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Effect of Germination, Boiling and Co-fermentation on the Viscosity of Maize/cowpea Mixture as Complementary Infant Food

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ABSTRACT

Traditionally prepared cereal based complementary food are too dilute for adequate energy and nutrient density as infant complementary food. The consistency of complementary food is of particular importance for infants who cannot masticate and therefore, depend on liquid or semi solid foods. In Nigeria mothers regard cereal malting and supplementation with legume as extra-labor. Increase of gruel energy density is important to improve the energy intake of young children in developing countries. This study investigated the effect of malting and co-fermentation bi-component flour (co-fermented maize/cowpea70:30w/w) on the consistency of the gruel product. Five processes in which either of the grain is germinated, un-germinated, un-germinated and boiled, un-germinated boiled, wet-milled and sieved before co-fermentation were explored. Consistency of the gruel of the products with concentration ranging from 4-18%; was measured using Bostwick Consistometer. The dry matter of the gruel was determined according to standard method. It was observed that boiling and milling of un-germinated maize and cowpea before co-fermentation was more effective in viscosity reduction at 12% flour concentration. At 12% flour concentration that boiling and milling of un-germinated maize and cowpea before co-fermentation can enhance the consistency and by implication reduce the viscosity of co-fermented maize/cowpea as infant complementary food.

Key words: Germination, co-fermentation, cereals, cowpea, consistency

INTRODUCTION

Fermented cereal (one-seeded fruit) especially maize (*Zea mays*) processed and made into porridges is the main complementary food for infants in Nigeria (Inyang and Zakari, 2008). They have low energy density due to great deal of large volume of water relative to its solid matter contents during preparation leading to a thin drinkable consistency. The low energy density of complementary food in developing countries is also an etiological factor of PEM (WHO, 1992) infants due to their stomach capacity cannot consume more than 30-40 mL kg^{-1} body weight. If the solids in gruel are increased to improve the nutrient and energy density, the gruel becomes too thick and viscous for infant's to eat and too large for their stomach capacity. Infants therefore, are unable to fulfill their energy requirement (Ikujenlola and Fashakin, 2005). Among low-cost methods in altering the high volume/high viscosity of cereal based gruels germination seem to be the most effective. In this process, α-amylse activity is developed, tropical cereals in general tend to yield malt that is rich on alpha-amylase(which gives thining effect on the germinated grain) and low in beta-amylase (Noveille, 1982; Katina *et al*., 2007). The enzymes degrade the starch granules, reduces their water binding capacity and consequently lowers the viscosity of the gruel. When malted grains are used, liquid gruel can be prepared with a higher concentration than that of gruel made from non-malted grains. Germination however, is not widely practiced in Africa especially complementary food preparation but mainly for local brewing.

Cowpea (*Vigna unguiculata*) (true seed) in Nigeria is used in the production of moin-moin, gbegiri and akara as adult food but are fed to infants as broth or soup from cowpea cooked without dehulling. These are unsuitable for infants due to presence of high tannin content from seed coat which may result in poor protein digestibility, diarrhea and other gastrointestinal distresses (Lyimo *et al*., 1992).

The cost involved in the germination process in terms of time, labor and negative attitudes which associate germination with alcohol, may constrain its feasibility. Also women who manage meals for the household might hesitate to prepare malt flours separately because it is a delicate and time-consuming procedure (Uebersax, 2006) However, to increase the energy density and by implication the nutritional quality is a priority in infants nutrition. Davila *et al*. (2003) reported that the use of germination and fermentation improve the nutritional value of legumes and that germination and fermentation are alternatives that are able to inactivate anti-nutritional factors in legumes, preserve and possibly improve the potential of legumes as functional foods and as ingredients for use in functional foods.

