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Research Article

Physicochemical and sensory properties of porridge made from a composite flour of *Ipomoea batatas* flour and *Ricinodendron heudelotii* meal fermented with *Lactiplantibacillus plantarum* A6

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Abstract

Composite mixtures of sweet potato flour (SP) and *Ricinodendron heudelotii* meal (NM) were fermented with *Lactiplantibacillus plantarum* A6 for either one day, two days, or left unfermented (0 hours). The resulting porridges were then analysed for their sensory characteristics. The results showed that increasing the level of incorporation of *Ricinodendron heudolottii* meal significantly ($p \leq 0.05$) increased crude protein (3.18 ± 0.77 - 52.78 ± 5.42) g/100g, total lipid (7.0 ± 0.36 - 57.41 ± 0.60) g/100g, total ash (4.3 ± 0.01 - 11.44 ± 1. 50) g/100g, fibre content (4.83 ± 0.76 - 11.95 ± 0.74) g/100g and total carbohydrate (12.43 ± 0.93 - 20.81 ± 0.5) g/ 100g contents of composite mixtures while reducing moisture content (6.96 ± 0.11 - 2.76 ± 0.58) g/100g, water absorption capacity and oil absorption capacity. The sensory evaluation of porridge made from composites showed that the overall acceptability was influenced by the composition of the mixture and the duration of fermentation. The composite mixture with 50:50 sweet potato flour, *Ricinodendron heudolottii* meal ratio, fermented for 24 h was the most accepted by the panelists. The results of the viscosity measurement and energy determination indicate that the optimal composite contains 465.4 kcal/100 g of mixture and exhibits a porridge viscosity of 32 mPa.s. The in vitro digestibility of proteins for the preferred porridge is 40.46%, which represents a significantly higher rate of digestibility than that observed for the unfermented counterpart (30.60%). The addition of a starter culture during the fermentation process resulted in an improvement in the safety and nutrient quality of the mixture.

1. Introduction

The persistent prevalence of protein-energy malnutrition, which is most prevalent in poor and underdeveloped countries, particularly in sub-Saharan Africa, has prompted the search for nutritious local plant products that also serve economic purposes [1]. These plant products have been employed primarily as composites to supplement nutritional compositions and obtain the requisite nutrients. This is exemplified by the utilisation of local products such as tubers (cassava, yam, cocoyam, sweet potato), cereals (maize, sorghum), and oilseeds (peanuts, *Ricinodendron heudelotii*).

The sweet potato (*Ipomoea batatas*) is a herbaceous perennial root and tuber crop belonging to the family Convolvulaceae. It represents 12% of the most

important root crops globally and is the fifth most significant crop among the primary basic products in Cameroon, following cassava, plantain, cocoyam, and maize. Despite the nutritional value of the sweet potato making it an attractive option for industrial applications in food production, its low protein content (less than 2%) presents a challenge in terms of its effective use [2]. It is therefore imperative to increase the protein content of sweet potato-based foods in order to achieve a suitable nutritional profile. As documented in the literature, the majority of tubers exhibit low protein content. Consequently, the protein content of these tubers can only be enhanced through the inclusion of legumes. [3].

Indeed, *Ricinodendron heudelotti*, commonly referred to as "njansang" in Cameroon, is an oilseed-bearing plant native to the tropical rainforest zones of Africa. It has been documented to be a rich source of protein hydrolysates [4]. The ratio of essential amino acids to total amino acids is 40.6%, which is slightly higher than the ratio of 33.3% found in a balanced protein. Ngangoum et al. [4] demonstrate that the proteins in question possess a high nutritional value and can be employed in the enhancement of foodstuffs with a low protein content. In light of these findings, *Ricinodendron heudolottii* flour has been employed as a substitute in the production of energy-dense biscuits [5]. However, the low consumer acceptance of these produced biscuits due to the strong odour induced by *Ricinodendron heudolottii* represents a significant challenge for their industrialisation [5]. Furthermore, the presence of anti-nutritional factors in *Ricinodendron heudolottii* impedes the digestibility and assimilation of its proteins and mineral components. This issue could be addressed through the utilisation of the fermentation process, which has been demonstrated to enhance the biodigestibility and flavour of food matrices such as sorghum [6].

One of the most effective and cost-efficient biotechnological techniques for enhancing or maintaining the sensory, nutritional, shelf-life, safety, and shelf-life of vegetables and fruits has been reported to be fermentation utilising lactic acid bacteria. In the fermentation of roots and tubers, lactic acid bacteria such as *Lactobacillus plantarum*, *Lactobacillus lactis*, *Lactobacillus acidophilus*, *Lactobacillus xylosus*, *Lactobacillus paracasei*, and *Lactobacillus brevis* have been employed extensively [7]. Indeed, lactic acid fermentation has been demonstrated to enhance consumer appetite for food products, which in turn has been shown to positively impact the linked health characteristics of foods.

