

Drying Kinetics, Physico-chemical and Nutritional Characteristics of "Kindimu", a Fermented Milk-Based-Sorghum-Flour

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Abstract

"Kindimu", a fermented milk-based cereal foods made by sun drying a mixture of fermented milk and cereal flour is a common flour ingredient in the central African region. A study was carried out to evaluate the effect of processing methods on the drying behaviour, functional and nutritional quality of such a food prepared from sorghum flour and fermented milk. A mixture of 1 part sorghum flour (germinated or non-germinated) and the 2 part (w/w) on fermented milk was coated on aluminium trays to a depth of 5mm and dried at 50, 65 or 80°C. Results obtained indicated that a simple mass transfer equation $\ln [(C-C^*)/(C_0-C^*)] = -(K/L)t$ can be used to model the drying behaviour of the fermented milk-sorghum flour mixtures. The magnitude of mass transfer coefficient K, increased with drying temperature and the germination of sorghum. Germination and addition of milk increased the *in vitro* protein digestibility of sorghum flour by 19.03%, protein solubility by 11.5% and available lysine content by an average of 3.04% and reduced the phytate content by 30%. The water absorption capacity of flours was equally reduced by an average of 4%.

Key words: Fermented milk, sorghum, malting, drying kinetic, physico-chemical properties, nutritional properties.

Introduction

Fermentation is one of the oldest methods of producing and preserving foods. In Africa, this technology plays a very important role in the nutrition and daily diets of many populations. The common characteristics of such fermentation is the production of organic acids resulting in a reduction of the pH and a typical sour taste. Besides the beneficial effects of shelf life extension and improvement of sensory properties, it has been shown that certain fermented milk based products have a therapeutic effect in diarrhoea disease (Boudraa *et al.*, 1989).

Fermentation and germination are two classical technologies commonly used to improve on the protein digestibility and the B₆ vitamin content of cereals, either by decreasing the amount of inhibitors or releasing the nutrients for absorption (Dhankher and Chauhan, 1987a; Dhankher and Chauhan, 1987b). By using a lactic fermentation technique combined with flour of germinated seeds, the energy density in cereal based gruel is significantly increased (Svanberg and Sandberg, 1989), while at the same

time bulk density is reduced (Mosha, and Svanberg, 1990; Marero, *et al.*, 1988). Germination of cereals has equally been found to increase the protein quality of the malted flours apart from modifying the starch granules (Opoku *et al.*, 1983). Germination studies have also shown increase in vitamins and bioavailability of traces minerals in the cereals sprouts. In the central African region, and especially in the northern parts of Cameroon, cattle rearing and milk production is the principal preoccupation of the people. Excess milk produced is often fermented and mixed into a dough with cereal flour (maize, sorghum, millet or rice) which is subsequently cooked and consumed in the form of gruel. This traditional method of processing milk and cereals permits the utilisation of excess milk and contributes to ensure food security in these areas. It certainly also improves the protein-energy value of cereal based diets. However the method is laborious, very susceptible to bacterial contamination and very likely to influence the functional properties of the flours obtained

As part of main study aimed on reducing the production time and improving on the hygienic quality of this milk-based cereal product, the present study was carried out to determine the effect of such production parameters as germination and drying temperature on the drying kinetic, the physico-chemical and nutritional properties of the fermented milk-based-sorghum flours.

Material and Methods

Production of sorghum flours

A white cultivar of sorghum (*Sorghum bicolor*), was obtained from the experimental farm of the Institute for Agronomic Research (IRAD) in Maroua, Cameroon. Sorghum was cleaned and soaked in distilled water (100 g in 300 ml) for 12 hours, rinsed and divided into 2 parts. One part was germinated in the dark for 72 hours while the second part was drained dry at ambient temperature and dried in an oven at 50°C to a constant weight. The germinated seeds were equally drained and dried at 50°C. The different sorghum samples were

each milled into a fine flour (150 μ) using a hammer mill. Flours obtained were packaged in polyethylene bags and stored in a fridge at 4°C until needed for use.

Fermentation of milk

Fresh milk was obtained from the Canadian-run pilot dairy farm (SOGELAIT) located close to the University of Ngaoundere – Cameroon. Pasteurised whole fresh milk was aseptically inoculated with a dried starter (Rhône – Poulenc, France) containing a strain of *Streptococcus thermophilus* and one strain of *Lactobacillus bulgaricus*, followed by incubation for 3 hours at 40°C in a thermostatically controlled water bath and incubated for 3 hours at 40°C.