A number of research work on germination of cereals has been done; Natres *et al*. (1987) observed that germinated grains addition reduced viscosity of maize-cowpea blends. According to Zanna and Milala (2004) supplementation of fermented cereals with cowpea reduced viscosity of fermented cereals ogi. Also a number of work has been done to increase energy density of gruels while retaining a suitable consistency e.g., that addition of oil, groundnut or sugar (Kikafunda *et al*., 1997; WHO, 1998a). However, not much has been done on germination, boiling followed by co- fermentation of maize/cowpea in relation to the consistency of the gruel. Consistency flow of gruel is a function of their energy density (WHO, 1998b), recommended the minimal complementary food energy density of 128 kcal/100 g for 6-8 month-old infants receiving two gruel meals/day. Thus it is necessary to prepare gruels with energy density that will be high enough to meet energy needs of infants. The objectives of this study therefore, were to: employ the process of germination of either maize or cowpea followed by co-fermentation to assess the viscosity of the co-fermented mixture. Assess possible reduction in viscosity which by implication might be an increase in nutrient density of infant complementary food. Relate the desirable level of gruel viscosity that would encourage adequate nutrient density and the compare gruel dry matter to their consistencies.

MATERIALS AND METHODS

Materials: Winnowed grains of maize and cowpea, Bostwick Consistometer Extra Long (90/24299-000 Christison Particle Technologies Limited, Albany Road, Gateshead, NE8 3AT,UK), millipore water, hot plate, timer, cooking pot, stirrer and oven. Maize (*Zea may* L.) and cowpea (*Vigna unguiculata*) were bought from a local market in Ibadan, Nigeria. The grains were winnowed, hand sorted before use. Germination which involved moistening of grains was allowed to proceed for 72 h for maize and 48 h for cowpea. Grains were allowed to sprout to about 1 cm long (for both radical and plumule), in a moistened jute bag while exposed to air (Ariahu *et al*., 2009). Germinated seeds were dried in the cabinet dryer at 55°C for 10 h after which the seeds were cleaned of sprouts and hulls by rubbing and winnowing. The dried seeds were milled using attrition mill to a flour of about 60 mesh. Germination was achieved by layering the seeds on moistened jute bags placed in wooden dark cupboard.

Simple empirical measurement for consistency: For each of the five processes, four percent to 18% Gruel was prepared by weighing 4-18% of flour of mixture. The concentration of flour was obtained by using the formula:

$$C/100\times150 = FQ \text{ (Flour Quantity)}. \ 150\text{-}FQ = \text{volume of water added}$$

Where:
C = Desired concentration of flour/100 e.g., 4%, 150 = a constant

Weighed flour plus appropriate water volume were placed on 80°C thermostatically controlled hot plate; at the appearance of the first bubble, cooking was done with stirring for 5 min, after which each gruel was cooled to 45°C before measurement. The temperature at which gruel is usually consumed by infants is 45°C (Mouquet, 1998).

The first compartment of the Consistometer was filled with the gruel for consistency measurement. At time = 0, trigger was pressed to release the spring-loaded gate; the gruel flowed freely by gravity from the first compartment to the second compartment. The distance of flow from the gate after 30 sec was measured in millimeters as the Bostwick Consistometer reading. On Bostwick Consistometer the thickest gruel has the value of 0 while the thinnest is 240 mm (upper limit of Bostwick Consistometer).

Dry matter of gruel: Consistency measurements and dry matter content of the gruels were determined after cooking and cooling to 45°C.

Into already pre- weighed plastic dish, a spoonful (10 mL) of gruel from each process was added, weighed and the weight was recorded. This was later transferred into an oven at 105°C for 24 h, after which it was weighed the percentage difference in weight is the dry matter content.

This study investigated the effect of germination and or boiling before fermentation on the consistency (Bostwick flow) of co-fermented maize/cowpea. Five different processes were investigated as shown in Fig. 1-5.

Statistical analysis: Linear and quadratic equations were used in each process to indicate the relationship between consistency and dry matter.

RESULTS

At 4% flour concentration in Table 1 and Fig. 1, had dry matter of 2.5 g/100 g and 165 mm/30 sec consistency, the dry matter of Fig. 2 was 3.5 g/100 g and consistency was too-fast-to be measured, as shown in Table 2. In Table 3 and Fig. 3 dry matter was 4.2 g/100 g and consistency 180 mm/30 sec. Figure 4, according to Table 4 had dry matter content of 4.6 g/100 g and consistency was too-fast-to be measured; while for Fig. 5 and Table 5 the dry matter was 2.9 g/100 g and the consistency was too-fast to be measured.

