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EFFECT OF INLET-AIR TEMPERATURE ON PHYSICO-CHEMICAL AND SENSORY PROPERTIES OF SPRAY-DRIED SOY MILK

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ABSTRACT

Samples of spray-dried soy milk powder were produced at various spray-dryer inlet-air temperatures and characterized. Soybean seed (*Glycine max* TAX 1448 – 2E Var.) was sorted, boiled for 40 min, manually dehulled, wet milled using plate mill and sieved with muslin cloth to obtain water soluble extract (soy milk). The soy milk was divided into two portions (samples A and B) and spray-dried using co-current spray dryer at a constant feed rate (20.5 ml/sec) but at air-inlet temperatures of 204°C and 260°C, respectively. Preliminary investigation carried out on this study showed that samples produced at air inlet temperatures below 200°C exhibited wet and agglomerated particles. The recovered powdered samples were analyzed for proximate composition, pH, available lysine, total solids, pack bulk density, viscosity, solubility and wettability at different reconstituting water temperatures, and sensory properties. Results showed that 38.60% and 45.55% yield (soy milk powder) were achieved at the end of the process for samples A and B respectively. The samples showed no significant differences ($P \geq 0.05$) in some of these evaluated parameters such as fat, ash and pH. Soy milk powder showed high protein content (62.05±0.23%), fat (19.92±0.08%), ash (1.41±0.02 %) and available lysine (5.02±0.29%), but low carbohydrate content (12.85±0.01 %) and moisture (3.66±0.23%). The physical properties showed that the mean total solid of the samples was 10.33±0.33%, pack bulk density (0.57±0.00 g/ml), while the mean viscosity was 47 mpas. The sample spray-dried at 204°C had solubilities of 48% and 78% at reconstituting water temperatures of 40°C and 80°C, respectively while the sample produced at 260°C showed lower solubility of 38.46% and 45.01% when temperature of reconstitution were 40°C and 60°C, respectively. However, the sample produced at 260°C exhibited decreased solubility when the reconstituting water temperature was raised above 60°C. Its solubility was 40.39% at reconstituting water temperature of 70°C which further decreased to 38% at 80°C. The wettability of the samples steadily decreased as the reconstituting water temperature increased from 40 to 80°C. The wettability of the sample spray-dried at 204°C decreased from 36 to 22 sec, while that of sample spray-dried at 260°C decreased from 29 to 18 sec. Sensory scores showed that the sample spray-dried at 204°C was preferred to the sample spray-dried at 260°C.

Key words: Soy milk, spray-drying, proximate, physical, sensory

INTRODUCTION

In Nigeria, greater than 70% of the soybean processing industry is involved in oil extraction activities and full-fat soy flour production, while the rest is involved in direct food product manufacture using soy flour [1]. Soybean recently has found increasing acceptance in Nigerian diets due to claims linking the consumption of soy protein to a lower risk of heart disease, reduction of blood cholesterol level and prevention or treatment of chronic diseases, most notably cancer, osteoporosis and kidney disease [2, 3]. In South East Asia, the average consumption of soybeans in various forms per person is as high as 77 g on daily basis [4]. In Japan and China, soybean meal has been used in production of animal feeds and fertilizers [5, 6]. In the United States of America, commercial corn-soy milk and wheat-soy meal blends serve as cheap but nutritious infant formula ingredients. Breakfast cereals, macaroni, spaghetti, noodles flakes and sausage binders are partly made of soy meal [7, 8]. Lactose intolerant people who feel discomfort and pain when they consume dairy milk can drink soy milk as an alternative to dairy milk because soy milk being a plant product lacks lactose [9, 10]. Full fat soy flour nutritive content ranks close to that of cow milk, and could be used for fighting protein malnutrition [6]. Characterization of a spray-dried soy milk powder and changes observed during storage had been studied; it was observed that powder particles are covered by a layer of fat, and during storage at 25^{o}C, fat spreads over the surface, while at -12^{o}C the fat contracts [11]. Soy milk can be produced for roughly one third the cost of producing the weight equivalent of spray-dried cow milk [12]. Spray-drying of soy milk at varied temperatures to ascertain the extent of heat destruction of the trypsin inhibitor and available lysine content has been studied [9, 13]. Thermal processing of soy milk destroys biologically active anti-nutritional components of soybean like trypsin inhibitors, urease, hemagglutinins, goitrogens and saponins. However, overheating could cause adverse effect on the nutritional value by reducing the protein efficiency ratio due to loss of lysine [14]. Optimal heat treatment of soybeans should not be based only on destruction of deleterious components, but consideration should be given to extent of destruction of the nutrients [15]. Soy milk heated at 93^{o}C for 60min had residual trypsin inhibitor activity of 14% but when heated at the same temperature for 120 min, the residual trypsin inhibitor activity reduced to 4%. Soybean seed steamed at 121^{o}C for 5 min exhibited residual trypsin inhibitor activity of 8% while soybean seed steamed at 100^{o}C for 30 min. exhibited residual trypsin inhibitor activity of 100% [13].Taking advantage of the high production rate of soybean seeds in Nigeria, embarking on commercial scale processing and utilization of dried soy milk is a worthy enterprise. Factors that could improve the properties of spray-dried milk and the advantages of spay drying over other means of drying had been reported [16, 17]. Excessive heat treatment could adversely affect both the nutrient and physical properties of dehydrated foods. In this study, the proximate composition, physico-chemical and sensory qualities of soy bean milk were studied at two different spray-drying temperatures.