Production of milk-based sorghum flours (MBSF)

MBSF were prepared by mixing fermented milk and cereal flours in a 2:1 ratio (w/w) using a food mixer (Kenwood, UK) to ensure proper mixing and allowed to rest for 1 hr. The dough obtained was spread uniformly on aluminium plates of dimension 20 x 20 x 0.5 cm and dried to constant weight in an air drought oven at 50, 65 or 80°C. The drying process was monitored by weighing the plates at regular intervals using a Sartorius balance (sensitivity 0.001g). At the end of the drying determined by a constant weight, the dried dough was packaged in polyethylene bags and stored in a dessicator at 4°C until needed for use.

Analysis of chemical composition of flours

MBSF were analysed for moisture, proteins, ash and lipids essentially according to standard AOAC methods of the Association of Official Analytical Chemists (AOAC, 1975). Flour samples were acid-hydrolysed and the resulting reducing sugar designated as available carbohydrates, was determined by the Dinitrosalicylic acid (DNS) method of Fisher and Stein as described by Fombang (1999). Phytates were determined by the method described by Thompson and Erdman (1982).

Analysis of functional properties of flours

Water absorption capacity (WAC)

The evaluation of the rate of water uptake of flour was carried out by the

Baumann method as described by Dumay *et al.* (1986). At least three measurements were conducted for each sample and the mean was expressed as mL of liquid retained per gram of sample.

Protein water solubility (PWS)

PWS of the MBSF was determined essentially by the method of Oshodi and Ekperigin (1989). A sample (0.02g) of flour was added to 10 ml of distilled water, mixed with a spatula and centrifuged at 3500 rpm. The proteins in the supernatant was determined by the method of Lowry *et al.* (1951). The solubility of proteins in water was expressed as a percentage of the total proteins.

Analysis of nutritional properties of the milky flours.

In vitro protein digestibility was determined by the method of Savoie and Gauthier (1986). Following this method, a sample containing about 450mg of protein was suspended in 17ml of 0.1 N HCl and incubated in a shaking water bath for 5 min. The pH was adjusted to 1.9 and 2.5ml of 0.7% (w/v) freshly prepared pepsin solution (Sigma chemical Co, St Louis Mo) was added, mixed and incubated at 37°C for 30 min. The reaction was stopped by the addition of 1ml of 1N NaOH and the volume adjusted to 23ml with sodium phosphate buffer 0.1M, pH 8. The lot was then transferred into a dialysis tubing (Molecular weight cut

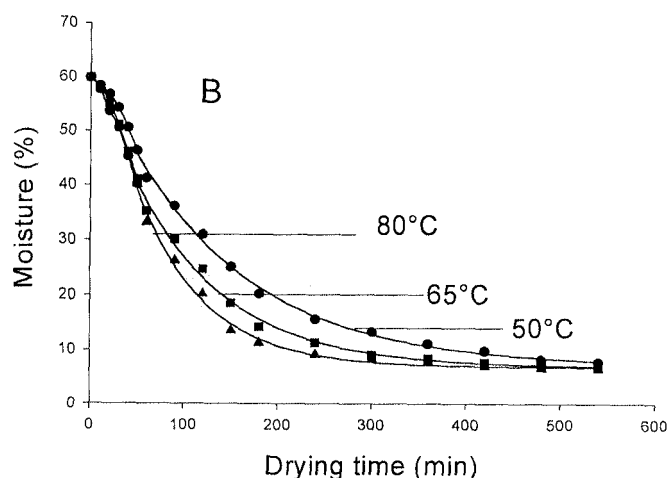
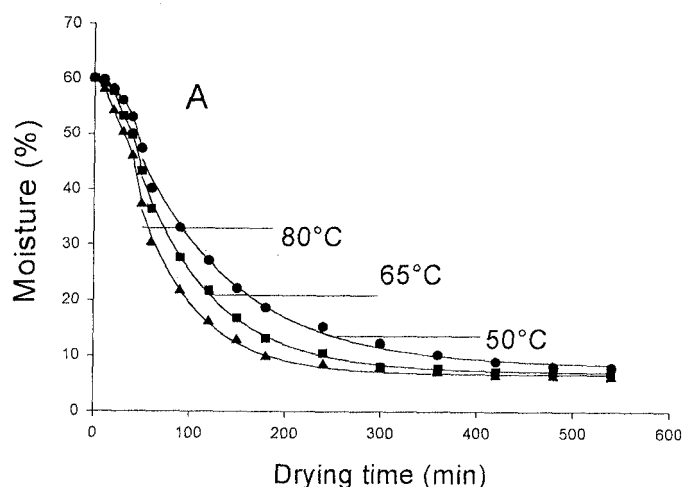


