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Rheological and Functional Characteristics of Infant Formula Based on Banana, Soybean and Maize

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ABSTRACT

The aim of the project was to evaluate the pasting profile and functional properties of green banana composite flour. Banana samples obtained from the Volta River Estate Limited were solar dried and milled into flour. Soybean and maize were obtained from a local market at Madina in Accra, mechanically dried and made into flour. Banana, soy bean and maize flour were mixed into composite flour in seven different percentage ratios. Pasting profile and functional properties were analyzed on the composite flour. The values ranged from 6.28±0.87 to 7.41±0.46 for swelling power. Solubility index values were 15.0±3.65 to 19.37±0.92 for BMS 3 and 6 respectively. There were significant differences. Water absorption capacity values ranged from 9.67±0.58 to 14.33±0.58 for BMS 2 and 6 respectively, Oil Absorption Capacity also had values ranging from 7.0±1.0 to 10.33±0.58 for BMS 5 and 3 respectively. The bulk density values where 0.71±0.11 and 0.81±0.01 for BMS 2 and 1 respectively. The pasting profile showed significant difference between the individual samples in all the parameters. The results obtained so far indicates that banana composite flour would be good for infants.

1.0 Introduction

Bananas are one of the most consumed fruits in tropical and subtropical regions. New economic strategy that seeks to increase utilization of banana includes the production of banana flour when the fruit is unripe and to incorporate the flour into various flours from maize and soybean to form a composite flour. Green banana flour is an alternative to reducing banana wastes and it is also a low cost material for the food industry [1]. The preparation of banana flour from unripe banana has been reported [2] and the flour has been shown to possess thickening and cooking properties nearly identical to those of isolated starch [3]. Banana is usually eaten ripe but unfortunately, about one-third of all bananas harvested is lost since it is a climacteric fruit and also because the population in general have the habit of consuming only ripe bananas.

The large amount of wasted green bananas could be directed to the food industry, thereby improving banana utilization and economics. This would also be an important strategy to alleviate the environmental problem presented by banana waste. Banana flour is rich in starch granules and this biopolymer constitutes an excellent raw material which modifies the texture and consistency of food.

Consequently, banana flour appears to have some commercial potential by itself or as bases with other foods such as weaning foods, puddings, soups and gravies. Despite all these, its use is still very limited by the food industry. It is considered a sub product of low commercial value and insignificant industrial advantage [1]. Rheological properties of the food is of prime concern to the food industries. As would be expected, the rheological properties of the resultant composite flour are dependent on the relative hydrophobicity or hydrophilicity of food components such as proteins endogenous to the composite flours. Consumers are interested in those foods which have the traditional nutritional aspects and which provide health benefits by regular ingestion. In view of this, green banana flour was mixed with maize and soybean flour in different proportions. The objective of this study was to evaluate the pasting profile of the green banana composite flour and its functional properties.

2.0 Methodology

2.1 Sample Preparation

2.1.1 Banana Flour

Unripe banana samples were obtained from the Volta River Estates Limited (VREL) farms at Akuse in the Eastern Region of Ghana. The samples were peeled and cut into suitable sizes and dried in a solar dryer for three days at the Food Research Institute, Root and Tuber Division at Pokuase. The dried banana samples were subsequently milled into flour using a hammer mill. The samples were then stored at -4^{o}C till all analyses were done.

2.1.2 Soybean Flour

Soy bean purchased from Madina market, Accra. The soy beans was sorted to remove all debris from the beans and washed under running water. The samples were blanched for 30mins to remove the beany flavour and bitterness from the bean. After blanching for 30 mins the soy bean samples were drained and put under running water to allow for easy dehulling. The dehulled samples were dried in a mechanical dryer at 60^{o}C overnight. Dried soybean samples were milled into flour using the hammer mill. Blended soy bean flour was stored at -4^{o}C till all analyses were done.

2.1.3 Maize Flour

Maize purchased from Madina market, Accra

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and sorted to remove all debris. The maize samples were roasted in a hot air oven at 80°C till it became golden brown and cooked. The roasted maize was milled in to flour using a hammer mill. The milled maize flour was stored at -4°C till all analysis were performed.

2.1.4 Composite Flour Formulation

The three main ingredients (banana, soy bean and maize) flours were mixed into composite flour in seven different percentage ratios based on a modified recommendation [30] for soy bean usage in composite flour for infants. In all 700g of each formula were made and used for the various laboratory analyses.