MATERIALS AND METHOD

Source of raw material

Soybean (*Glycine max.* TAX 1448-2E var.) used for this research was bought at the farm of University of Agriculture, Markurdi, Nigeria.

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Production of Spray-dried Soy milk Powder

Five hundred gram of sorted soybean was boiled in 3 litres of potable water for 40 min and manually dehulled. The cotyledon was wet-milled to a very fine paste in two passes using a plate mill. During milling, 2 litres of water was added to the cotyledon for effective milling. The recovered paste was dissolved in 4 litres of water, stirred and sieved using muslin cloth. The filtrate (soy milk) was boiled for 10 min and cooled to 28ºC by dipping the container inside cold water.

The soy milk was divided into two portions (samples A and B) which were separately spray-dried in a 0.9 meter diameter, 2.6 meter high co-current spray-dryer (Komline Sanderson) at inlet air temperatures of 204ºC and 260ºC with corresponding outlet - air temperatures of 93ºC and 125ºC, respectively. The temperature of the exhausted air was measured as the outlet air temperature. Preliminary investigation carried out on this study showed that samples produced at air inlet temperatures below 200ºC exhibited wet and agglomerated particles. The spray-dryer was started and run for 30 min before introducing the soy milk. This was in order to stabilize the inlet air temperature and the corresponding outlet- air temperature.

The feed rate into the dryer was 20.5 ml/min and the feed entered into the dryer through a peristaltic feed pump (Watso-Mrlow, Flamouth Cornwall TR 4 Ru) connected to the atomizer nozzle. A pressure nozzle features a small orifice with a diameter in the range of 0.4 - 4 mm. As the feed was introduced into the dryer, it was instantly sprayed by compressed air (4 bar) supplied through a compressor. The type of flow created by air and feed was con-current with spiral flow path. The soy milk powder produced was simultaneously transported by air through a cyclone separator where the powder separated from the air and descended into the product tank, while the hot air was exhausted through the chimney. At the end of the process, the spray-dryer was shut down before removing the product tank and the product was recovered for analysis.

ANALYSIS

Crude protein content was determined using Macro Kjeldahl method as described by Pearson [18].

Crude fat content determination

Crude fat content was determined using Soxhlet extractor as described by Pearson [18].

Moisture content determination

Moisture was determined using the method described by AOAC [19].

Ash content determination

Ash content was determined using the method described by AOAC [19].

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Carbohydrate content determination

Carbohydrate was determined by subtracting the sum of % moisture, % crude protein % ash and % crude fat from 100

% Carbohydrate = 100% – (% moisture + % crude protein + % ash + % crude fat)

Determination of Available Lysine Content

Available Lysine content determination was carried out using titration method [20].