At 6% flour concentration, Fig. 1 gave a dry matter content of 2.5 g/100 g and consistency value of 165 mm/30 sec (Fig. 2), dry matter content 5.1 g/100 g, consistency 104 mm/30 sec (Fig. 3), dry

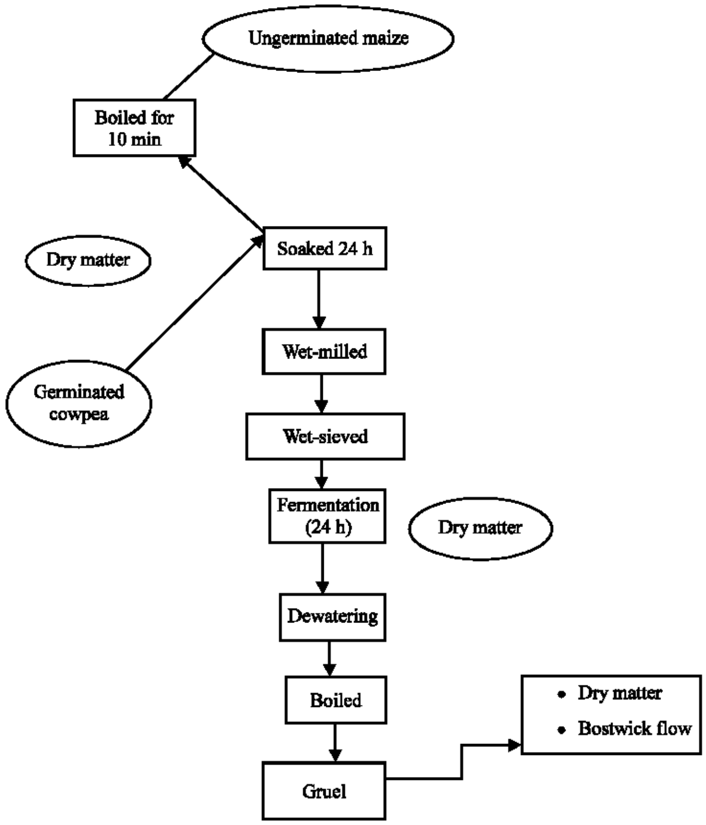

Fig. 1: Flow chart showing co-fermentation of ungerminated maize and germinated cowpea

Table 1: Ungerminated maize (70%) and germinated cowpea (30%)

Process 1	Flour concentration (%)	Dry matter of gruel	Bostwick flow mm/30 sec
	2		
	4	2.50	165
	6	2.50	165
	8	5.70	95
	10	8.21	38
	12	10.80	25
	14	13.90	8
	16	14.10	4
	18	16.00	3

Table 2: Ground germinated cowpea (30%) and ungerminated maize (70%)

Process 2	Flour concentration (%)	Dry matter of gruel	Bostwick flow cm/30 sec
	2		
	4	3.5	-
	6	5.1	104
	8	7.0	65
	10	8.1	40
	12	9.7	38
	14	13.0	14
	16	14.0	5
	18	14.8	4

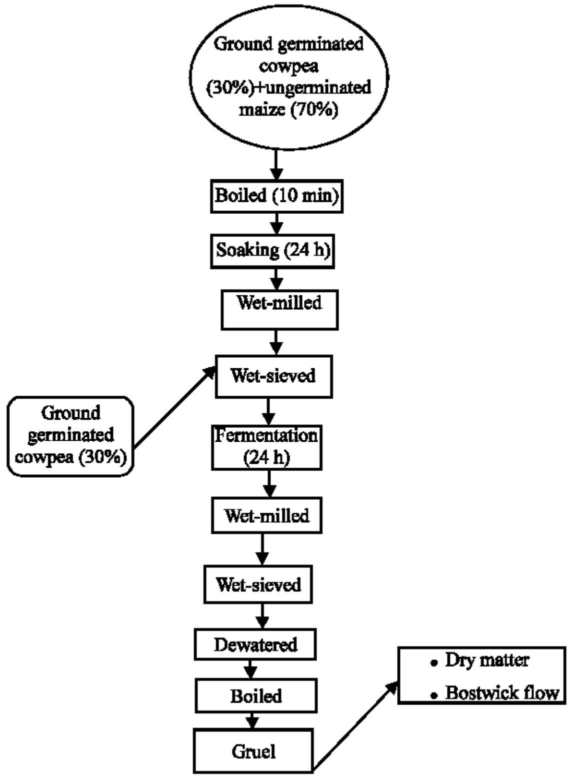

Fig. 2: Showing co-fermentation of ground germinated cowpea/ungerminated maize

Table 3: Ground germinated maize (30%) and Ungerminated cowpea (30%)

