EFFECTS OF PROCESSING PARAMETERS ON THE IRON AND ZINC SOLUBILITY OF INFANT SORGHUM PORRIDGE

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INTRODUCTION

In many developing countries, cereal porridges are introduced in infant feeding before the age of 4 months and this practice is associated with malnutrition problems. Thirty-two percent of children under 5 years old suffer from being underweight and 39% from stunting in developing countries.

Zinc (Zn) is an essential trace element for human nutrition. It supports important functions in the organism; its deficiencies in the diet lead to much suffering; particularly in developing countries where cereals and vegetables are the main sources of macro- and micronutrients for the population (Svanberg and Lorri, 1997; Frossard et al., 2000). The mineral content and bioavailability in cereals like sorghum are low due to the presence of anti-nutritional factors such as condensed phenolic compounds and phytate. Basically, the processing of infant porridges in many areas of West Africa involves soaking, grinding, occasionally fermentation, and cooking. In spite of its nutritional benefit, germination is not used in the production of infant complementary food in many African countries. In order to improve the nutritional and the functional properties of indigenous infant porridges, modifications may be incorporated in the traditional processing method by introducing the germination step. The purpose of this study was to improve the micronutrient quality of the indigenous African infant flour using the traditional techniques available in the region. The Response Surface Methodology was used to study the effect of duration of soaking, germination and fermentation on phytate and phenolic compounds (PC), pH, viscosity and the in vitro solubility (IVS) of Zn of infant sorghum flour.

MATERIALS AND METHODS

Experimental design

An orthogonal rotatable central composite design (Montgomery, 2001) for K = 3 factors was used to estimate the simultaneous effect of three process variables on phytate, phenolics, Fe and Zn solubility in a quadratic function. The design generated 23 observations to which six additional in-between and extreme points were added to increase the accuracy.

Experimental processing

Cleaned sorghum grains (200 g) were soaked in distilled water during 6-14 h. Subsequently, the grains were germinated during 0-72 h. Grains were sprayed with distilled water twice daily. At the end of germination, the sprouted grains were dried at 50 °C in an oven for 16 h. The rootlets were removed and the grains were ground to flour using a *Retsch* mill (type ZM 1, Retsch, Haan, Germany) fitted with a 0.5 mm screen. For the fermentation, the flour was mixed with distilled water (45% w/w), and allowed to ferment in a plastic bucket with lid.

The fermented dough was dried and ground to flour as described above. Samples were packed in polythene bags and stored at –20 ºC until analysis.

In vitro digestion and samples analysis

The in vitro digestion method (Kiers et al., 2000) was used. Fe, Zn, phytate and total phenolic compounds were measured following the methods described by Kayodé et al. (2006). The final apparent porridge viscosity, was measured following the method of Mestres et al. (1997). The data were analysed using the statistical program SPSS 11.0.

RESULTS AND DISSCUSION

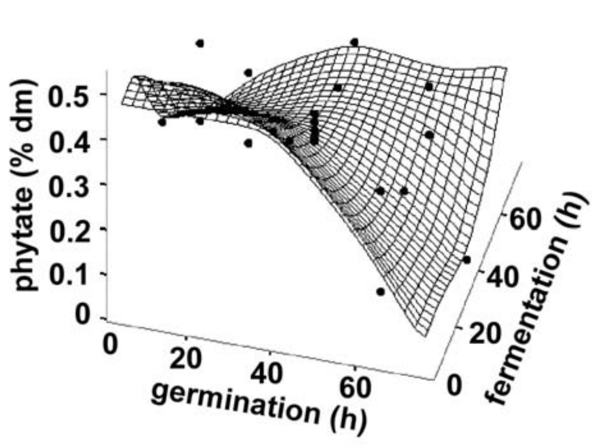
Among the different treatments, the highest solubility of Zn (38.1%) was obtained from the treatment that involved 10 h of soaking, 72 h of germination and 36 h of fermentation. The lowest (19.4%) from treatment 27 (10 h soaking, 14.6 h germination and 36 h fermentation). Values found for the % IVS Zn (19.4-38.1%) are of the same order of magnitude as those reported by Drago and Valencia (2004) for zinc dialyzability (18-31.59%) in infant formulas prepared with casein, whey, lactose, vitamin and corn oil.