Figure 1: Drying curves of MBSF (A) with non germinated sorghum (B) with germinated sorghum.

off ~ 1200, Medicell International Ltd, London, U.K) following by the addition of 2.5 ml of a phosphate buffer solution containing pancreatine (0.7% w/v) (Sigma chemical Co., St Louis Mo). The tubing was then tied and introduced each into a beaker containing 400ml of phosphate buffer. The whole was incubated at 37°C under agitation. At regular time intervals, 2ml of dialysate was withdrawn and the proteins determined by the methods of Lowry *et al.*, (1951). The protein digestibility (PD) at each time was calculated using the formula:

$$PD(\%) = \frac{Pd}{Pt} \times 100$$

Pd = protein in dialysate and Pt = total protein in dialysate bag.

Available lysine was determined according to the method of Kakade and Liener (1969). Exactly 10.00 mg of sample was mixed with 1ml of 4% NaHCO₃, pH 8.5 and incubated at 40°C with agitation for 10min. This followed by the addition of 1ml of 1% 2,4,6 trinitrobenzenesulfonic acid (TNBS) further incubation for 2 hours at the end of which 3ml of concentrated HCl was added. The tubes were then autoclaved at 120°C for 1 hr before cooling down at room temperature. The contents of the tubes were then diluted with 5 ml of distilled water, filtered, washed twice with 5ml of diethyl ether and placed in boiling water to evaporate traces of ether. The optical density of the solutions were read at 346 nm against a blank treated in the same manner but without flour. The concentration of lysine was calculated using the specific absorbance of e-TNP lysine which is 14600Mcm⁻¹.

Results and Discussion

Drying behaviour of the flours

The drying curves of the different MBSF are shown in figure 1. The initial moisture content of the different milk-sorghum mixtures of germinated and non germinated sorghum were 60.08% and 59.92 % respectively. Because of the high level of the initial moisture content, a constant rate period was observed during the early parts of the drying process. The falling rate period appears directly after the constant rate

phase. During this phase, it was assumed that the resistance to mass transfer of water vapour from the solid surface to the air was negligible and the internal resistance controlled the rate of drying (Yener *et al.*, 1987).

In this respect, an internal mass transfer coefficient K was defined as

$$\frac{dC}{dt} = -\left(\frac{K}{L}\right)(C - C^*) \quad (1)$$

Where K = mass transfer coefficient, m/hr,

L = Thickness of dried material, m,

t = drying time

C = Total moisture, kg moisture/kg dry solid,

C* = Equilibrium moisture, kg moisture/kg dry solid

Integration of equation (1) from C₀ to C give

$$\frac{(C - C^*)}{(C_0 - C^*)} = \exp\left(-\frac{K}{L}\right)t \quad (2)$$

Equation (2) was rearranged as

$$\ln\left[\frac{(C - C^*)}{(C_0 - C^*)}\right] = -\left(\frac{K}{L}\right)t$$

and drying curves were drawn as Ln[(C - C*)/(C₀ - C*)] versus time (Figure 2). Slopes of the curve from the beginning of the falling period were determined and used to calculate the values of K/L. Dependence of K/L values on temperature and germination of sorghum is shown in table 1. This table indicate that K/L increased with increase in drying temperature (P < 0.05) and germination of sorghum grain (P < 0.05). This increase of K/L with germination of sorghum might be due to the hydrolysis of the starch and other hygroscopic macromolecules which reduce polar bonds capable of binding to water molecules.