Determination of pH

pH of a 10% suspension of the sample in water was determined using Metrohm 620 pH meter [21]

Determination of Bulk Density

A 10 g of the power was put into a 100 ml graduated cylinder, and the cylinder slightly tapped to a constant volume. The volume occupied by the powder was calculated and the bulk density determined [22].

$$\text{Bulk density} = \frac{\text{Wt. of the powder (g)}}{\text{Volume of the powder (ml)}}$$

Determination of Wettability

Wettability was estimated by measuring the wetting time of 1 g of the sample flour dropped from a height of 15 mm on to the surface of 200 cm^3 of distilled water in 250 cm^3 beaker at different temperatures. The wetting time was regarded as the time required for all the powder to become wet and penetrate the surface of the distilled water [22].

Determination of Total Solids

Total solids content (insoluble carbohydrates and proteins) of the sample was determined using a standard method [23]. A 10ml of 10% (w/v) of the reconstituted sample was pipetted into a previously dried and weighed Petri dish. The Petridish was then placed in a preheated water bath at 100^{o}C and the weight checked at 30 min intervals until constant weight was obtained.

Total solids were calculated thus:

$$\text{\% Total solids} = \frac{\text{Wt. of sample after drying} \times 100}{\text{Wt. of the sample before drying}}$$

Determination of Viscosity

Simple rotational Viscometer (Hake Viscote Ster VT – 01) was used to determine the viscosity of the sample. The unit was set and held in position using a clamp. The reconstituted sample (10% w/v) was poured into the sample holder up to the mark on the shaft bearing the rotor. The instrument was switched on and the viscosity read.

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Determination of Solubility

A 2.5 g of the sample power was put into a 60 ml centrifuge tube and 30 ml of hot water (40-90ºC) added. The tube was kept inside water bath at each selected temperature for 5 min. At the end of 5 min, 10 ml of the suspension was pipetted after stirring the mixture. The 10 ml was used for determination of total solids. Then the remaining fraction of the suspension was centrifuged at 2000 rpm for 20 min using (IEC-HN-5) centrifuge machine. After centrifugation, 10 ml of the supernatant was removed for determination of total solids [23].

Solubility was calculated thus

$$\% \text{ Solubility} = \frac{T_1 S_2 \times 100}{T_2 S_1}$$

Where:

T_1 = wt. of 10 ml dispersion collected before centrifugation.
T_2 = wt. of 10 ml dispersion collected after centrifugation
S_1 = wt. of dried solids remaining after evaporation of T_1
S_2 = wt. of dried solids remaining after evaporation of T_2

Sensory Evaluation

The sensory properties of the samples were evaluated by 10 panelists drawn from members of staff and students of department of Food Technology Institute of Management and Technology, Enugu using 9 point hedonic scale where 9 = like extremely and 1 = dislike extremely. Parameters evaluated were appearance, flavour, homogeneity, mouth feel and general acceptance. Each panelist evaluated all the samples for each parameter. Evaluation of all the samples took place in one session between 1-2 pm local time [24].

Statistical Analysis of Data

Numerical data generated from the analysis were analyzed using Statistical Package for Social Science (SPSS version 16.0 for windows, SPSS Inc, Illinois, USA) through the appropriate one way analysis of variance (ANOVA). Significant difference between samples was defined at $P<0.05$.

RESULTS

Result shows that a 38.60% yield was achieved at the end of the process using 204ºC, while a higher yield (45.55%) was obtained at inlet temperature of 260ºC. Table 1 shows the proximate composition of the samples. The samples exhibited significant differences ($P < 0.05$) in some of these evaluated parameters. The moisture content of soy milk powder produced at 204ºC was 4.20%, and that produced at 260ºC was 3.12%. Soy milk powder exhibited high mean protein content (62.05±0.23), fat (19.9±0.08), ash (1.41±0.02), available lysine (5.02±0.29), and carbohydrate (12.85±0.01). The samples had pH 6.02 and 6.05 after spray-dried at 204ºC and 260ºC, respectively. The physical properties showed that the mean total solid of the reconstituted sample was 10.33±0.33 and packed bulk density was 0.57±0.00, while

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the viscosity was 47 mpas. The solubility of the sample spray-dried at 204°C increased as the temperature of water used in reconstituting the powder increased from 40 to 80°C as shown in Figure 1.

