bcd</sup>	7.27 ± 1.03 <sup>bc</sup>	7.07 ± 1.03 <sup>bc</sup>	6.40 ± 0.99 <sup>c</sup>	7.80 ± 0.86 <sup>a</sup>
G	MUS	0	7.20 ± 0.86 <sup>abcd</sup>	7.40 ± 0.83 <sup>ab</sup>	7.53 ± 0.83 <sup>ab</sup>	7.60 ± 0.63 <sup>a</sup>	8.07 ± 0.70 <sup>a</sup>
H	MUS	1	7.47 ± 0.64 <sup>a</sup>	7.13 ± 0.74 <sup>bc</sup>	7.13 ± 0.99 <sup>bc</sup>	7.73 ± 0.79 <sup>a</sup>	8.20 ± 0.56 <sup>a</sup>
I	MUS	2	7.40 ± 0.63 <sup>bc</sup>	7.93 ± 0.46 <sup>a</sup>	8.00 ± 0.76 <sup>a</sup>	7.27 ± 0.79 <sup>ab</sup>	8.13 ± 0.83 <sup>a</sup>

A is the un-sprouted soybeans with no ginger, B is the un-sprouted soybeans with whole ginger, C is the un-sprouted soybeans with peeled ginger, D is the sprouted soybeans with no ginger, E is the sprouted soybeans with whole ginger, F is the sprouted soybeans with peeled ginger soymilk, G is mixed (50% sprouted soybeans and 50% un-sprouted soybeans) with no ginger, H is the mixed (50% sprouted soybeans and 50% un-sprouted soybeans) with whole ginger and I is the mixed (50% sprouted soybeans and 50% un-sprouted soybeans) with peeled ginger \*Values with the same letters as subscripts along the same column have no significant difference ( $P \geq 0.05$ ).

## Conclusions

A dual-powered milk pasteurizer that uses both electricity and liquefied propane gas combustion was developed and used to produce soymilk. The sprouting of soybeans and the addition of ginger significantly influence the proximate composition, calorific value, total phenolic content and phytic acid contents of soymilk. There was an increase in the crude protein content of soymilk produced from the mixture of sprouted soybeans and un-sprouted soybeans with the addition of whole ginger. Soymilk with the highest ash content was produced from a mixture of sprouted and un-sprouted soybeans with the addition of peeled ginger while the soymilk with the highest fat content was produced from sprouted soybeans with the addition of whole ginger. The total phenolic content increased appreciably due to the effect of sprouting of soybeans and the addition of ginger, while the phytic acid was reduced in soymilk produced from sprouted soybeans but increased with the addition of whole or peeled ginger. Therefore, the adoption of sprouting technique with the addition of ginger could be a strategic process of enriching the quality and sensory attributes of soymilk. In addition, the developed dual-powered milk pasteurizer could be adopted for mass production of soymilk.

*Author Contributions:* Sanusi Mayowa Saheed designed the study, analyzed the data and wrote the

manuscripts. Sunmonu Musiliu Olushola and Sani Rafat assisted in the supervision of the work and review of the manuscript, Al Ameen Adeola Adesanya, Ameen Gegele Hamed and Abodunrin Tolulope assisted in the laboratory analysis of the study and were also involved in the review of the manuscript. It is herein agreed that we will not publish her contribution mentioned above anywhere else without prior written permission from the publisher.

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