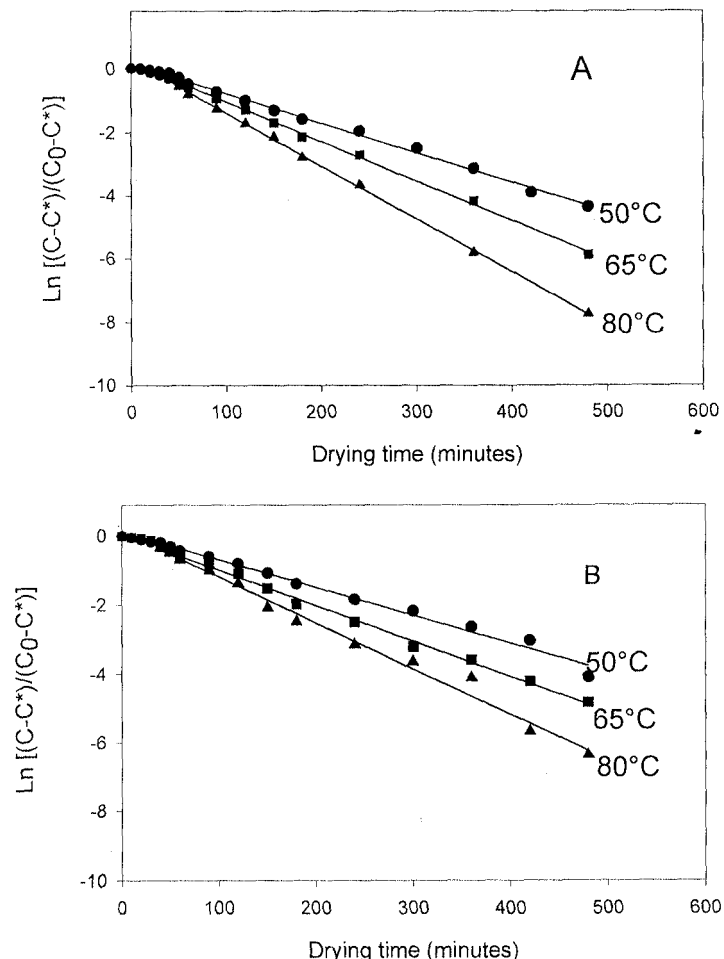


Figure 2 : Ln[(C - C*)/(C₀ - C*)] versus drying time at different drying temperature for germinated (A) and non germinated (B) sorghum based flours.

Table 1: Dependence of K/L values on germination and drying temperature

| Flour-sorghum mixtures | Drying temperature [°C] | K/L ($\times 10^{-3} \text{ mn}^{-1} \text{ cm}^{-1}$) | R ² | CV [%] |
|------------------------|-------------------------|---|----------------|--------|
| Non germinated sorghum | 50 | 8.5 ± 0.313 | 0.985 | 3.694 |
| | 65 | 10.68 ± 0.257 | 0.993 | 2.413 |
| | 80 | 13.05 ± 0.576 | 0.982 | 4.411 |
| Germinated sorghum | 50 | 9.28 ± 0.230 | 0.990 | 2.884 |
| | 65 | 12.55 ± 0.183 | 0.998 | 1.456 |
| | 80 | 15.46 ± 0.6687 | 0.99 | 4.325 |

Chemical composition of the flours

Sorghum flours:

Proximate composition of the sorghum flours is shown in table 2. Germination of cereals is known to influence its phytate content (Larson and Sandberg, 1995). Germination led to a 30% decrease in phytate content of sorghum. This level of decrease in phytate is much lower than that of 79% reported by Larson and Sandberg (1995) for germinated barley. The differences in the rate of reduction obtained in this study may be due to the difference in phytase activity in both cereals or to the different germination time.

The germination of sorghum also results in a significant ($P < 0.05$) fall in the proximate composition of sorghum. In this respect, a decreases in protein, fat and carbohydrates content were in the range of 9.9%, 20.8% and 8.2% respectively. The decrease in fat content during germination has been reported by several authors (Kaukovirta *et al.*, 1993; Dibofori *et al.*, 1994). A reduction in carbohydrates following germination has also been reported (Nout, 1991). The decrease in content of macromolecules during germination could be due to the synthesis and activity of hydrolytic

enzymes (lipases, proteases amylase). Germination also led to a 7.67% decrease in ash content of sorghum. This decrease in ash content which represents loss in minerals could be due to the rootlet and to the washing of the grains during germination.

Milky-based-sorghum flours (MBSF)

Proximate composition of the different MBSF is as shown in table 2. The composition was not influenced by the drying temperature. The addition of fermented milk increased the protein content in the blend by 43.84% and 45.32% for the flours with non germinated sorghum and germinated sorghum respectively. The reducing sugar levels ranged from 37.7 to 38.9% for non germinated and 32.4 to 33.6% for germinated sorghum and reflected the reducing sugar content of the sorghum flour. As it would have been expected, fermented milk also increased the ash content by 5.17 to 7.24% respectively for flours with germinated sorghum and non germinated sorghum. This significant ($P < 0.05$) increase in ash is due to the fact that milk is an important source of such minerals as calcium and phosphorus. The crude fat content ranged from 7.61 to 7.83 for non

germinated sorghum based flour and from 7.02 to 7.25 for germinated sorghum based flour.