Process 3	Flour concentration (%)	Dry matter of gruel	Bostwick flow cm/30 sec
	2		
	4	4.2	180
	6	6.0	106
	8	8.0	75
	10	9.6	35
	12	11.3	10
	14	13.0	4
	16	-	Too thick

Table 4: Ungerminated maize (70%) and ungerminated cowpea (30%) mixture soaked and boiled before co-fermentation

Process 4	Flour concentration (%)	Dry matter of gruel	Bostwick flow cm/30 sec
	2		
	4	4.6	Too fast
	6	5.2	148
	8	6.7	95
	10	8.6	64
	12	9.7	40
	14	11.0	18
	16	13.1	10
	18	14.5	5

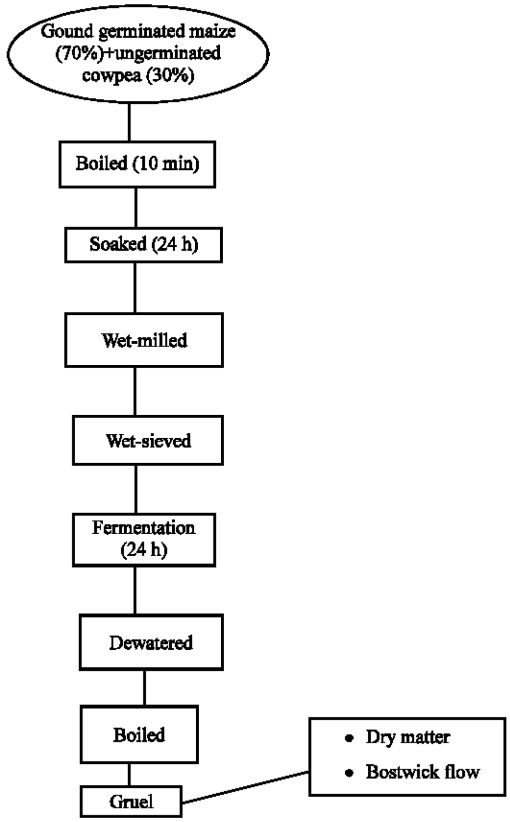

Fig. 3: Showing co-fermentation of ground germinated maize/ungerminated cowpea

Table 5: Ungerminated maize (70%) and ungerminated cowpea(30%) mixture boiled, wet-milled and sieved before co-fermentation

Process 5	Flour concentration (%)	Dry matter of gruel	Bostwick flow cm/30 sec
	2		
	4	2.9	Too fast
	6	4.8	205
	8	6.1	145
	10	7.2	100
	12	8.7	53
	14	9.9	13
	16	10.9	10
	18	12.2	5

matter content 6.0 g/199 g, consistency 106 mm/30 sec (Fig. 4), dry matter content 5.2 g/100 g, consistency 148 mm/30 sec while for Fig. 5, dry matter content 4.8 g/100 g and the consistency value was 205 mm/30 sec as shown in Table 1-5, respectively. At this 6% flour concentration, Fig. 3 gave a higher dry matter value and a lower consistency than all the other four processes.

At 8% flour concentration, Table 1 and Fig. 1 had dry matter content of 5.7 g/100 g consistency, 95 mm/30 sec; while Fig. 2-5 had dry matter of 7.0 g/100 g, consistency 65 mm/30 sec, dry matter 8.0 g/100 g consistency 75 mm/30 sec, dry matter 6.7 g/100 g consistency 95 mm/30 sec and dry matter value of 6.1 g/100 g and a consistency value of 145 mm/30 sec, respectively as shown in Table 1-5. At 8% flour concentration, Fig. 3 had higher dry matter and therefore, lower consistency than others.