Despite the fact that some researchers have published findings on the impact of fermentation on the nutritional properties of plant-based food products, there is a paucity of studies on the effect of lactic acid fermentation on sweet potatoes and *Ricinodendron heudelotii* flours, particularly with regard to their functional properties and the digestibility of the resulting porridge. Accordingly, the present study aimed to evaluate the influence of *Lactiplantibacillus plantarum* A6 fermentation time on the water absorption capacity, solubility, swelling index, and in vitro digestibility of porridge prepared from a composite flour of Ipomoea batatas flour and *Ricinodendron heudelotii* meal.

2. Materials and methods

2.1. Materials

The raw materials employed in this study were yellow-fleshed sweet potato tubers (with a maturity of six months) and seeds of the *Ricinodendron heudelotii* plant, procured from the Mokolo market in Yaoundé. The *Lactiplantibacillus plantarum* A6 strain was sourced from DuPont (Shanghai, China).

2.2 Flours preparation

The sweet potato tubers were initially washed with tap water and subsequently peeled using a manual stainless-steel knife. They were then cut into chips of approximately 2–5 mm in diameter using a tuber slicer (Crypto Peerless). The seeds of *Ricinodendron heudelotii* and sweet potato slices were distributed on drying trays and subjected to a drying process at 70 °C for 48 hours in a drying oven (DGX-9143B-1, Shang hai Fuma Test Equipment Co. Ltd). Subsequently, the desiccated seeds and chips were extracted and finely ground in an electronic blender (Moulinex) to produce the dry sweet potato and *Ricinodendron heudelotii* flours.

2.3 Mixture formulation

The flour mixtures were prepared using the mixture design, which was carried out in Minitab 18. In summary, five formulations were generated, wherein the minimum values for each mixture component

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were set at 0% and the maximums at 100%, respectively. The diverse flour mixtures were based on an incremental increase in the proportion of one ingredient in comparison to the other (Table 1).

Table 1. Flour Mixture formulation table with Minitab 18

Standard Order	Trial Order	Sweet potato flour (%)	*Ricinodendron heudelotii* meal (%)
5	1	25	75
3	2	50	50
2	3	0	100
4	4	75	25
1	5	100	0

2.4. Lactic acid fermentation

The culture employed for fermentation was *Lactiplantibacillus plantarum* A6, which was incubated for 24 hours at 37 °C in a sterile saline solution. On Plate Count Agar (PCA) culture media, a series of dilutions were seeded, and the dilution with countable cells was selected for further analysis. The range of 30–300 was employed to ascertain the cell density of the microbial solution. The objective is to achieve a cell density of 106 CFU/mL during the fermentation process. In summary, 5% (v/w) of *Lactiplantibacillus plantarum* A6 was added to 275 g of mixed flour with water at a 1:1 ratio, and the mixture was allowed to ferment for 24 and 48 hours at 37 °C. Subsequently, the fermented composite flour was subjected to oven drying for 24 hours at a temperature of 55 °C. These conditions were selected based on the results of preliminary assays.

2.5. Proximate analyses of flour mixtures.

The physicochemical properties of both the fermented and unfermented samples were determined according to the AOAC 2000 method, including the moisture content, crude protein (Method 920.87), total lipid (Method 996.06) total ash (Method 972.15) crude fiber (Method 993.21), and total sugars [8].

2.6. Evaluation of the functional parameters of flours.

The functional properties of flours, including their swelling capacity, water absorption capacity (WAC), and oil absorption capacity (OAC), were determined in accordance with the methodologies outlined by Chandra et al. [9].

2.7. Porridge Assays

Yadang [2] prepared a variety of porridge from slurries containing 10% (w/v) of the sample and cooked them for 10 minutes on an electronic heater.

2.7.1. Sensory analysis of porridge made from composite mixture.

A hedonic test was employed to conduct a sensory analysis. In summary, a panel of 15 adults with a comprehensive understanding of the quality parameters evaluated in the porridge was selected. The porridge was evaluated on a 9-point hedonic scale, based on its colour, odour and viscosity. Each descriptor was assigned a score value on a scale of 1 to 9, with 1 representing the least favourable and 9 the most favourable rating.

The scale ranged from 9 (extremely like) to 1 (extremely dislike). Intermediate ratings were assigned as follows: 8 (very much like), 7 (moderately like), 6 (slightly like), 5 (neither like nor dislike), 4 (slightly dislike), 3 (moderately dislike), and 2 (dislike). The data obtained for each parameter were reported as the mean of 15 judgments.

2.7.2 Determination of energy value of porridge.

The energy values of the preferred sample were calculated based on the results of the sensory analysis, using Atwater's conversion factors [10].