Table 2.1. Percentage (%) formulation of the three flours.

Sample code	Maize	Banana	Soy bean
BMS 1	25	50	25
BMS 2	25	60	15
BMS 3	30	50	20
BMS 4	20	70	10
BMS 5	45	30	25
BMS 6	55	20	25
BMS 7	35	40	25

BMS means Banana, Maize and Soybean composition

2.2. Water Absorption Capacity

This property was determined using the method of [4] as modified by [5]. 1.0 g of the sample (dry matter based) was dispersed in 10 ml distilled water and stirred the suspension using a magnetic stirrer for 5 mins. The suspension was centrifuged at 3500rpm for 30 mins to obtain the supernatant. The supernatant was poured into a 10 ml graduated cylinder and the volume noted. The density of the water was taken as 1.0 gcm-3. The water absorption capacity (%) was calculated as the ratio of the volume of the supernatant to the initial volume of water added to the sample expressed in percentage.

2.3. Oil Absorption Capacity (OAC)

Oil absorption capacity was determined according to the method described by [6]. 2 g of the sample (on dry matter basis) was weighed into a 50 ml graduated conical centrifuge tube and 20ml of refined oil was added and centrifuged at 3000rpm for 20 min. The density of the oil was taken as 0.889 gcm-3. The volume of the supernatant oil was measured. The fat absorption capacity was expressed as percentage fat absorbed based on the original volume of fat.

$$\text{Oil Absorption Capacity (OAC) (\%)} = \frac{\text{Volume of supernatant}}{\text{Initial volume of oil added}} \times 100$$

2.4. Swelling Power and Solubility Index Determinations

The determination of the swelling power and solubility determinations were carried out based on modifications of the method by [7]. 1 g of starch sample (on dry matter basis) was weighed into a previously weighed 40 ml capacity centrifuge tube and 40 ml of distilled water added to it. The suspension was stirred uniformly and gently to avoid excess force that might rapture the starch granules. The suspension was heated in a thermostatically controlled water bath at 85 °C for 30 minutes, with constant stirring. The tube was removed from the water bath, wiped to dry and cooled to room temperature. The tubes were centrifuged (Centrikon T-42K, Italy) at 2200 rpm for 15 minutes. Each supernatant was poured into a weighed crucible and allowed to evaporate to dryness in an oven at 105°C. The dried supernatant was weighed after cooling and the weight was used to calculate the solubility. The sediment paste were also weighed and used in the calculation of the swelling power

$$\text{Solubility index} = \frac{\text{Weight of dried supernatant}}{\text{Weight of starch sample}} \times 100$$

$$\text{Swelling Power} = \frac{\text{Weight of sedimented starch paste}}{\text{Weight of dry starch sample}}$$

2.5. Bulk Density

A calibrated centrifuge tube was weighed (W1) and filled with starch samples to the 5 ml mark by constant tapping until there was no further change in volume. The starch samples were weighed (W2) and the differences in weight were recorded. The bulk density of the starch sample was calculated by dividing the differences in weight by the volume [8].

2.6. Rheological/Pasting property Determination

The pasting characteristics determined are; the temperature and viscosity at the beginning of gelatinization, the temperature of the peak viscosity as well as the peak viscosity, the breakdown viscosity and set back viscosity. These parameters were determined using Brabender Viscograph-E (Brabender GmbH& Co. KG, Germany). About 40 g moisture-free sample was suspended in 420 ml distilled water to prepare slurry in a large beaker. Once the moisture content of the sample was fed into the windows interface of the software, the corrected weight (more than 40 g) of the test sample to be weighed and the volume (less than 420 ml) of distilled water to be measured were automatically generated. The starch suspension was mixed thoroughly and poured into the measuring bowl of the Brabender Viscograph-E. The test was run at a speed of seventy-five (75) revolution per minute (rpm) with a measuring range of 700 cmg. The temperature profile of the analysis was programmed to commence measurement at a temperature of 50 °C with heating at the rate of 3 °C/min up to a temperature of 92 °C. The temperature of the sample was held constant for fifteen (15) minutes and then cooled at the rate of 3°C/min to a temperature of 55 °C. This temperature was also held constant for fifteen (15) minutes.

Table 3.1. Functional properties of the composite flour.