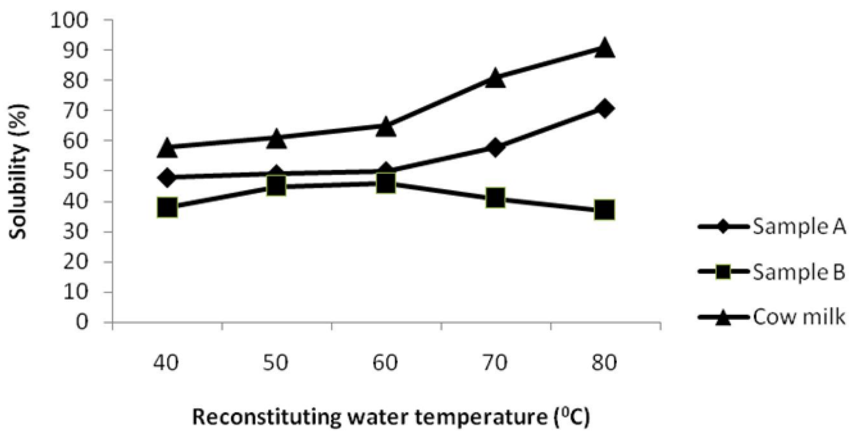

Figure 1: Solubility of samples at various temperatures (°C)

Solubility increased from 47% to 58% when the reconstituting water temperature increased from 40°C to 80°C, respectively. However, the sample spray-dried at 260°C showed a decline in solubility when the reconstituting water temperature was raised above 60°C. The solubility decreased from 42% at 50°C to 38% at 80°C. The solubility of cow milk powder progressively increased as the reconstituting water temperature increased from 40°C to 80°C.

The wettability of the samples and the control is shown in Figure 2. Soy milk powder and cow milk powder showed similarity in the pattern of wettability.

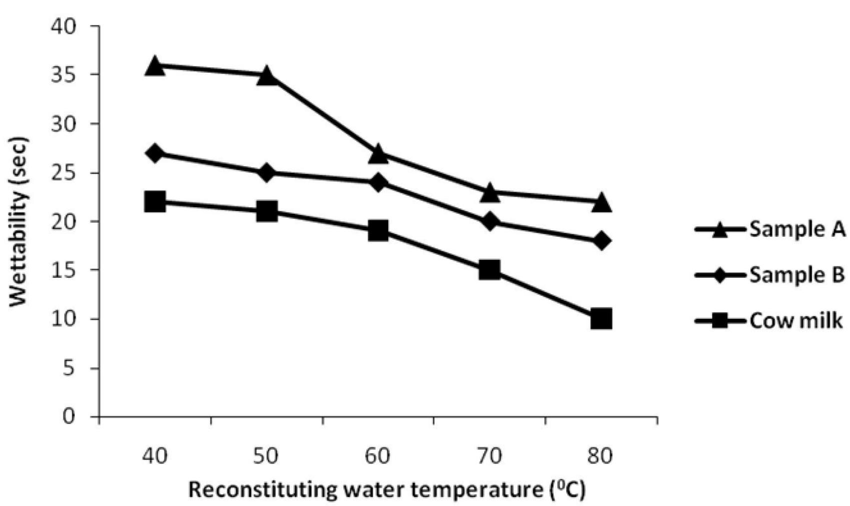

Figure 2: Wettability of samples at different temperatures (ºC)

Both the soy milk powder and the cow milk powder exhibited progressive decrease in wettability as the reconstituting water temperature increased from 40ºC to 80ºC. The time it took cow milk powder to become wet was lower than the time for spray-dried soy milk powder at the same reconstituting water temperature. The soy milk powder spray-dried at 260ºC got wet at shorter time than the counterpart spay-dried at 204ºC.