Energy content (Kcal) = (9 * fat content) + (4 * carbohydrate content) + (4 * sample protein)

2.7.3 Determination of porridge viscosity.

The viscosity of the preferred sample was determined according to the method described by Makame et al. [11], based on the results of the sensory analysis.

2.7.4 Determination of digestibility proteins after dialysis.

In vitro digestibility was determined using the methodology proposed by Mezajoug-Kenfack [12]. In summary, 10 ml of 0.01N HCl and 2 ml of phosphate buffer (KH2PO4 0.01M, pH 2) were added to the protein solution. The mixture was incubated for 30 minutes at 37 °C in a stirred water bath. The digestion process was terminated by adjusting the pH of the mixture to 7.5. A second digestion was performed within a dialyze bag with exclusion limits between 800 and 1200 D, using a trypsin solution prepared at 1 mg/l in phosphate buffer (KH2PO4 0.01 M, pH 8). Subsequently, the dialyze bag was immersed in a phosphate buffer within a 100-ml beaker, and digestion was conducted at 37 °C within a stirred water bath for three hours. Fractions of the digested

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Table 2. Proximate composition of composite mixtures expressed in g/100g (Dm) of flour

Treatment	Composite mixture	Moisture (g)	Crude Protein (g)	Total Lipid (g)	Total ash (g)	Crude fibre content (g)	Total sugars (g)
UN	100:0	6.96^{a} ±0.11	3.18^{a} ± 0.77	7.0^{e} ± 0.36	4.3^{b} ± 0.01	4.83^{d} ± 0.76	12,43 ± 0,93
	75:25	6.22^{b} ±0.03	14.10^{a} ± 0.27	20.84^{d} ± 0.69	6.40 ^{b}± 0.00	6.93^{cd} ± 0.75	31,11 ± 2,68
	50:50	6.07^{b} ±0.08	27.15^{b} ± 0.73	35.55^{c} ± 1.48	10.65 ^{a}± 0.01	10.11^{bc} ± 2.26	16,1 ± 2,16
	25:75	3.80^{c} ±0.21	45.42^{c}± 3.53	47.25^{b} ± 0.60	11.44 ^{a}± 1.50	11.95^{ab} ± 0.74	24,37 ± 2,41
	0:100	2.76^{d} ±0.58	52.73^{c} ± 5.42	57.41^{a} ± 0.27	10.33^{a} ± 0.01	15.99^{a} ± 0.73	20,81 ± 0,5
Ft(24h)	100:0	8.83^{a} ±0.09	1.76^{a} ± 0.17	8.46 ± 3.34	6.58^{c} ± 0.00	4.94^{c} ± 0.80	12,29 ± 1,16
	75:25	7.32^{b} ±0.10	11.73^{b} ± 1.03	23.39 ± 1.83	7.55 ^{bc}± 1.53	7.55^{bc} ± 1.53	30,45 ± 7,60
	50:50	4.93^{c} ±0.15	25.42^{c} ± 1.97	34.07^{c}± 1.58	11.57^{ab} ± 1.46	10.52^{ab} ± 1.49	14,47 ± 0,81
	25:75	6.80^{d} ±0.08	31.46^{d} ± 1.06	50.84^{b} ± 0.96	12.88^{a} ± 0.01	12.34^{ab} ± 2.28	22,08 ± 0,52
	0:100	1.57^{e} ±0.10	18.14^{e} ± 1.76	60.18^{a} ± 0.43	11.19^{ab} ± 1.43	15.75 ^{a}± 0.72	18,55 ± 5,39
Ft(48h)	100:0	5.71^{b}±0.16	4.50^{a} ± 0.04	6.71^{c} ± 2.16	9.54^{c} ± 1.48	7.95^{b} ± 0.75	10,54 ± 1,53
	75:25	6.61^{a} ±0.09	12.22^{b} ± 1.42	9.93^{bc} ± 1.74	7.49^{c} ± 1.50	8.03^{b} ± 0.80	18,38 ± 2,07
	50:50	6.14 ^{ab}±0.15	23.27^{c} ± 0.55	13.05^{ab} ± 1.86	4.25^{d} ± 0.01	10.65^{ab} ± 1.51	13,93 ± 0,51
	25:75	5.14^{ab} ±0.16	28.37^{d} ± 1.84	14.45^{ab} ± 0.68	14.77^{b} ± 0.02	12.12^{ab} ± 2.24	21,98 ± 5,90
	0:100	6.00^{c} ±0.26	44.93^{e} ± 0.74	17.71^{a} ± 2.55	22.33^{a} ± 1.59	15.43^{a} ± 0.75	17,54 ± 2,31

Values of mean on same treatment lot having different superscripts (a, b, c, d, e) are significantly different (p≤0,005). UN: unfermented composites, Ft: fermented composites et time (t).

foodstuff (5 ml) were collected at 30-minute intervals, and the kinetics of nitrogen liberation were monitored. The number of digested proteins was calculated using the following formulas:

$$Digested\ proteins\ (mg/g) = \frac{Q * f * Dm * 100}{M}$$

$$Digestibility = \frac{Digested\ protein}{Initial\ protein\ content\ of\ sample} * 100$$

Where Q is the quantity of protein (mg/ml), f is the dilution factor, Dm is the sample dry matter, and M is the mass of protein sample

2.8. Statistical analysis

One-way analysis of variance (ANOVA) and Fisher's least significant difference (LSD) tests were performed using Xlstat software (version 2017.5) (Addinsoft, 2019) for the purpose of comparing the mean differences of the samples.

