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Effects of processing and addition of a cowpea leaf relish on the iron and zinc nutritive value of a ready-to-eat sorghum-cowpea porridge aimed at young children

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ABSTRACT

While dietary diversification of monotonous cereal-based diets using legumes and vegetables can alleviate the high prevalence of iron and zinc deficiencies in sub-Saharan African children, laborious cooking times limit the use of particularly legumes.

This study investigated the effects of high-temperature short-time (HTST) processing on sorghum (extrusion) and cowpea (micronisation), compositing sorghum-cowpea (70:30) (ESMC) in a ready-to-eat porridge and addition of cowpea leaves on iron and zinc bioaccessibilities compared to a commercial fortified maize:soy ready-to-eat porridge.

HTST processing increased iron bioaccessibility from both grains and the zinc bioaccessibility from the sorghum. One serving of ESMC porridge with cowpea leaves could contribute ≈85 and 18% towards the iron and zinc RDA of preschool children, compared to the commercial product at ≈84 and 125%, respectively. However, the higher iron and zinc bioaccessibilities from the ESMC porridge with cowpea leaves, compared to the commercial product (11.8 vs. 5.0% and 18.9 vs 2.7%, respectively) means it would provide more bioaccessible iron (2.24 vs. 0.86 mg/100 g, db) and similar levels of zinc (0.35 vs. 0.32 mg/100 g) towards the absolute/basal requirements of preschool children.

The ESMC porridge with cowpea leaves could improve the iron and zinc nutritive value of preschool sub-Saharan African children's diets.

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1. Introduction

Globally, Africa has the highest estimated prevalence of anaemia in preschool aged (0–5 years) children at 64.6% (McLean, Cogswell, Egli, Wojdyla, & De Benoist, 2009). While information on the prevalence of zinc deficiency is limited, it is believed that where iron deficiency persists, zinc deficiency is very likely to also occur (Ramakrishnan, 2002).

Many households in Africa, where iron and zinc deficiencies are prevalent, depend on monotonous cereal-based diets for micronutrients as well as energy (Oniango, Mutuku, & Malaba, 2003). These diets often contain high levels of antinutrients such as phytate and sometimes tannins, which reduce the already low bioavailability of the non-haem iron and zinc in the diet (Hunt, 2003). Legumes, often used to increase the protein nutritive value of the cereal based diets, have also been found to increase mineral nutritive value (Anigo, Ameh, Ibrahim, & Danbauchi, 2009).

Legume preparation, however, is time consuming and laborious, which consequently limits their use (dos Santos Siqueira, Vianello, Fernandes, & Bassinello, 2013). With the increase in urbanization and more women working outside the home, even in the low socioeconomic and/or rural areas (Tacoli, 2012), there is an increased need for affordable, culturally acceptable and convenient foods (Kennedy, Nantel, & Shetty, 2004).

The use of underutilised crops is increasing as their economic potential is realised (Gruère, Giuliani, & Smale, 2006). Underutilised crops are commercialised for various reasons including; providing culturally acceptable options, increasing commercial

Abbreviations: AR, absolute requirements; CE, catechin equivalent; db, dry basis; ESMC, extruded sorghum-micronised cowpea; HTST, high-temperature short-time; ICP-OES, inductively coupled plasma - optical emission spectrometry; RDA, recommended dietary allowance; RTE, ready-to-eat; WAI, water absorption index; WSI, water soluble index.

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opportunities for local farmers, lowering production costs and/or increasing the nutritive value of the product.

Information on mineral bioavailability from processed indigenous foods, however, is still severely lacking. This is especially important in areas where mineral deficiencies are often prevalent, but interventions such as supplementation and fortification are impractical.

Sorghum and cowpeas are very important as traditional staple foods in sub-Saharan Africa, as shown by Oyarekua (2010). In a previous study with the aim of providing a high protein quality product, we explored the potential of using sorghum and cowpeas to develop a ready-to-eat (RTE) composite porridge as a complementary food for preschool aged children (2–5 years old) (Vilakati, MacIntyre, Oelofse, & Taylor, 2015). It was found that a single serving of the RTE porridge, with a cowpea leaf relish, could meet 40% of the children's protein and lysine requirements.

In the current study the effect of high-temperature short-time (HTST) processing technologies on sorghum (extrusion cooking) and cowpea (micronisation), their compositing (70:30) and addition of a cooked cowpea leaf relish on the iron, zinc and phytate contents and iron and zinc bioaccessibilities was evaluated. The iron and zinc nutritive value of the extruded sorghum (ES)-micronised cowpea (MC) (ESMC) porridge, with or without cooked cowpea leaf relish, was also compared with a commercial fortified maize: soy RTE porridge.

