Application of low cost extrusion in development of nutritionally enhanced instant millet-fruit blended porridges for West Africa

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ABSTRACT

Interest in leveraging micronutrient-dense native plants as ingredients for fortification cereal foods has been intensified, especially that with a focus on delivery of shortfall micronutrients, including vitamin A. Low cost extrusion technology is gaining prominence in developing countries by virtue its ability to generate high quality instant food products. The present study assessed the compatibility of natural fortification strategies with a low-cost extrusion technology that is currently operating in Africa. Blended products were formulated by combining whole grain (WG) millet (Senegalese Souna var.) with native African plant materials recognized as sources of micronutrients, including dried carrot (CRT-15%), *Adansonia digitata* (Baobab-5%) and *Moringa oleifera* (Moringa-5%). Products were extruded on a Technochem Mini-Extruder© (35% moisture; 900rpm; Final Temp = 115 °C in average). Extruded products were assessed for quality (color, water absorption/solubility index, pasting properties and dynamic rheology) and nutritional value (provitamin A content, bioaccessibility and starch digestibility). Extrusion affected the color of the extrudates after CRT and Baobab addition, showing greatest impact on browning index (156) and chroma (57.5) values respectively. Water solubility and absorption indexes were significantly increased with CRT and Baobab. However, Baobab and Moringa addition decreased product final viscosities. Rheological parameters including storage (G') and loss modulus (G'') were lower by addition of Boabab and Moringa. Starch digestibility was not altered by the formulation. Provitamin A carotenoid stability through processing was significantly enhanced with the inclusion of Boabab and Moringa (60% in WG/CRT relative to 69% and 90% in WG/CRT/Boabab and /Moringa). Moreover, WG/CRT/Baobab had higher provitamin A bioaccessibility (~20% or 707 μg/100g porridge), showing an enhancement of carotenoid bioavailability from cereal blends. Results suggest that production of naturally fortified millet blends can be achieved without compromising the product quality and recovery of provitamin A carotenoids.

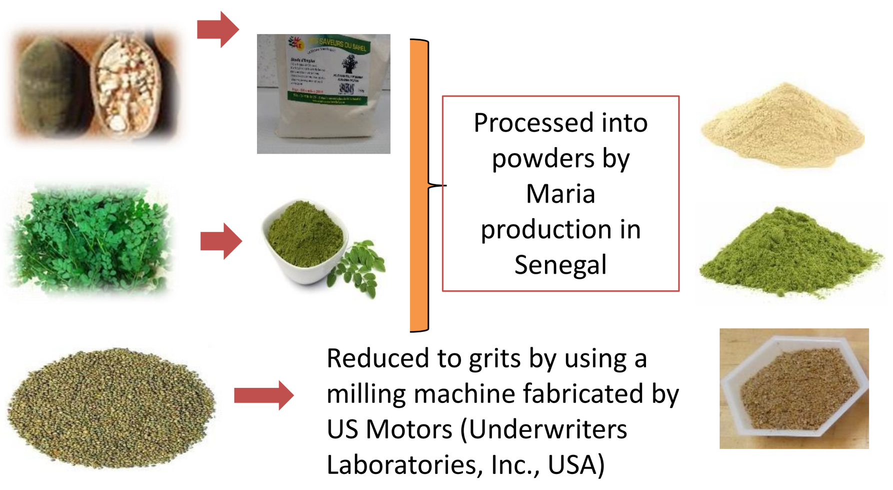
INTRODUCTION

Vitamin A deficiency remains one of the most significant nutritional deficiencies in Africa[1]. In addition to supplementation and traditional fortification of foods, alternative solutions including the development of inexpensive nutrient-dense, ready-to-eat products from the locally grown iron and provitamin A carotenoid rich plant materials has been proposed as a sustainable solution to address micronutrient deficiencies in developing countries[2].