3. Results and discussion

3.1 Proximate composition of flours from different treatments.

The physicochemical results presented in Table 2 demonstrated that the level of incorporation of *Ricinodendron heudelotii* flour (Nm) and the fermentation time of the mixtures had a significant effect (p≤ 0.05) on the proximate properties of these flours. The reduction in moisture content resulting from the incorporation of *Ricinodendron heudelotii* flour can be attributed to the higher dry matter content of *Ricinodendron heudelotii* in comparison to sweet potatoes.

However, the increase observed after 1 day of fermentation could be explained by the addition of water to the mixture and the starter solution before fermentation, and the result is similar to that obtained during the fermentation of Bambara groundnut flour using a Lactobacillus consortium [13]. In contrast to the samples fermented for 24 h, the moisture content of samples with higher proportions of sweet potato flour (100-75% of the total) decreased, while that of samples with higher proportions of *Ricinodendron heudelotii* meal increased (50-100%). This could be related to the fact that fermentation leads to the breakdown of the food matrix, exposing hydrophilic molecules that can absorb water, thereby increasing the moisture content. However, the moisture contents of the flours are within the favourable range for effective flour storage without risk of microbial contamination. Flours with moisture contents below 14% can resist microbial development; therefore, the samples would be shelf stable and have a reduced risk of flour rancidity [14]. The range obtained was lower but not very different from that obtained for sweet potato flour enriched with indigenous, underutilised seasonal vegetables [1].

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There is a significant (p≤0.05) increase in protein content (3.18 ± 2.77 to 52.73 ± 5.42) in the unfermented samples with increasing incorporation of *Ricinodendron heudelotii* meal. This work also shows that *Ricinodendron heudelotii* meal, even at an incorporation rate of 25%, can effectively improve the nutritional composition of flour and, as such, can contribute to the resolution of protein deficiencies as reported by Makame et al [11]. After fermentation, a decrease in crude protein content was observed in all samples, but a drastic decrease in the 100% Nm sample. This can be explained by the fact that in media with limited sugar content, some microorganisms with protease and peptidase activity use available amino acids and nitrogen compounds as substrates for energy acquisition [12]. After a decrease in the protein content of the mixtures after 24 h of fermentation, there is a slight increase in the protein content of some samples after 48 h; this could be due to the production of microbial protein in the culture medium during fermentation [13].

There was a significant (P≤0.05) increase in the lipid content of the blends as the proportion of *Ricinodendron heudelotii* meal increased; this is due to the high lipid content of *Ricinodendron heudelotii* oilseeds, which increased from 57.41 in the unfermented sample to 60.18 in the sample fermented for one day and later decreased to 17.71 after the second day of fermentation. These values are in agreement with previous studies which reported lipid contents of these oilseeds ranging from 49.25% to 63.48% [14]. An increase in the lipid content of the flour mixtures after the first day could be explained by the amylase activity of lactic acid bacteria on amylose-lipid complexes in the mixtures, resulting in the release of bound lipid molecules. However, a decrease after 24 h could be due to the hydrolysis of fat constituents into fatty acids and glycerol, thereby enhancing aroma and flavour, and also due to energy-consuming biochemical and physiological changes that accompany the fermentation process [13]. Some microorganisms can also use fat as an energy source.

Increasing levels of *Ricinodendron heudelotii* meal inclusion result in a corresponding increase (p≤ 0.05) in the total ash content of the composite mixture, from 4.30 g in 100% sweet potato flour, to 10.65 g in a 50/50 composite, to 10.32 g in 100% *Ricinodendron heudelotii* meal. After fermentation for 24 and 48 hours respectively, there is an observable increase in the total ash content of the fermented composites compared to their unfermented counterparts. These increases in total ash content can be attributed, on the one hand, to the high mineral content of *Ricinodendron heudelotii* seeds, expressed as total ash content of up to 10.32 g. However, this value is lower than that obtained by Mezajoug-Kenfack [12]. Secondly, the increase after fermentation can be attributed to the fact that fermentation has a positive effect on making minerals more available by breaking down complex matrices that bind these minerals; it also leads to a reduction in dry matter, resulting in the exposure of mineral ions [15]. A high total ash content, as well as a high mineral content, is critical in overcoming micronutrient deficiencies.