Sample ID	Swelling Power	Solubility Index	Water Absorption Capacity	Oil Absorption Capacity	Bulk Density
BMS 1	6.87 ± 0.09^{a}	16.03 ± 1.21^{ab}	11.33 ± 0.58^{bc}	7.67 ± 0.58^{ab}	0.81 ± 0.01^{b}
BMS 2	7.35 ± 0.08^{a}	17.90 ± 0.44^{bc}	9.67 ± 0.58^{a}	9.67 ± 0.58^{c}	0.71 ± 0.11^{a}
BMS 3	6.74 ± 1.42^{a}	15.00 ± 3.65^{a}	12.00 ± 1.0^{cd}	10.33 ± 0.58^{c}	0.78 ± 0.02^{ab}
BMS 4	7.43 ± 0.96^{a}	17.07 ± 1.25^{abc}	10.33 ± 0.58^{ab}	9.67 ± 0.58^{c}	0.74 ± 0.03^{ab}
BMS 5	6.43 ± 0.16^{a}	18.50 ± 0.36^{bc}	12.67 ± 0.58^{de}	7.0 ± 1.0^{a}	0.77 ± 0.03^{ab}
BMS 6	6.28 ± 0.87^{a}	19.37 ± 0.92^{c}	14.33 ± 0.58^{f}	9.33 ± 1.15^{c}	0.78 ± 0.03^{ab}
BMS 7	7.41 ± 0.46^{a}	17.40 ± 0.87^{abc}	13.33 ± 1.15^{ef}	9.0 ± 1.0^{bc}	0.74 ± 0.03^{ab}
	Lsd = 1.314	Lsd =2.829	Lsd = 1.324	Lsd = 1.430	Lsd = 0.084

Means ± Standard Deviation from three replicates

$^{a-f}$ different alphabets on the same column are significantly different ($P \leq 0.05$)

3.0. Results and Discussion

3.1. Functional Properties

The results from the functional properties showed significant differences between the samples ($p \leq 0.05$) with the exception of the swelling power that showed no significant differences.

3.1.1. Swelling Power (SP)

Swelling power of a sample is the ability of the sample to imbibe water and expand. Granule swelling therefore occurs with parallel increase in sample solubility [9]. Swelling power and solubility of starches provide evidence of non–covalent bonding between molecules of the starch granules. The values obtained for the SP were not consistent due to the different formulation ratios used. The least value obtained was 6.28% for BMS 6 and the highest value was 7.41% for BMS 7. It has been Reported [10] that the swelling power of flour granules is an indication of the extent of associative forces within the granules. SP is also related to the water absorption index of the starch – based flour during heating [11]. Starch granules contain 'blocklets' of amylopectin consisting of crystalline and amorphous areas. As the granules absorb water, they swell and lose crystallinity which results in the leaching of amylose into the continuous phase. The higher the amylose content, the lower the swelling power and the smaller the gel strength for the same starch concentration. To a certain extent, however, a lower swelling power can also be attributed to a larger granule size [12].

3.1.2: Solubility Index (S.I)

The S.I values in Table 1 ranged from 15.00±3.65 to 19.37±0.92 % respectively with BMS 3 having the least value whiles BMS 6 had the highest. Solubility Index is a measure of the dextrinisation of starch. S.I had a weak correlation value with the swelling power R = 0.2425 (Table 3). The higher values are indication of higher amylose content and larger granular size. Solubility index on the other hand had a strong correlation with gelatinization temperature R = 0.4052 (Table 3). This indicates that as temperature is increased, there is the disruption of the granule structure, thus causing more of the soluble solids to leach out during cooking which results in increased in the solubility values. The ability of food materials to absorb water is sometimes attributed to its protein content [13].

3.1.3 Water Absorption Capacity (WAC)

The WAC of the samples showed significant differences ($P \leq 0.05$) with BMS 2 having a value of 9.67±0.58 and BMS 6 having 14.33±0.58 respectively. Water absorption capacity of a sample might be due to the nature of the starches present [4]. The ability to absorb water is a very important property of all flours and starches used in food preparations. High water absorption capacity is also attributed to loose structure of starch polymers present in the sample while low value indicates the compactness of the structure [5], [14]. Increased water absorption capacity in food systems enables bakers to manipulate the functional properties of dough in bakery products [15]; [16]. WAC also has a positive correlation with gelatinization temperature R = 0.8218 (Table 3). This indicates that as temperature is increased, there is the disruption of the granule structure of the starches present in the sample which gives room for higher absorption of water.