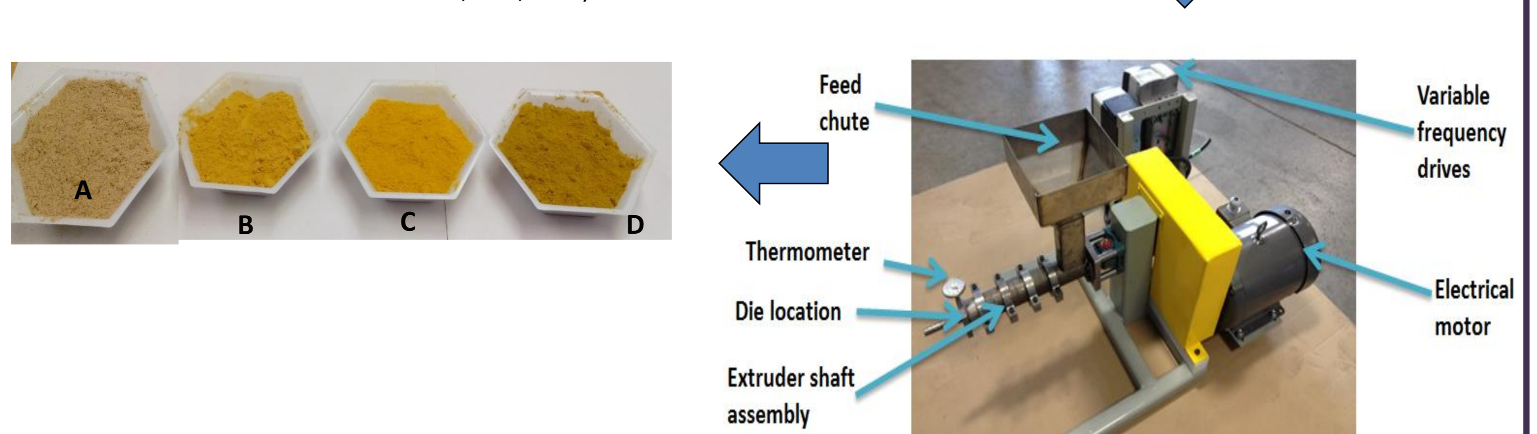
Development of micronutrient dense staple foods, such as cereal porridges, requires some level of processing to deliver quality products and preserve micronutrient content[3]. Extrusion is one such process that allows for generation of a diverse array of product forms. As a High Temperature Short Time (HTST) process, extrusion is commonly used to produce a wide range of products with relatively low cost, high energy efficiency, and flexibility to incorporate a variety of ingredients into product[4,5]. For example, extruded cereals can be used as vehicle for vitamin and mineral fortification by micronutrient rich plant materials including carrots, mango, sweet potato, cassava, and moringa. While promising, the potential for interactions between ingredients and through extrusion processing that can affect both quality and micronutrient delivery must be established.

MATERIALS & METHODS

Preparation of extruded products. Powdered Carrot, Baobab, and Moringa were combined with whole grain millet in proportions described below, adjusted to ~30% moisture and processed by extrusion (Technochem MODEL 900 rpm; Final Temp = 87.9-115 °C).



Formulations	A	B	C	D
Carrot (%) :	—	15	15	15
Baobab (%) :	—	—	5	—
Moringa (%) :	—	—	—	5
Millet (%) :	100	85	80	80



Associated Analyses:

Provitamin A Analysis was conducted by LC-DAD as described by Kean et al.[6]
Color analysis was as described by Ndiaye et al.[7] using HunterLab colorimeter.
Water solubility index (WSI) and **Water absorption index** (WAI) were determined as described by Bouvier and Campanella[8].
Pasting properties were determined by RVA as described by Parada et al. [9]
DSC was done using TA Instruments DSC 2920 Modulated DSC.
Amylopectin and amylose size by HPLC-SEC[10].
Carotenoid bioaccessibility was determined by in vitro digestion as described by Lipkie et al[11].