Dietary fibre is one of the most important nutritional components of flour products and is known to improve laxation, lower blood glucose and cholesterol concentrations, and reduce the risk of heart disease by binding to cholesterol and preventing its absorption by the body [1]. The incorporation of *Ricinodendron heudelotii* flour has a positive effect (p≤ 0.05) on the dietary fibre content of the resulting blends, increasing the dietary fibre content of 100% sweet potato flour from 4.83 g to 10.11 g in a 50/50 blend. An increasing trend is observed in all three batches of composite mixtures and is related to the high fibre content of *Ricinodendron heudelotii* seeds used in this work (15.99 g/100 g); the value obtained for the seeds used in this work is higher than that obtained by Mezajoug-Kenfack [12]. However, there is little or no significant difference in the crude fibre content of the unfermented composites and their fermented counterparts; this is because fermenting microorganisms are unable to degrade fibrous materials present in a food matrix. Slight increases, such as those observed with sweet potato flour, may be explained by the loss of dry matter during fermentation, which increases the appearance of fibrous molecules.

3.2 Functional Properties

Functional properties of foods are those that have a direct influence on their usability and on the final quality of products derived from these foods. They define the best areas of application for these foods

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and relate the interactions of food macromolecules (starch, lipids and proteins) with their environment. Results for some functional properties of a composite mixture of sweet potato flour and *Ricinodendron heudelottii* meal are presented below.

3.2.1 Water absorption capacities of composite mixtures

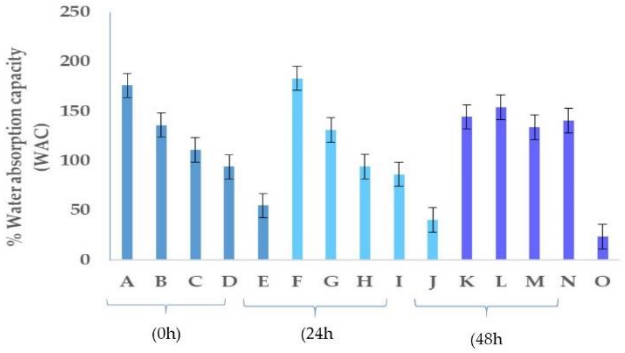
Fig. 1A shows the water absorption capacity of flour, which varies with the level of incorporation and the time of fermentation. The water absorption capacities of the samples decrease progressively, from 176.13% to 55.04% for unfermented composites and from 183.33% to 40.31% for samples fermented for 24 hours. The water absorption capacities of the composites fermented for 48 hours show a variable decrease. Flour samples with low ratios of hydrophilic amino acids absorb less water and have low water absorption capacities [7]. The result is also in agreement with Oloyede et al [16] who reported that Moringa seed flours showed an increase in water absorption capacity with increasing fermentation time. The decrease in water absorption capacity observed in this work may be a result of the amino acid profile of *Ricinodendron heudelotii* meal, which has been reported to be high in hydrophobic amino acids [8].

3.2.2 Oil absorption capacities of composite mixtures

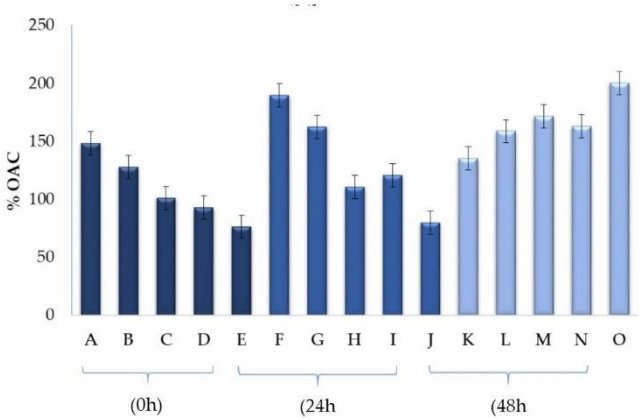
Fig. 1B illustrates the variation in oil absorption capacity of the composite blends with the level of incorporation of *Ricinodendron heudelotii* meal and the duration of fermentation. The oil absorption capacity in the unfermented composites decreases significantly ($p \leq 0.05$) as the level of incorporation of *Ricinodendron heudelotii* meal increases (148.14% to 76.37%). The same pattern, but slightly higher values, are obtained for samples fermented for 24 hours. The result is also in agreement with Oloyede et al [16] who reported that Moringa seed meals showed an increase in oil absorption capacity with fermentation time. When the samples were fermented for 48 hours, there was a significant increase in oil absorption capacity. This implies that reducing the moisture content of the composites by adding *Ricinodendron heudelotii* meal reduces their oil absorption capacity accordingly.

3.2.3 Swelling capacities of fermented and unfermented composite mixtures

Fig. 2 shows the effect of fermentation on the swelling capacity of flours heated in water at different temperature ranges (55°C, 65°C, 75°C and 85°C). It can



A: water absorption capacities with level of incorporation and time of fermentation.