Table 1: Response for phytate, total phenolics, IVS Zn and Fe

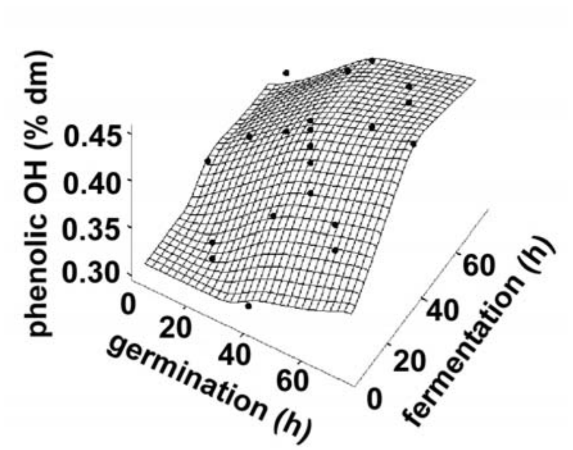
Treatment code	soaking (h)	germination (h)	fermentation (h)	IP6 (%)	PC (%)	IVS Zn (%)	IVS Fe (%)
1	10.0	36.0	36.0	0.29	0.38	23.2	9.4
2	10.0	36.0	36.0	0.22	0.47	25.4	17.4
3	10.0	36.0	36.0	0.22	0.41	26.0	16.4
4	10.0	36.0	36.0	0.25	0.5	25.4	17.5
5	10.0	36.0	36.0	0.25	0.44	19.6	13.2
6	10.0	36.0	36.0	0.24	0.43	26.8	9.8
7	10.0	36.0	36.0	0.32	0.4	26.4	6.6
8	10.0	36.0	36.0	0.26	0.46	19.8	16.7
9	10.0	36.0	36.0	0.17	0.41	27.0	9.5
10	7.82	14.59	14.59	0.24	0.26	22.4	7.5
11	7.82	57.4	14.59	0.09	0.36	26.7	9.3
12	7.82	14.59	57.4	0.28	0.29	21.9	14.8
13	12.18	14.59	14.59	0.68	0.29	22.4	17.8
14	12.18	57.4	57.4	0.27	0.46	27.3	5.6
15	7.82	57.4	57.4	0.11	0.43	35.2	13.8
16	12.18	14.59	57.4	0.02	0.41	30.3	5.7
17	12.18	57.4	14.59	0.21	0.39	34.1	16.8
18	6.0	36.0	36.0	0.27	0.41	22.3	16.1
19	10.0	0.0	36.0	0.15	0.37	29.1	24.6
20	10.0	36.0	0.0	0.56	0.35	28.6	22.3
21	14	36.0	36.0	0.17	0.37	27.6	15.7
22	10.0	72.0	36.0	0.02	0.45	38.1	11.3
23	10.0	36.0	72.0	0.19	0.41	25.5	15.0
24	10.0	36.0	57.4	0.14	0.4	30.8	12.6
25	10.0	36.0	14.59	0.16	0.39	24.3	11.8
26	10.0	57.4	36.0	0.18	0.44	32.3	11.0
27	10.0	14.59	36.0	0.28	0.39	19.4	6.5
28	12.18	36.0	36.0	0.31	0.38	27.3	13.4
29	7.82	36.0	36.0	0.31	0.37	23.1	17.5

IP6: myoinositol hexaphosphate; PC : total phenolic compounds; IVS : in vitro solubility; V50 : final apparent viscosity at 50ºC.