Rating of the sample sensory attributes is presented in Table 3. The samples were not rated equally, but showed significant differences in their sensory attributes ($P < 0.05$). The sample spray-dried at 204ºC was moderately liked in appearance, while that spray-dried at 260ºC was neither liked nor disliked ($P < 0.05$). In terms of general acceptance, the sample spray-dried at 204ºC was liked slightly, while the sample spray-dried at 260ºC was neither liked nor disliked.

DISCUSSION

Preliminary investigation carried out in this study showed that samples of spray-dried soy milk powder produced at air inlet temperatures below 200ºC exhibited wet and agglomerated particles.

Significant differences existed between the chemical compositions of the samples. The moisture content of spray-dried samples was within the range observed for flour samples [22]. At this moisture value, the samples could store well if properly packaged. The moisture content of food is an important factor that affects stability of the stored food. The high protein content of spray-dried soy milk suggests that soy milk powder could be used as one of the major sources of protein in human nutrition. The available lysine content of the sample spray-dried at 260ºC decreased more than the soy milk spray-dried at 204ºC. This observation corroborates the report that excessive heat adversely affects the lysine content of protein [17]. The pH of the samples was below the neutral value, suggesting that soy milk is an acid food in terms of pH classification. The pH values of the samples are closely related to the pH of a 12% (w/v) reconstituted spray-dried soy milk powder by previous researchers [11].

Table 2 shows bulk density, viscosity and total solids of the samples. It was shown that increase in inlet-temperature of the spray-dryer increased the bulk density of the products. The bulk density of the soy milk powder is within the range of bulk density reported for milk powder and cowpea flour [21, 22]. Maximum solubility by selfdispersion of milk powder can only be obtained with powders having bulk densities of less than 0.4 g/ml [16]. Increase in bulk density, wettability and water holding capacity increases dispersibility and solubility of powdered products. Blending nitrogen gas to concentrated milk prior to spray-drying produced milk powder characterized by increase bulk and improved dispersibility [16]. Viscosity of the samples closely compared with the viscosity of cow milk and earlier researchers have reported means of improving the viscosity of milk powder [10]. The total solids content of the reconstituted soy milk powder is similar to that of freshly prepared liquid. Figure 1 showed that there are significant differences between the solubility of the samples. Solubility is dependent on the inlet air-temperature used in sample production and also on the temperature of water used to reconstitute the soy milk powder. The solubility of samples increased with increase in reconstituting water temperature and this is in agreement with the earlier reports that solubility index of cow milk powder is most directly affected by heat treatments during powder manufacture, and the temperature of water used for reconstitution [25, 26]. Reconstituting water when heated to 80ºC gave the highest solubility value for the sample spray-dried at 204ºC including the control sample [commercial cow milk] but at 80ºC the solubility of the samples spray-dried at inlet air temperature of 260ºC decreased significantly. This could be due to adverse effects of high inlet temperature on the carbohydrate and protein present in the sample [26]. The recommended temperature for reconstituting samples spray-dried at 260ºC to achieve highest solubility is between 50ºC and 60ºC. The samples spray-dried at 204ºC exhibited similar solubility values to that of the control. Several factors such as type of dryer and system of atomization, preheat treatment of the milk, total solids, storage time and temperature have been reported to affect solubility [27]. Additives have been used to improve solubility and other properties of milk powder [28] and in their report, addition of sucrose in granulated form, not very fine powder improved milk solubility.

Wettability of the samples and control presented in Figure 2 showed that the samples took higher time to get wet at lower temperature than at higher temperature of reconstituting water. This is in agreement with the findings that the wettability of skim milk powder is poor at water temperature below the melting point of fat because the surface of the particles is always covered by fat, forming a water repellent layer around the dry powder particles [29, 30, 31]. Significant differences were observed in the wettability of the samples, caused mainly by the inlet air temperature. The sample spray-dried at inlet air temperature of 204ºC exhibited higher wettability compared to the sample produced at 260ºC. The wettability of both samples improved with increase in reconstituting water temperature. At temperature of 40ºC, the samples spray-dried at 204ºC took 36 sec to become wet, while that spray-dried at 260ºC took 28 sec. The wettability of the samples is closely related to that reported earlier for soy milk powder blended with 10% (w/v) maltodextrin [32].