Functional properties of the flours
Water absorption capacity and the protein solubility are important characteristics of flours because physico-chemical properties such as viscosity and gelation are dependent on them (Cheftel *et al.* 1977).

The initial water absorption rate (V_i) (measured between 0 to 45 sec), the maximum absorption capacity (Q) and the water protein solubility (PWS) of the milky flours are shown in table 3. V_i and Q for the flours with non germinated sorghum were higher than that for germinated sorghum. Germination of sorghum led to a reduction in the initial rate of water absorption and also in the maximum water absorption capacity. Depending on drying temperature, reduction in the initial rate of water absorption varied between 36.55 and 42.05% while that of maximum water absorption capacity varied between 2.84 and 4.7%.

On the other hand, germination led to an increase in PWS with value ranging from 10.58 to 12.86%. Drying beyond 65°C led to a reduction in PWS. For flours dried at 80°C, protein solubility decreased by 14.25 and 15.95% for non germinated and germinated sorghum respectively. The observed negative effect of high drying temperature on the solubility of proteins may be potentially due to the formation of complexes between soluble proteins and sugars such as is often the case in Maillard reactions.

Table 2: Proximate composition of sorghum and of milk-sorghum flours.

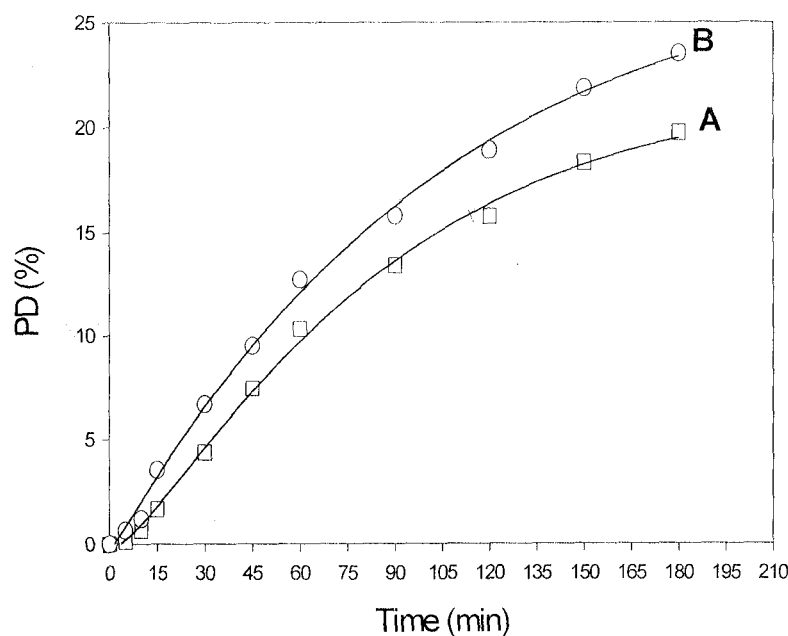
| Cereal | Fermented Milk:flour ratio [W/W] | Drying temperature [°C] | Moisture [%] | Phytates [%] | Ash [%] | Crude proteins [%] | Reducing sugar [%] | Crude fat [%] |
|-------------------------|--|-------------------------------|-----------------|-----------------|-------------|-----------------------|-----------------------|------------------|
| Ungerminated sorghum | 0:1 | 50 | 6.01 | 1.33 ± 0.08 | 2.9 ± 0.4 | 11.61 ± 0.10 | 38.35 ± 0.33 | 8.84 ± 0.7 |
| | | 50 | 5.25 | | 3.22 ± 0.22 | 16.8 ± 0.13 | 39.3 ± 0.26 | 7.83 ± 0.06 |
| | 2:1 | 65 | 5.57 | | 3.33 ± 0.14 | 16.6 ± 0.12 | 38.9 ± 0.55 | 7.76 ± 0.12 |
| | | 80 | 5.41 | | 3.15 ± 0.28 | 16.7 ± 0.10 | 37.9 ± 0.75 | 7.61 ± 0.33 |
| Germinated sorghum | 0:1 | 50 | 5.32 | 0.93 ± 0.03 | 2.65 ± 0.08 | 10.62 ± 0.10 | 34.2 ± 0.30 | 7.55 ± 0.16 |
| | | 50 | 5.07 | | 2.95 ± 0.11 | 15.5 ± 0.05 | 32.4 ± 1.12 | 7.02 ± 0.20 |
| | 2:1 | 65 | 5.11 | | 3.11 ± 0.93 | 15.4 ± 0.12 | 33.6 ± 0.62 | 7.17 ± 0.15 |
| | | 80 | 5.03 | | 2.97 ± 0.39 | 15.4 ± 0.09 | 33.13 ± 0.55 | 7.20 ± 0.24 |