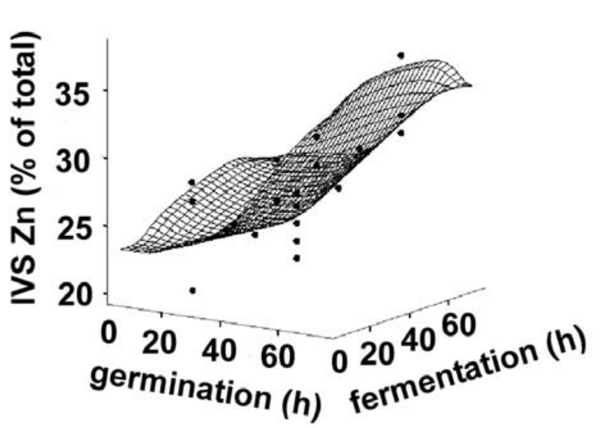
The germination time was the only processing parameter affecting the percentage of in vitro soluble Zn (IVS Zn), and its linear and quadratic terms were found to be significant. No significant changes took place in the Zn solubility during the first 24 h of germination. Thereafter, the % IVS Zn increased with the duration of germination, reaching 38% after 72 h (Figure 1c). There are significant correlations between % IVS Zn and phytate and % IVS Zn and PC content. This correlation is negative for phytate, meaning that the % IVS Zn increases when phytate content decreases and positive for PC. Our observation that changes in phytate and Zn solubility simultaneously took place (after 24 h of germination) would support the statement that phytate is the major inhibitor of this mineral (Frossard et al. 2000, Lestienne et al.2005). In absolute terms, the maximum amount of Zn available to consumers after 72 h of germination is about 8.5 mg per kg dry matter. In order to meet the daily Zn requirement of 5 mg for infants, they should consume 586 g dry matter daily. This is unfeasible because of the limited infant stomach capacity. However, with the lower porridge viscosity achieved as a result of germination, concentration of dry matter (and nutrients) daily consumed by infants can be increased while maintaining "spoonable" consistency.



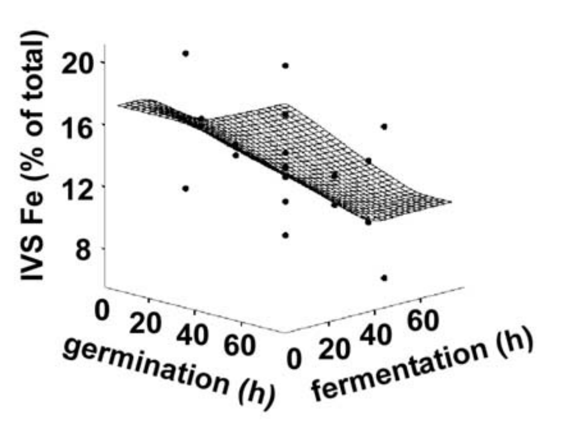
a: Effect on phytate



b: Effect on phenolic hydroxyl groups



c: Effect on IVS Zn



d: Effect on IVS Fe

Figure 1: Response surfaces showing the effects of germination and fermentation periods on (a) phytate, (b) total phenolic reactive hydroxyl groups of sorghum flour porridge, (c) IVS (in vitro soluble) Zn, and (d) IVS Fe in sorghum flour.

If the Zn supply to infants would solely depend on the consumption of sorghum-based porridges, we recommend a fortification with Zn. The type of flour designed in this study would constitute a suitable carrier for Zn, because of its desirable functional properties (sourness, viscosity) and its minimized levels of mineral chelating agents.

Contrary to expectation, the % IVS Fe tended to decrease as a result of germination and fermentation (Figure 1d), which is in disagreement with previous finding that germination and fermentation induce increased Fe solubility by degradation of mineral chelating factors (Kayodé et al., 2007). Nevertheless, except for the interaction of soaking and fermentation, none of these processing parameters exerted a significant effect on the IVS Fe. Overall, only 35 % of the variation in Fe solubility is attributable to the model. Actually, our Fe data show quite a large variation which is more perceptible at the central point of the design where nine replications were performed (see treatments 1-9 in Table 1). This variation is mainly due to the relatively low Fe levels which are close to the level of detection of the method of analysis used, and measurements may also have been disturbed by possible contamination of Fe from the environment.

CONCLUSIONS

The introduction of germination in the traditional processing of sorghum brought significant improvements in the nutritional quality and functional properties of the infant flour. Germination induces important desirable nutritional modifications and its effect is enhanced by the fermentation. Such modifications could not be achieved by the current traditional method of producing porridge for infant in many African countries. The low level of anti-nutritional factors achieved in the flour, would make it suitable as a carrier for micronutrient fortification. We therefore recommend further studies of technical and economical opportunities and bottle-necks of incorporation of germination in the production of infant flour.

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