B: oil absorption capacities (OAC) with level of incorporation and time of fermentation.

Figure 1. Effect of *Lactiplantibacillus plantarum* A6 fermentation of *Ipomoea batatas* flour and *Ricinodendron heudelotii* meal on functional properties (*Legend:* A: 100/0, B: 75/25, C: 50/50, D: 25/75, E: 0/100, F: 1/100/0, G: 1/75/25, H: 1/50/50, I: 1/25/75, J: 1/0/100, K: 2/100/0, L: 2/75/25, M: 2/50/50, N: 2/25/75, O: 2/0/100).

be seen that the swelling behaviour of a mixture is influenced by the composition of the mixture and the heating temperature.

The curves for unfermented samples follow the normal curve for the hydrothermal behaviour of starch with temperature (Fig. 2). Similar results were obtained by Oloyede et al [16] in evaluating the swelling behaviour of *Moringa olifera* flour as a function of fermentation time. Starch granules are said to vibrate more vigorously as temperature increases, breaking intermolecular bonds and allowing hydrogen bonding sites to engage more water molecules [16]. With further increases in temperature, the swollen starch molecules burst, releasing pockets of water (syneresis); this isillustra ted by the decrease in viscosity on retro-gradation.

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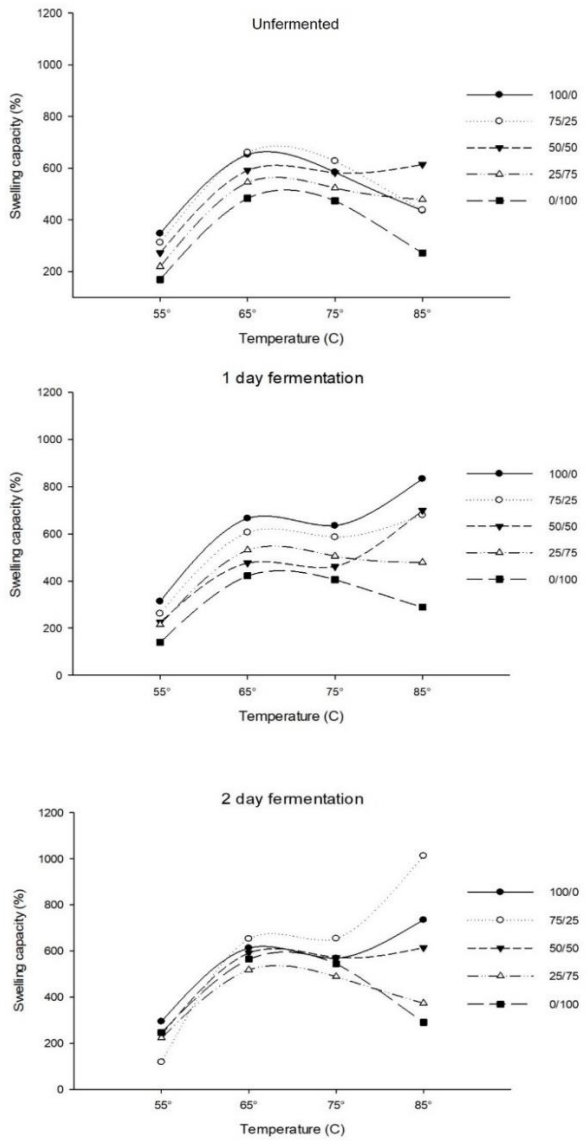

Figure 2. Kinetics of the swelling capacities of unfermented; 1 day fermentation; 2 days fermentation composites with increasing temperature. 100/0: hundred percent sweet potato flour, 75/25: seventy five percent sweet potato flour, 50/50: fifty percent sweet potato flour, 25/75: twenty five percent sweet potato.

The swelling curves of the 24 h and 48 h samples do not follow the same pattern of hydrothermal behaviour as the unfermented starch samples. These turn to a further peak after an initial peak in viscosity, and the further peak is more pronounced in samples fermented for 2 days. These changes in viscosity patterns can be attributed to fermentation, which may have produced molecules with viscosity-imparting properties such as exopolysaccharides.

3.3. Sensory evaluation and acceptability of porridge made from composites

Results for overall mean general acceptability, calculated from preference scores for colour, odour and consistency, show that there is a significant influence ($p \leq 0.05$) of *Ricinodendron heudelotii* meal incorporation and fermentation time on porridge acceptability (Fig. 3).