RESULTS & DISCUSSIONS

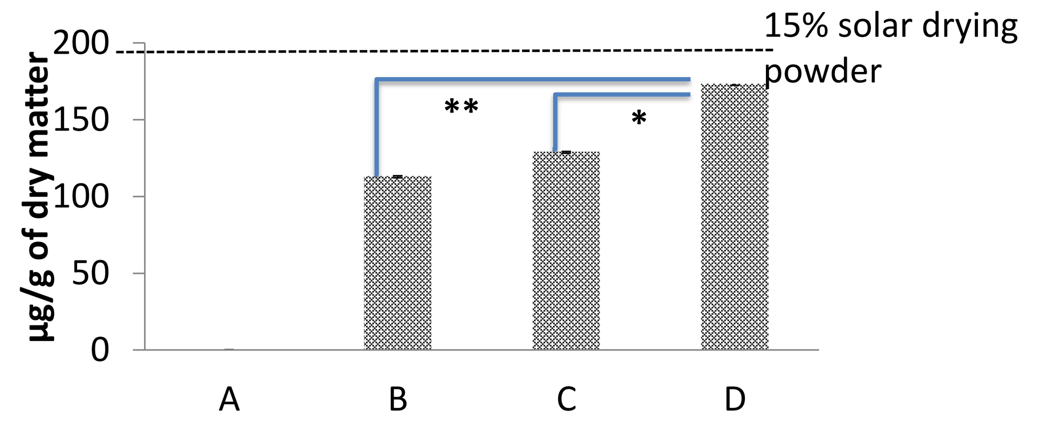


Figure 1: Boabab and Moringa enhance retention of provitamin A carotenoids through extrusion.Iincreases of 17 and 62.71 μg/g respectively in 80% WG millet, 15% Carrot was observed with addition of 5% Baobab and 5% Moringa respectively. Dotted line illustrated provitamin A levels formulated through 15% carrot (pre-extrusion).

Table 1 Starch digestibility of extruded blends

	C_∞ (%)	k (min^{-1})
Extruded millet (EM)	41.9ab±4.5	0.26a±0.02
EM-carrot-Moringa	45.7a±3.2	0.26a±0.04
EM-carrot	39.6ab±2.5	0.29a±0.06
EM-carrot-Baobab	37.4b±1.7	0.27a±0.07

Table 2 Rheological properties of co-extruded products determined by RVA

Sample name	Peak viscosity	Trough viscosity	Breakdown viscosity	Final viscosity	Setback viscosity
A. Millet	2328 ± 14.1a	249 ± 6.50	2079 ± 8.5a	653.5± 0.7b	404.5± 11.7b
B. Millet+Carrot	2202.5 ± 1.8b	262 ± 9.9a	1940 ± 10.6b	730.5 ± 2.3a	468 ± 12.0a
C. Millet+Carrot+Baobab	1706 ± 7.5d	239.7 ± 8.3b	1466 ± 9.1d	499.7 ± 4.7c	261 ± 3.6d
D. Millet+Carrot+Moringa	1976 ± 8.9c	272 ± 4.7a	1683± 10.4c	648 ± 7.8b	376.7± 4.5c

Table 3. Color and Water Solubility Index of extruded millet blends

	L	A	B	WSI (% of DM)
A. Millet	66.95±0.1b	3.13±0.01b	21.27±0.12c	8.66 ± 1.1b
B. Millet+Carrot	67.06±0.30a	8.84±0.13b	45.97±0.52b	12.85 ± 0.41b
C. Millet+-Carrot-Baobab	67.24±0.08a	12.52±0.19a	56.08±0.54a	17.3 ± 1.34a
D. Millet +Carrot-Moringa	57.81±0.18b	6.02±0.02c	45.31±0.46b	17.59 ± 1.53a

Figure 2. Average hydrodynamic radius of (A) amylose and (B) amylopectin as impacted by formulation and extrusion