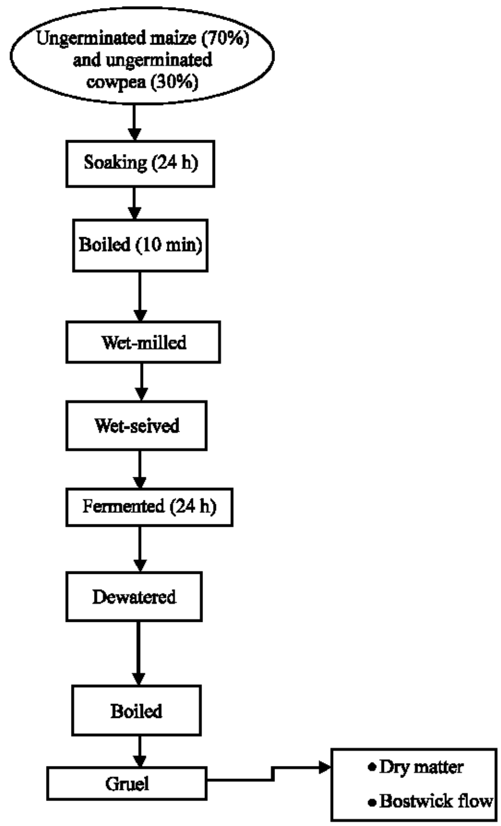

Fig. 4: Showing ungerminated maize/cowpea soaked and boiled before co-fermentation

At 10% flour concentration, process 1 (Table 1), dry matter 8.21 g/100 g consistency 38 mm/30 sec, Fig. 2 and Table 2 dry matter 8.1 g/100 g consistency 40 mm/30 sec, (Fig. 3, Table 3) dry matter 9.6 g/100 g consistency 35 mm/30 sec; Fig. 4 and Table 4 dry matter 8.6 g/100 g consistency 64 mm/30 sec while Fig. 5 and Table 5 had dry matter content of 7.2 g/100 g and consistency value of (100) 53 mm/30 sec. At 10% Fig. 3 had a higher dry matter value and a lower consistency value compare to the other four Processes.

At 12% flour concentration Fig. 1 and Table 1 dry matter 10.8 g/100 g consistency 25 mm/30 sec, Fig. 2 and Table 2 dry matter 9.7 g/100 g consistency 38 mm/30 sec, Fig. 3 and Table 3 dry matter 11.3 g/100 g consistency 10 mm/30 sec, Fig. 4 and Table 4 dry matter 9.7 g/100 g consistency 40 mm/30 sec while Fig. 5 and Table 5 had dry matter value of 8.7 g/100 g and consistency of 53 mm/30 sec. At this 12% flour concentration, the gruel of Fig. 3 had a higher dry matter and a lower consistency value than the remaining four Processes.

At 14% flour concentration, Fig. 1 and Table 1 dry matter 13.9/100 g consistency, 8 mm/30 sec Method 2, Table 2 dry matter 13.0 g/100 g consistency 14 mm/30 sec, Method 3, Table 3 dry matter 13.0 g/100 g consistency 4 mm/30 sec; for Fig. 4 and Table 4, 11.0 g/100 g, consistency 18 mm/30 sec and in Table 5 and Fig. 5, dry matter was 9.9 g/100 g consistency 13 mm/30 sec. Also, at 14% Fig. 3 had the highest dry matter value and lowest consistency compared to other Processes.

At 16% flour concentration, (Fig. 1 and Table 1) had dry matter of 14.10 g/100 g consistency 4 mm/30 sec, (Fig. 2, Table 2) dry matter 14.0 g/100 g, consistency 5 mm/30 sec; (Fig. 3 and Table 3) dry matter. Consistency was too thick to be measured, (Fig. 4 and Table 4) dry matter