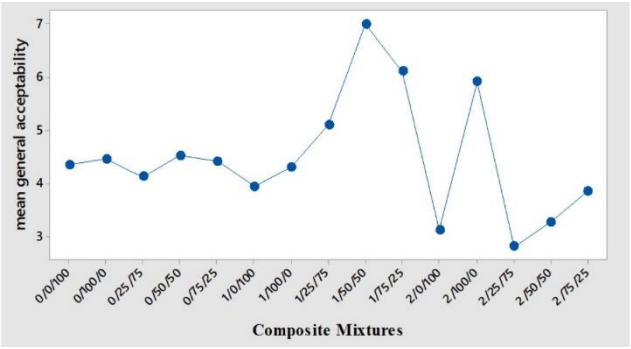

Figure 3. General acceptability of porridge prepared from composites, evaluated based on colour, odour and consistency (Legend x/y/z: x=time of fermentation; y=percentage of *Ricinodendron heudelotii* and z=percentage of potato flour)

Porridge samples made from flour samples with higher amounts of *Ricinodendron heudelotii* meal showed lower acceptability (Fig. 3) due to the pungency of the *Ricinodendron heudelotii* odour. The best porridge sample was made from flour fermented for 24 hours and containing a 50:50 ratio of raw material composition. It had a creamy white colour, a very pleasant odour and a suitable consistency that was appreciated by all panelists. The least acceptable porridge was made from flour fermented for 48 hours and containing 75% *Ricinodendron heudelotii* meal. A similar report of reduced acceptability was observed for energy biscuits containing *Ricinodendron heudelotii* flour [11]. Mash samples containing more than 50% sweet potato flour were also disliked due to their dark colour. Fermentation improves the sensory properties of porridge by enhancing colour, odour and viscosity (Fig. 3).

3.4. Results on preferred composite mixture

3.4.1. Porridge viscosity

Viscosity measurements of the preferred formula (10 % w/v) using the Brookfield DV III Ultra Programmable Rheometer show a viscosity value of 32.03±0.01 mPa.s. This value is quite low compared to the unfermented formula. It is also low compared to the recommended porridge viscosities of 1 psi for infants

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under 5 months and 2 psi for infants over 8 months [17]. Therefore, it is possible to prepare porridge samples with a higher energy density per unit volume and a viscosity suitable for maximum assimilation.

3.4.2. Energy value

According to the Atwater general factor system, the energy value for preferred composite is:

E = (9*34.07) + (4*25.24) + (4*14.47) = 465.47 kcal for preferred composite flour

E = (9*27.15) + (4*35.55) + (4*16.10) = 450.95 kcal for unfermented composite flour

This energy value is slightly higher than that fixed by codex standards for flours for complementary feeding (379.4400 kcal/100 g) (CODEX STAN 074-1981, REV. 1—2006), but has great prospects for classification as an energy dense mixture. The energy value of unfermented composite flour is lower than that fermented for 24h.

3.4.3. In vitro digestibility

Fig. 4 shows the in vitro digestibility of selected composites compared to their unfermented counterparts. The digestibility of the fermented composites is higher than that of the unfermented composites. The rate of protein digestion increases with hydrolysis time in both samples, but is greater in the preferred composite (50:50 and fermented for 24 h). This could be due to the degradation of complex molecules such as carbohydrates bound to proteins, which increases the exposure of protein molecules to enzymatic cleavage during digestion.

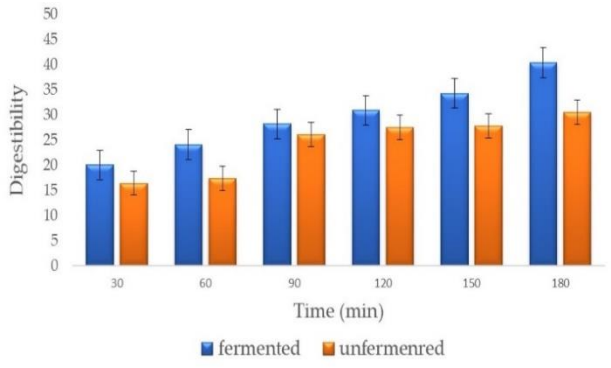

Figure 4. In vitro digestibility of preferred composite compared to the unfermented counterpart

4. Conclusions

Incorporation of *Ricinodendron heudelotii* flour into sweet potato flour significantly improves the nutritional and functional properties of these flours. Flour blends of up to 50 sp/50 n can produce an acceptable and digestible energy and protein dense porridge for infants. Fermentation significantly improved some of the nutritional and functional properties of the flours, thus extending the range of use of these blends. Fermentation for 24 hours is sufficient to produce improved flour properties, but fermentation for 48 hours produces other technologically important molecules, such as exopolysaccharides in some flour blends.

Authors' contributions

Conceptualization, Y.G. and P.A.E.; Methodology and formal analyses, M.N.E.; Writing—original draft preparation, Y.G and P.A.E.; Writing—review and editing, Supervision, K.L.B and T.C.

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Availability of data and materials

All data will be made available on request according to the journal policy.