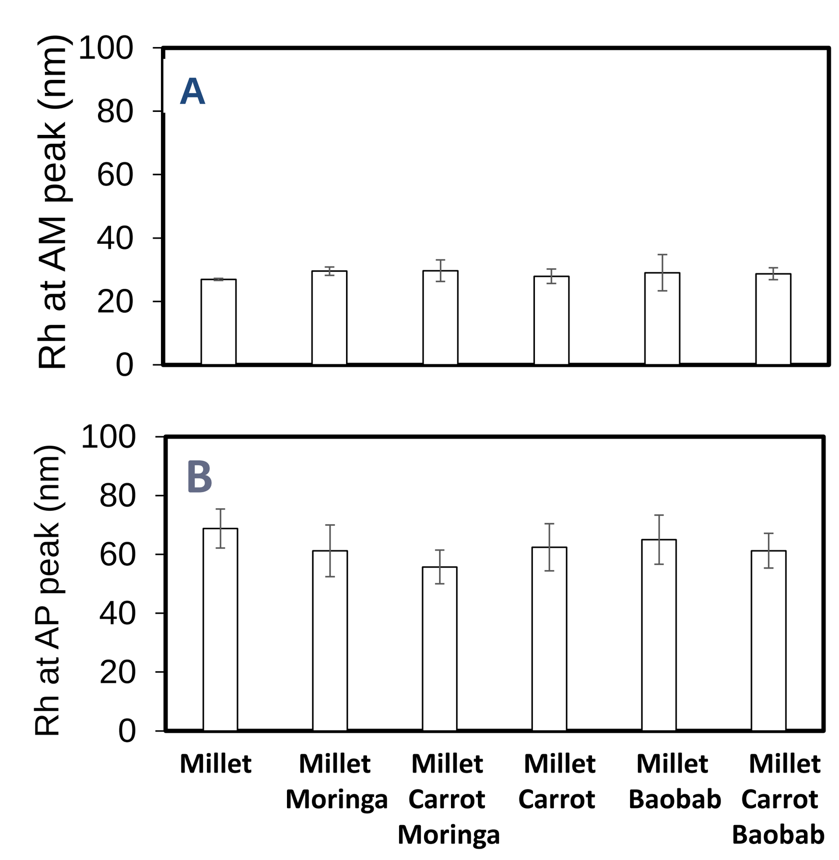


Figure 3. Bioaccessibility of proVA carotenoids is impacted by formulation and extrusion.

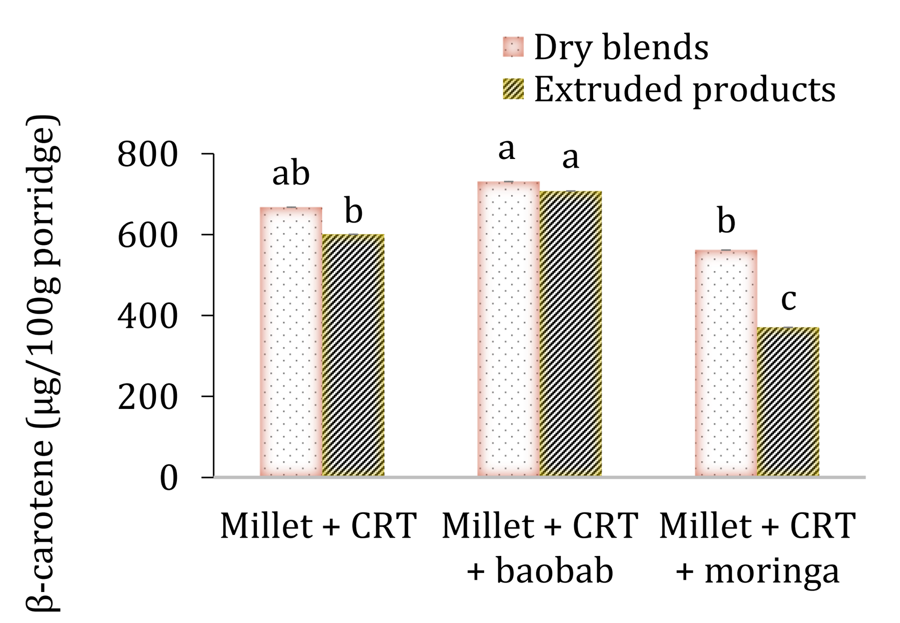


Table 4 Complex formations in extruded blends (protection)
(Tp (ºC) & ΔHp (J/g): temperature and enthalpy of the sample)

Samples	Tp (ºC)	ΔHp (J/g)
Millet	115.1 ± 0.4	0.40 ± 0.11a
Millet+Carrot	98.8 ± 0.1	0.26 ± 0.01b
Millet+Carrot+Baobab	109.1 ± 2.6	0.20 ± 0.00b
Millet+Carrot+Moringa	100.7 ± 0.4	0.03± 0.01c

Table 3 Delivery of proVA carotenoids by test products as adjusted by bioaccessibility

	μg provitamin A required for 100% RDA	% of RDA delivered by 250g of porridge
M/F 1-3 years	300	67.5
F 14-18 years	700	27.5
M 14-18 years	900	22.5

CONCLUSIONS

- Low cost extrusion provides a path to generation of quality processed cereal products
- Extrusion of blended products does impact quality (pasting properties and color) as well as nutrient recovery and bioaccessibility
- Extruded blends of cereal with, provitamin A rich plant materials could be used to develop products targeting micronutrient deficient populations by virtue of their ability to deliver high levels of micronutrients in readily bioaccessibile forms.

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