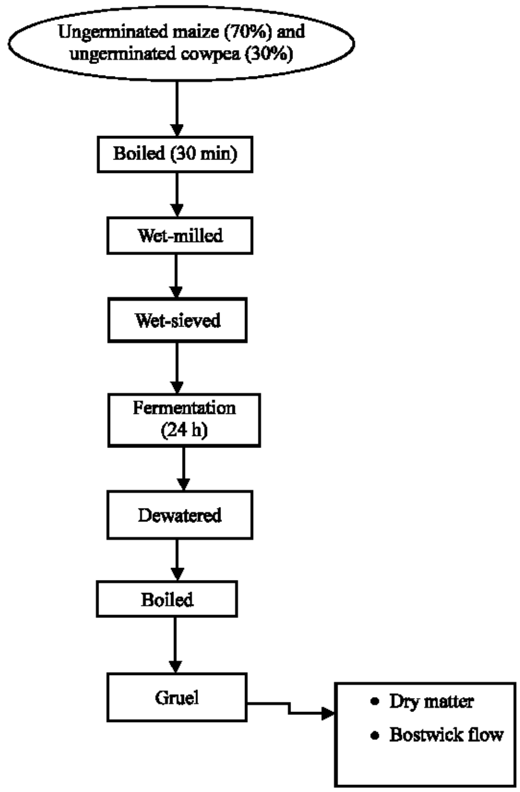

Fig. 5: Showing ungerminated maize/cowpea boiled before co-fermentation

13.1 g/100 g consistency value was 10 mm/30 sec (Fig. 5 and Table 5) 10.9 g/100 g flow 10 mm/30 sec Fig. 1 at 16% flour concentration had the highest dry matter value and lowest consistency.

At 18% flour Fig. 1-5 had dry matter value of 16 g/100 g, consistency value of 3 mm/30 sec, dry matter 14.8 g/100 g, consistency 4 mm/30 sec; Fig. 3 and Table 3 and in Table 4 and Fig. 4 both had dry matter value of 14.5 g/100 g and consistency of 5 mm/30 sec. Method 5 12.2 consistency 5 in Table 5.

DISCUSSION

The apparent consistency values of all gruels appeared to be inversely related to the dry matter. The consistency decreased very rapidly the dry matter content increased. It was noted that as gruel consistency decreased as the gruel cools irrespective of the concentration. The most common temperatures at which viscosity and consistency measurements are performed are 40°C (Wanink *et al.*, 1994) or 45°C (Treche and Mbome, 1999).

The incorporation of cowpea either germinated or ungerminated into maize must have affected the viscosity and by implication the consistency of gruels prepared from them this might be due to interaction of cereal starches with protein which can influence gelatinization and retrogradation of starches. Cooked gruel consistency and value appeared relevant when combined with dry matter content. This agrees with the reports of Ikujenlola and Fashakin (2005). In comparing all the processes as shown in Table 6 and 7, four percent flour concentration, process 4 had a higher dry matter content and lower consistency value than all the remaining four processes this indicated higher viscosity at 4% flour concentration.

Table 6: Comparable dry matter values of gruels from all processes

	Flour concentration (%)							
Process	4	6	8	10	12	14	16	18
1	2.5	5.7	7.6	8.2	10.9	13.9	14.1	16.0
2	3.5	5.1	7.0	8.1	9.7	13.0	14.0	14.8
3	4.2	6.0	8.0	9.6	11.3	13.0	-	-
4	4.6	5.2	6.7	8.6	9.7	11.0	13.1	14.5
5	2.9	4.8	6.1	7.2	8.7	9.9	10.9	12.2

Table 7: Comparable consistency (mm/30 sec) values of gruels of all processes

	Consistency (Bostwick flow mm/30 sec)							
Process	4	6	8	10	12	14	16	18
1	165	95	60	38	25	8	4	3
2	TF	104	65	40	38	14	5	4
3	180	106	75	35	10	4	-	-
4	TF	148	95	64	40	18	10	5
5	TF	205	145	100	53	13	10	5

Process 1 had the lowest dry matter at 4, 6 and 8%; while process 3 at 16 and 18%, gave gruels that were too-thick to be measured.

These flour concentrations were too dilute in terms of solid: water ratio for adequate nutrient and energy densities as infant complementary foods. The highest dry matter content of Fig. 4 at 4% might have been contributed from the seed coat and starch since there was no germination to generate alpha-amylase for hydrolyses of maize starch. Starch content is the main determinant of gruel consistency. However, at 14-18% flour concentration the dry matter was higher than in other methods and the consistency lower which could be equivalent to higher viscosity than what infants can consume.

Process 3 had the highest dry matter/highest viscosity/ lowest consistency at 6, 8, 10, 12 and 14%. At 12, 14, 16 and 18% the consistency were too low with too high viscosity. At 10 and 12% processes 1-4 meet the equivalent of 1 to 1.5 p.a.s viscosity needed for infant complementary food in agreement with Mouquet (1998) who reported that viscosity of 1-3 p.a.s is ideal for infant complementary foods. Viscosity level of 3.0 p.a.s is considered the upper limit for gruel that young infant readily accept.