Conflicts of interest

The authors declare no conflict of interest

References

1. Teye E.; Agbemafle R.; Lamptey P. Development and examination of sweet potato flour fortified with indigenous underutilized seasonal vegetables. Beverages. 2018, 4(1), 5. https://doi.org/10.3390/beverages4010005
2. Yadang G. Développement des farines de complément à base de patate douce (*Ipomoea batatas*) et de légumineuse. Ngaaoundéré: Université de Ngaoundéré. 2015.
3. Vaz Patto, M.C.; Amarowicz, R.; Aryee, AN.; Boye, J.I.; Chung H.J.; Martín-Cabrejas, M.A.; Domoney, C. Achievements and challenges in improving the nutritional quality of food legumes. CRC Crit. Rev.

https://doi.org/10.58985/jafsb.2024.v02i03.57

Plant Sci., 2015 *34*(1-3), 105-143. https://doi.org/10.1080/07352689.2014.897907.

4. Ngangoum, E S.; Mezajoug, K.L.; Sanjit, K.; Mookambeswaran, V.; Tchiégang, C. Functional and antioxidant properties of protein hydrolysates from *Ricinodendron Heudelotii* (Bail.) flours from Cameroon. Res. Adv. Pharm. Nutr. Ind. Enzym. 2018, 90-100. https://doi.org/10.4018/978-1-5225-5237-6.ch014.
5. Fombang, E.; Agamou, J.; Mbofung, C. Incorporation of *Ricinodendron heudolotti* meal into blends of wheat and precooked taro flour for the production of nutrient dense biscuits Indian J. Nutr. 2014,131-136.
6. Pranoto, Y.; Anggrahini, S.; Efendi, Z. Effect of natural and *Lactobacillus plantarum* fermentation on vitro protein and starch digestibilities of sorghum flours. Food Biosci. 2013, *2*, 46-52. https://doi.org/10.1016/j.fbio.2013.04.001
7. Garcia, C.; Guerin, M.; Souidi, K.; Remize, F. Lactic fermented fruit or vegetable juices: Past, present and future. Beverages, 2020, 6(1), 8. https://doi.org/10.3390/beverages6010008
8. AOAC. Official Methods of Analysis of the Association of Official Analytical Chemists. The Association of Official Analytical Chemists, Inc., Arlington, 2000.
9. Chandra, S.; Singh, S.; Kumari, D. Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. **J. Food Sci. Technol.** 2015, 52(6), 3681-3688.. https://doi.org/10.1007/s13197-014-1427-2.
10. Fulgoni, V.L.; Iii Keast, D.R.; Drewnowski, A. Development and validation of the nutrient-rich foods index: A tool to measure nutritional quality of foods. J. Nutr. 2009, 139, 1549–1554. **https://doi.org/10.3945/jn.108.101360**
11. Makame, J.; De Kock, H.; Naushad, M.E. Nutrient density of common African indigenous/local complementary porridge samples. LWT. 2020, 133. 109978. **https://doi.org/10.1016/j.lwt.2020.109978**
12. Mezajoug-Kenfack. Propriétés nutritionnelles et fonctionnelles des protéines de tourteaux, de concentrats et d'isolats de *Ricinodendron heudelottii* (Bail) Pierre ex Pax et de Tetracarpidium conophorum (mull.Arg). These de Doctorat (PhD): Université de ngaoundéré, 2010.
13. Ogodo, A.; Ugbogu, O.; Onyeagba, R.; Okereke, H. Proximate composition and in-vitro starch/protein digestibility of bambara groundnut flour fermented with lactic acid bacteria (LAB)-consortium isolated from cereals. Ferment.Technol. 2018, 7(1), 1000148. **https://doi.org/10.4172/2167-7972.1000148.**
14. Tchiégang, C.; Mezajoug Kenfack, L. Influence of pH, temperature and ionic strengh on some functional properties of defatted flour from *Ricinodendron heudelotii* (Bail.) and *Tetracarpidium conophorum* (Müll. Arg.). J. Food Technol. 2003, 1(3): 133-138.
15. Pranoto, Y.; Anggrahini, S.; Efendi, Z. Effect of natural and *Lactobacillus plantarum* fermentation on vitro protein and starch digestibilities of sorghum flours. Food Biosci. 2013, *2*, 46-52. https://doi.org/10.1016/j.fbio.2013.04.001
16. Oloyede, O.O.; James, S.; Ocheme, B.O.; Chiemela, E.C.; Akpa E.V. Effects of fermentation time on the functional and pasting properties of defatted *Moringa oleifera* seed flour. Food Sci. Nutr. 2016, 4(1), 89–95. https://doi.org/10.1002/fsn3.262.
17. Ayele, D.; Teferra, F.; Frank, J.; Gebremedhin, S. Optimization of nutritional and functional qualities of local complementary foods of southern Ethiopia using a customized mixture design. Food Sci. Nutr. 2022, 10(1), 239-252. https://doi.org/10.1002/fsn3.2663.