3.1.4: Oil Absorption Capacity (OAC)

The Oil Absorption Capacity values of the sample ranged from 7.0±1.0 to 10.33±0.58 respectively. Oil Absorption Capacity (OAC) is useful in structure and interaction in foods especially in flavour retention, improvement of palatability and extension of shelf life particularly in bakery or meat product [5]. The increase in the OAC value of the sample could be due to its higher protein and fat content which can entrap more oil. Basically, the mechanism of fat absorption capacity is mainly due to the physical entrapment of oil by capillary attraction [13].

3.1.5: Bulk Density (BD)

The bulk density values ranged from 0.71±0.11 to 0.81±0.01 g/cm3 with BMS 2 having the least while BMS 1 had the highest respectively. Bulk density is depended upon the particle size of the samples and it is a measure of the heaviness of a flour sample. The low bulk density of the blends could be an advantage in the formulation of baby foods where high nutrient density to low bulk density is desired. It is reported that a bulk density value of raw flour from Jackfruit seeds was about 0.61g/cm^3, also values of 0.55 – 0.62 g/cm^3 for tiger nut flours [17] [18]. The results obtained were fairly higher than what was reported by these researchers.

3.2 Rheological Properties of the Composite Flour

The rheological properties of the composite flour showed a significant difference ($p \leq 0.05$) in all the parameters identified. Rheological properties of the food produced is of prime concern to the food industries. Rheological properties of the composite flour are dependent on the relative hydrophobicity or hydrophilicity of food components such as proteins endogenous to the composite flours.

Table 3.2. Rheological properties of the composite flour.

Sample ID	Gel Temp (^{0}C)	Peak Viscosity (BU)	Break down Viscosity (BU)	Setback Viscosity (BU)
BMS 1	78.3±0.15^c	202±6.2^d	17.7±5.5bc	19.7±5.0a
BMS 2	77.5±0.17^b	272±12.4^e	20.3±4.2c	33.3±0.6c
BMS 3	78.2±0.15^c	211±10.5^d	12.7±2.5b	25.3±0.6b
BMS 4	77.1±0.06^a	429±6.8^f	30.3±0.6d	65.7±2.5d
BMS 5	79.6±0.40^d	122±3.0^b	2.0±1.0a	28.7±3.1b
BMS 6	80.1±0.35^e	92.0±4.2^a	1.3±1.5a	26.0±1.7b
BMS 7	79.2±0.15^d	143±4.9^c	6.0±1.7a	26.0±1.0b
	Lsd=0.413	Lsd=13.26	Lsd = 5.155	Lsd = 4.473

Means ± Standard Deviation from three replicates

$^{a-f}$ different alphabets on the same column are significantly different ($P \leq 0.05$)

3.2.1 Gelatinization Temperature

Gelatinization temperature is the temperature at which the starch granules begin to swell to imbibe more water. The gelatinization temperature values ranged from 77.1±0.06 to 80.1±0.35 0C with the least being BMS 4 and the highest was BMS 6 (Table 2). It is also the minimum temperature required for flour samples to cook, the energy cost involved and other component stability [19]. Pasting temperature is the temperature at which the first detectable increase in viscosity is measured [20]. The differences in the gelatinization temperature values could be due to the various proportions of the composite flour. High temperature of gelatinization can be an indication of the higher stability of the starch crystallites in the sample, which means that more heating is required to swell the granules. It is clear from the results that the samples will cook faster and less energy consumed thereby saving cost and time.

3.2.2 Peak Viscosity

Peak Viscosity values from Table 2 were 92.0±4.2 and 429±6.8 BU respectively with BMS 6 having the least and BMS 4 the highest. There were significant differences ($P \leq 0.05$) between the samples with the exception of BMS 1 and 3 that showed no significant difference ($P \geq 0.05$). The differences in the peak viscosity values might be due to the different proportions of the different samples. Peak viscosity is related to a situation where the granules show an optimum balance between swelling and rigidity. Further heating and shear promoted the weakening and disruption of the swollen granules. This variation in the peak viscosity might be as a result of the amylose content of the starch. A study conducted by [21] Reported that the associative bonding of the amylose fraction is responsible for the structure and pasting behaviour of starch granules in a sample. It is reported [22] that peak viscosity values of 106 and 57.50 BU for flours from black and yellow tiger nut types. This was a bit lower than the results obtained in this study. Peak viscosity has a strong negative correlation with WAC, r = -0.7491 (Table 3).