Table 3: Dependence of water absorption capacity and protein solubility on germination and drying temperature

| Flour-sorghum mixtures | Drying temperature [°C] | Water Retention [mL/g] | | PS [%] |
|------------------------|-------------------------|------------------------|-------------|-------------|
| | | Vi | Q | |
| Non germinated sorghum | 50 | 1.04 ± 0.05 | 2.55 ± 0.25 | 44.4 ± 1.66 |
| | 65 | 1.07 ± 0.03 | 2.46 ± 0.11 | 45.7 ± 0.53 |
| | 80 | 1.00 ± 0.11 | 2.49 ± 0.14 | 37.3 ± 0.61 |
| Germinated sorghum | 50 | 0.66 ± 0.06 | 2.43 ± 0.09 | 49.1 ± 0.60 |
| | 65 | 0.61 ± 0.05 | 2.39 ± 0.16 | 50.9 ± 0.75 |
| | 80 | 0.59 ± 0.11 | 2.37 ± 0.13 | 42.1 ± 0.77 |

Table 4: Dependence of available lysine on the drying temperature and sorghum germination

| Flour-sorghum mixtures | Drying temperature [°C] | Available lysine [mg/g of protein] |
|------------------------|-------------------------|------------------------------------|
| | | |
| Non germinated sorghum | 50 | 40.52 ± 0.14 |
| | 65 | 38.88 ± 0.72 |
| | 80 | 36.86 ± 0.11 |
| Germinated sorghum | 50 | 40.74 ± 0.12 |
| | 65 | 39.96 ± 0.91 |
| | 80 | 37.46 ± 0.32 |

**Figure 3:** *In vitro* protein digestibility (PD) in the milky flours drying at 50°C. Flours with non germinated (A) and germinated (B) sorghum.

Nutritional characteristics

The incorporation of fermented milk into sorghum flour significantly ($P > 0.05$) improved on its protein content. Germination of sorghum further improved on the protein *in vitro* digestibility of the protein (Figure 3). After 180 minutes of *in vitro* digestion, flours made from fermented milk and germinated sorghum showed a digestibility rate of 23.51% as opposed

to that of 19.75% observed for flours containing non germinated sorghum. Thus a significant improvement rate of 19.03% was attained in the digestibility of the flours by germination of sorghum. This increased rate may partially be explained by the fact that during germination, proteolytic enzymes are synthesized which degrade proteins to small water soluble peptides (Nout, 1991). Also it may be partially due to

the fact that germination led to a felling in phytate content which is known to reduce protein digestibility (Poonam and Sahl, 1994).

Depending on drying temperature, the addition of milk increased the level of available lysine in non germinated sorghum from 18.25 to 40.52 mg/g of protein while that in germinated sorghum varied between 21.78 to 40.74 mg/g of protein on the average. Germination of sorghum increases the level of available lysine in flour. Increase in available lysine levels following germination has also been reported (Dalby *et al.*, 1976) for wheat. It is established that during germination the rate of synthesis of albumins and glutamins which are proteins rich in lysine decrease (Okkyung, and Yeshajahu, 1985).

Germination also led to a decrease of the phytate content of sorghum flour. In fact fermented milk-based-sorghum flours are acidic, at this pH range, proteins are generally charged positively whereas phytates are negatively charged (Reddy *et al.*, 1982). As such, phytate strongly bind protein particularly at their e-NH₂ group of lysine. This attraction seemed to have been potentiated by high drying temperatures, specially at 80°C which a reduction of about 8.05 and 9.03% for germinated and non germinated sorghum was observed.

Conclusion

On the whole, the results of this study demonstrate the fact that use of germinated sorghum and appropriate drying temperature can greatly improve the chemical and nutritional quality of the fermented milk-based sorghum flour commonly called *Kindimu*. Drying at temperature below 65°C seem to be preferable. Consumption of such foods formulated from locally available food stuffs may lead to the improvement of the protein-energy status of the local population. Several other types of cereals (maize, sorghum, millet, rice) are also traditionally used in the production of these flours. In view of the fact that these cereals differ in their characteristics (chemical composition, physico-chemical properties etc), it would be interesting to exploit the other cereals for this same

purpose to determine which is better suited to the production of the milk-based cereal flour.

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