2. Materials and methods

2.1. Raw and processed materials

The sample acquisition, preparation and the formulation of the composite meals have been described in previous work (Vilakati et al., 2015). In short, red non-tannin sorghum (cultivar MR Buster) grains were decorticated, milled and extruded in a TX 32 twin-screw, co-rotating extruder (CFAM Technologies, Potchefstroom, South Africa). Cowpeas (cultivar Bechuana white) were preconditioned to 41% moisture, manually dehulled, micronised (Techni lamp, Johannesburg, South Africa) and then milled. Young cowpea leaves were handpicked, cleaned and boiled, as has been described for amaranth (Faber, Van Jaarsveld, Wenhold, & Van Rensburg, 2010). A commercial maize:soy RTE composite porridge (FUTURELIFE®, Durban, South Africa) formulated for children aged 1–4 years was used. The commercial product had also been fortified with multiple micronutrients, including iron, zinc and calcium to levels of 30, 15 and 800 mg/100 g, dry basis (db), respectively (information provided on the packaging).

2.2. Analyses

2.2.1. Phytate content

Phytate content was determined using an indirect quantitative anion exchange chromatography method described by Frubeck, Alonso, Marzo, and Santidrian (1995). Glass barrel Econo-columns, 0.7 × 15 cm (BioRad, Johannesburg, South Africa), Dowex 1; anion-exchange resin-AG 1 × 4, 4% cross-linkage, chloride from, 100–200 mesh (Sigma, Johannesburg, South Africa) were used.

2.2.2. In vitro iron and zinc bioaccessibilities

Iron and zinc bioaccessibilities were determined using a dialysis method described by Luten et al. (1996) and modified by Kruger, Taylor, and Oelofse (2012). In short, simulated gastric digestion was performed at pH 2 using porcine pepsin (P-700) (Sigma, Johannesburg, South Africa). Intestinal digestion was simulated at pH 7 using porcine pancreatin (P-1750), bile extract (B-8631) (Sigma, Johannesburg, South Africa) and dialysis tubing (Spectra/Por 7 ($\phi = 20.4$ mm), molecular weight cut-off of 10 kDa G.I.C. Scientific, Johannesburg, South Africa). The dialysate was decanted and acidified using concentrated nitric acid to ensure that the minerals did not adsorb to the sides of the container and/or not precipitate out of solution. The iron and zinc that passed through the dialysis tubing was measured as bioaccessible. The assay is based on the theory that smaller, soluble iron and zinc compounds are better absorbed than large compounds (Fairweather-Tait et al., 2005). The gastric digestion was done in duplicate and from each gastric digestion 3 intestinal digestions were done ($n = 6$). Results are displayed as both the amount of bioaccessible iron and zinc (mg/100 g) as well as the percentage (%) of bioaccessible iron and zinc relative to respective total contents.

2.2.3. Mineral analysis

The total iron, calcium and zinc contents of the raw and processed flours, digested samples (dialysates) and blanks were determined using inductively coupled plasma optical emission spectrometry (ICP-OES), (SPECTRO ARCO, Spectro Analytical Instruments, Kleve, Germany) with a dual-view torch, spray chamber and cross-flow nebulizer. Multi-element standard solutions were prepared by dilution of stock solutions with deionized water (1000 mg/l Merck, Darmstadt, Germany) and a range of calibration standards to match expected concentration for Ca, Fe and Zn in samples were used (Operation conditions of the SPECTRO ARCO are given in Table 1). Prior to analysis of the raw undigested samples, acid assisted microwave digestion was performed using ultrapure nitric acid (65%, Merck, Darmstadt, Germany) and 2 mL hydrogen peroxide (30%, Merck, Darmstadt, Germany). The iron and zinc contents of the flour samples were measured in triplicates and each dialysate ($n = 6$) measured once.

2.2.4. Ascorbic acid determination

Ascorbic acid was determined only in the cowpea leaf relish using the method described by Nielsen (2010), chap. 7.

2.2.5. Statistical analysis

Data was analysed by single factor analysis of variance (ANOVA) using STATISTICA 10 (StatSoft, Johannesburg, South Africa). Fisher's LSD Post-hoc test was applied to determine significant differences between specific means at a confidence level of 95% ($p \leq 0.05$).

3. Results and discussion

3.1. Mineral and phytate contents

Compositing the raw and HTST treated sorghum and cowpea substantially ($p \leq 0.05$) increased the iron, zinc and calcium

Table 1
ICP-OES working conditions.

Parameters	Units
RF Power	1400
Coolant flow rate (L/min)	12.0
Nebulizer flow rate (L/min)	1.00
Auxiliary flow rate (L/min)	1.00
Pump speed (rpm)	30
Rinse time (s)	30
Replicate read time (s)	15
Element	**Emission line (nm)**
Ca	317.9
Fe	238.2
Zn	213.9

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