3.2.3. Breakdown Viscosity

Breakdown viscosity had values ranging from 1.3±1.5 to 30.3±0.6 BU for BMS 6 and 4 respectively. There were significant differences between the samples which is as a result of the different proportions of the individual samples. The difference between the peak viscosity and the minimum viscosity is the breakdown viscosity. Breakdown viscosity is regarded as a measure of the degree of disintegration of the swollen granules or paste stability. The decrease in breakdown viscosity values of the samples implied a higher hot paste stability (that is more resistant to shear thinning during cooking) [23], due to the irreversible change in the structure. It was reported [5] that the higher the breakdown in viscosity the lower the ability of the sample to withstand heating and shear stress during cooking. In view of that, the low breakdown viscosity samples might be able to withstand heating and shear stress compared to the higher values of samples. Breakdown viscosity had a positive correlation with peak viscosity, r = 0.9322 (Table 3). This indicates that as the peak viscosity value reduces, the breakdown viscosity will also reduce making the sample to be able to withstand shear stress during cooking. Breakdown also had a negative correlation with WAC, r = -0.8000 (Table 3), which indicates that as WAC increases, breakdown decreases.

3.2.4. Setback Viscosity

The values for the setback viscosity ranged from 19.7±5.0 for BMS 1 to 65.7±2.5 for BMS 4 respectively. There were significant differences ($P \leq 0.05$) between the samples and this was a result of the different proportions used in the preparation of the product. Meanwhile, BMS 3, 5, 6, and 7 did not show any significant difference ($P \geq 0.05$) between them. When a flour/starch is heated in water, certain characteristic changes occur. During cooling of the hot paste, there is initial sharp decrease which is followed by an increase in viscosity, viscosity increases again to a more or less constant value known as setback. Setback viscosity is regarded as a measure of gelling ability or the retrogradation tendency [24]. It is reported [25] that lower setback viscosity values during cooling indicated higher resistance to retrogradation. A study conducted by [26] established that a higher setback would cause undesirable gel texture or high syneresis (the leakage of water) and low freeze-thaw stability. The higher the setback viscosity, the lower the retrogradation of the flour paste during cooling and the lower the staling rate of the product made from the flour [27]. It has a strong positive correlation with peak viscosity r = 0.8409 and that of breakdown was r = 0.6912 (Table 3).

Correlation was done to relate the functional properties and the pasting profile of the banana composite flour (Table 3). All the viscosities of the pasting profile showed a positive correlation with each other but there was negative correlation with some of the functional properties.

3.3. Conclusion

The results of the study suggested that BMS 4 had the higher swelling power whiles BMS 6 had the least and the highest solubility index which makes the sample good. BMS 6 also had a better water absorption capacity, good oil absorption capacity and the bulk density is also good in terms of heaviness. Rheological properties showed impressive significant improvement on the sample.

BMS 4 had the least gelatinization temperature which is good for the sample with a corresponding highest peak viscosity. BMS 4 also exhibited the highest breakdown viscosity and setback viscosity. These properties make BMS 4 a good sample.

Table 3.3. Correlation coefficient between the functional properties and the pasting profile of the composite flour.

Main Effect	Gel Temp	Peak Viscosity	Break Down	Setback	Swelling Power	Solubility Index	WAC	O.A.C	Bulk Density
Gel Temp	-								
Peak Viscosity	0.9177**	-							
Break Down	0.9112**	0.9322**	-						
Setback	0.5769**	0.8409**	0.6912**	-					
Swelling Power	-0.4270	0.3965	0.3973	0.2632	-				
Solubility Index	0.4052	-0.2607	-0.3224	0.0272	0.2425	-			
WAC	0.8218**	-0.7491**	-0.8000**	-0.4707*	-0.5132	0.1726	-		
O.A.C	-0.3358	0.3467	0.3121	0.2931	0.0750	-0.2641	-0.1580	-	
Bulk Density	0.2259	-0.2614	-0.2934	-0.3120	-0.2787	-0.2173	0.1938	-0.1388	-

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