At 4-10% comparing processes 4 and 5 with other processes containing ungerminated gains the consistencies were higher this might be due to lack of saccarification or dextrinification caused by the activities of amylase that developed during germination (Ikujenlola and Fashakin, 2005), reported significant difference ($p<0.05$) in the viscosity of the complementary diet from germinated blend compared with diet prepared from ungerminated flour. The particle sizes, of the bi-component grains might also affect the consistency/viscosity in agreement with the report of Osungbaro (2009).

Figure 2, 4 and 5 at 12% met 1.3 to 1.8 p.a.s^{-1} viscosity for infants' complementary foods. In Fig. 2, 4 and 5 at 12%, ungerminated grains (maize or cowpea) followed by boiling were employed before co-fermentation thus boiling co-fermentation might have contributed to the lower dry matter, increased consistency and by implication reduced viscosity in all these samples. The application of such processes might have provoked physiochemical changes in components of maize and cowpea raw materials this agrees with the report of Kouakou *et al*. (2008).

Table 8: The linear and quadratic relationships of each process

Process	Linear	R^2	Quadratic	R^2
1	Y = 0.9714x±0.7471	0.969	Y = 1.3631x²+39.61x+293.786	0.984
2	Y = 0.8739x±0.0764	0.989	Y = 2.7708x²+73.577x+491.643	0.907
3	Y = 0.8077x±0.7798	0.999	Y = 1.6250x²+46.507x+336.314	0.993
4	Y = 0.7277x±1.1624	0.991	Y = 2.1339x²+64.863x+495.476	0.995
5	Y = 0.6434x±0.7739	0.995	Y = 1.6533x²+57.104x+497.256	0.997

Generally, boiling soaking and milling before fermentation in Fig. 2-5 were more effective at viscosity reduction at 12% flour concentration. Boiling might have destroyed some microbes which can hinder amylase activities during fermentation while milling must have resulted into more surface area, for the activity of amylase. Fermentation process led to viscosity reduction. We concluded that boiling, soaking and milling of germinated cereal/legume before co-fermentation might give adequate consistency at 12% flour concentration by the influence of alpha-amylase in the germinated grain.

The process of germination and or fermentation has been shown to substantially reduce dietary bulk of complementary foods. In this study, the use of bi-component flour (co-fermented maize/cowpea 70:30 w/w) might can enhance the balance nutrients supplied by each component and also boost the energy density of gruel without altering the consistency; this is in agreement with the report of Mouquet (1998).

This study also showed that Bostwick consistency is negatively related to flour concentration and gruel dry matter. The progressively lower values were obtained when flour concentrations were increased. It was noted that as gruel consistency decreased as the gruel cools irrespective of the concentration or processing method. Values for thickens gruels were close to 5 mm/30 sec while more liquid/gruels reached as much as 205/30 sec. According to Mouquet (1998), 1 to 3 p.a.s-1 is ideal for complementary food for infants with viscosity level of. Viscosity level of 3.0 p.a.s is considered the upper limit for gruel that young infant readily accept.

Table 8 shows the regression equations describing the relationship between flour concentration: as dry matter of cooked gruel) and Bostwick flow (mm/30 sec) in each of the processes for gruel viscosity reductions (x). It shows concentration matrix describing the relationship between flour concentration, gruel dry matter and Bostwick flow/30 sec. There was a strong relationship between flour concentrations in all methods. Regression (R = 0.99). While strong or inverse relationship was observed in flour concentration and Bostwick flow with(R value of -0.83 to-0.97). These results show the dependence of Bostwick flow on flour concentration furthermore, flour concentration can significantly influence Bostwick flow and dry matter.

CONCLUSION

Germination followed by fermentation did not adequately reduce viscosity to the required level as complementary foods. Of all these tested methods for viscosity reduction of co-fermented maize/cowpea to fall within recommended values of 1-3 p.a.s-1 for infant feeding, co-fermentation of boiled maize/cowpea mixture gave the best viscosity measurement of 1.8 p.a.s-1 at 12% flour concentration. It is therefore, recommended for adoption.

The results cannot be converted into fundamental rheological parameters because factors other than viscosity such as surface tension, wetting power and stickiness can be involved (Mouquet and Treche, 2001). However, sensory evaluation and nutrients composition of gruel needs to be evaluated.

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