There were significant differences in the sensory attributes of the control and the soy milk powders ($p < 0.05$). The control was ranked highest (liked very much) in all the sensory attributes evaluated. The appearance of the soy milk powder spray-dried at 204ºC was liked moderately, while the sample spray-dried at 260ºC was neither liked nor disliked. The flavour of the sample spray-dried at 204ºC was liked moderately, while that of the sample spray-dried at 260ºC was liked slightly. The mouth feel, homogeneity and general acceptance of the sample spray-dried at 204ºC were liked slightly, while these attributes were neither liked nor disliked for the sample spray-dried at 260ºC. Possibly, the higher inlet temperature (260ºC) used to produce sample B might have caused sample browning which adversely affected the appearance and the taste.

CONCLUSION

Given the proximate composition, sensory attributes and the physico-chemical properties of the spray-dried soy milk samples obtained in this study, production of spray-dried soy milk powder is feasible, and the production could be commercialized for the sample spray-dried at 204ºC in terms of general acceptance and solubility on reconstitution. Spray-dried soy milk could substitute for cow milk in selected food products where milk is used as part of the ingredients serving as protein supplement. Some other process variables and addition of some additives could be tried in production of soy milk powder for quality improvement.

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Table 1: Proximate composition, pH and available lysine content of soybean seed, liquid and powdered soy milk samples

Composition (%)	Raw soybean seed	Soy milk liquid	Powder spray-dried at 204°C (A)	Powder spray-dried at 260°C (B)
Moisture	$10.80^{b} \pm 0.02$	$90.26^{a} \pm 0.12$	$4.20^{c} \pm 0.08$	$3.12^{d} \pm 0.04$
Protein	$35.71^{a} \pm 0.13$	$3.82^{d} \pm 0.05$	$61.26^{c} \pm 0.09$	$62.86^{b} \pm 0.37$
Fat	$16.74^{b} \pm 0.01$	$1.73^{c} \pm 0.04$	$19.90^{a} \pm 0.05$	$19.93^{a} \pm 0.10$
Ash	$4.23^{a} \pm 0.02$	$0.80^{c} \pm 0.02$	$1.23^{b} \pm 0.03$	$1.59^{b} \pm 0.01$
Carbohydrate	$32.52^{b} \pm 0.14$	$3.39^{c} \pm 0.03$	$13.21^{a} \pm 0.01$	$12.50^{d} \pm 0.01$
pH	$6.00^{a} \pm 0.01$	$5.98^{a} \pm 0.06$	$6.02^{a} \pm 0.02$	$6.05^{a}. \pm 0.01$
Available lysine	$6.20^{a} \pm 0.01$	$5.94^{b} \pm 0.06$	$5.28^{b} \pm 0.55$	$4.76^{c} \pm 0.02$

Data are means of triplicate determinations ± SD. Data in the same row bearing different superscript differed significantly ($p < 0.05$)

Table 2: Physical characteristics of spray-dried soy milk

Parameter	Powder spray-dried at 204°C	Powder spray-dried at 260°C
Total solids (%)	$10.76^{a} \pm 0.55$	$9.89^{b} \pm 0.10$
Pack bulk density (g/ml)	$0.49^{b} \pm 0.00$	$0.64^{a} \pm 0.00$
Viscosity (mpas)	$45.00^{b} \pm 0.71$	$49.00^{a} \pm 1.23$

Data are means of triplicate determinations ± SD. Data in the same row bearing different superscript are significantly different ($p < 0.05$)

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Table 3: Sensory properties of the powdered soy milk and control

Attribute	spray-dried at 204ºC (A)	spray-dried at 260ºC (B)	Cow milk powder (Control)
Appearance	7.8^{b}	5.3^{c}	8.6^{a}
Flavour	7.7^{b}	6.1^{c}	8.6^{a}
Mouth feel	6.1^{b}	5.3^{c}	8.2^{a}
Homogeneity	6.9^{b}	5.6^{c}	7.9^{a}
General acceptance	6.0^{b}	5.1^{c}	8.8^{a}

Data are mean scores. Data in the same row bearing different superscript are significantly different ($p < 0.05$)

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