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Effects of Fermentation and Extrusion on the Amino and Fatty Acid Compositions of Unripe Plantains and Soybean Blends

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ABSTRACT

Background and Objective: Traditional processing methods can alter the nutritional composition of food, impacting the bioavailability of essential nutrients. However, limited research exists on how fermentation and extrusion affect unripe plantain-soybean blends' fatty acid and amino acid profiles. This study aims to evaluate the effects of fermentation and extrusion on the fatty acid and amino acid profiles of unripe plantain soybean blends. It investigates how these processes influence nutrient content and bioavailability. The goal is to determine whether these treatments enhance the blend's nutritional value and suitability as a protein and fat source. **Materials and Methods:** Unripe plantains and soybeans served as the foundational ingredients for the blending process in this investigation. Fermentation and extrusion were the two primary processing methods used on the materials. Fermentation was used on the unripe plantains and soybeans, a process that typically uses microbes to degrade chemicals and improve nutritional profiles. The parameters (temperature, pH, and time) and duration of fermentation were meticulously monitored. The fermented and non-fermented blends were further processed by extrusion, a high-temperature, high-pressure technique that simultaneously cooks and forms the materials. The assessment of the effect of fermentation and extrusion on the amino and fatty acid compositions of unripe plantains and soybeans blends from each treatment group (untreated-raw, fermented, extruded, and fermented-extruded) applied techniques such as chromatography (HPLC and GC), spectroscopy (FTIR and NMR) to identify and measure the constituents. Using SPSS 22.0, one-way ANOVA and Duncan's New Multiple Range Test ($p \leq 0.05$) were used for statistical analysis. **Results:** The essential amino acids in fermented extruded unripe plantains-soybeans blends increased significantly when compared with raw (unprocessed) unripe plantain-soybeans blends. Also, non-essential amino acids in fermented extruded unripe plantains-soybeans blends increased than the ones in raw (unprocessed) unripe plantains-soybeans blends. The fatty acid composition was significantly reduced in fermented extruded unripe plantains-soybeans blends while it was increased in the raw (unprocessed) blends. **Conclusion:** According to the study's findings, the fatty acid and amino acid compositions of unripe plantains and soybean blends are greatly influenced by the fermentation and extrusion procedures. Extrusion resulted in altered fatty acid profiles and boosted digestibility, whereas fermentation enhanced key amino acids and improved the quality of the protein. Both procedures improved the blends' nutritional value and increased their suitability for human ingestion. In general, these procedures enhance the blend's bioavailability and nutrient balance.

KEYWORDS

Unripe plantain, soybean, fermentation, extrusion, concentration of amino and fatty acids

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INTRODUCTION

Soybeans and unripe plantains are important agricultural products valued for their diverse culinary uses and high nutritional content[1]. Due to their high protein content, necessary amino acids, and advantageous fatty acids, both nutrients are considered vital parts of many diets across the globe[2].

Food ingredients' sensory qualities, nutritional makeup, and general quality are all greatly impacted by processing[3]. Fermentation and extrusion are two of the many processing methods that are particularly notable for their transformative powers to change the physicochemical characteristics of food matrices[4]. The enzymatic and microbial conversion of substrates during fermentation, a conventional food processing technique, results in biochemical alterations that impact flavor, texture, and nutritional value[5]. On the other hand, extrusion, a contemporary method of food processing, modifies the composition and characteristics of food ingredients by applying high heat and pressure[6]. To improve food processing methods and the nutritional quality of finished products, it is essential to comprehend how fermentation and extrusion affect the nutritional composition of food blends[7].

Optimizing processing conditions to maintain or improve the nutritional value of unripe plantain and soybean blends requires an understanding of how fermentation and extrusion affect the fatty acid and amino acid content of these blends[8].

The creation of functional food products with enhanced bioavailability, digestibility, and health-promoting qualities is guided by this understanding[9]. It also informs dietary guidelines on how to include fermented and extruded foods in balanced meals to promote general health and well-being[10].

Thus, the purpose of this work is to examine how fermentation and extrusion affect the amounts of amino acids and fatty acids in blends made of soybeans and unripe plantains. To support the creation of healthier and more sustainable food options to satisfy the changing dietary needs of consumers worldwide, this study aimed to advance scientific understanding of food processing methods and their implications on nutritional quality.

MATERIALS AND METHODS

Study area: The research work was conducted in the Microbiology Laboratory at the Federal University of Technology Akure, Ondo State, Nigeria. The study was carried out from July, 2023 to October, 2024.

Unprocessed materials: The green, mature, unripe plantain and soybean seeds utilized in this study came from Oja Oba in the Nigerian State of Ondo, specifically from Akure metropolitan.

Preparation of raw plantain flour: After being sorted for maturity, the unripe plantain was cleaned by giving it a wash in sterile water. After being cleaned and unripe, the plantain was thinly sliced into 2 mm diameter pieces and sun-dried for a full 72 hrs. Next, the unripe, dried plantain was fed into a Model 200L090 Bentall attrition mill. After being ground into fine flours using a 0.25 mm mesh sieve, the flours were stored in an airtight container.

Processing of soybean flour: Dirt and stones were removed from the soybeans to clean them. To separate the coat from the cotyledon, the cleaned seeds were roughly ground. To keep them safe from contamination, rat or insect infestation, and dampness, they were housed in an airtight container. Before being used, the ground flour was placed in an airtight container and sieved through a 0.25 mm mesh sieve into fine flour.

Formulation of plantain-soybean blends: The soybean and unripe plantain flours were combined to create six samples: Sample B (90:10) contains 10% soybean flour and 90% unripe plantain flour, while Sample A (100:0) contains 100% unripe plantain flour. Sample C (80:20) is composed of 20% soybean flour and 80% unripe plantain flour. Sample D (70:30) is composed of 30% soybean flour and 70% unripe plantain flour. 60% unripe plantain flour and 40% soybean flour make up Sample E (60:40). 50% unripe plantain flour and 50% soybean flour make up Sample F (50:50).

Blends' fermentation and extrusion: Semi-solid state fermentation was used to ferment a batch of the flour blend for 120 hrs. Each sample weighed 100 g. The containers were cleaned, the air shut, and 70 mL of sterile water were added. The fermentation process was stopped by oven drying for a full day at 60°C. Extrusion cooking was applied to two sets of samples. The unfermented mixtures make up the initial batch. To guarantee uniform water distribution, the blends were hand mixed in a sterile bowl after being hydrated and preconditioned by adding 50 mL of water to 1000 g of the sample. A Brabender 20DN single-screw laboratory extruder (Brabender OHG, Duisburg, Germany) was used to extrude the samples. The fermented samples make up the second group of samples. A Brabender 20DN single-screw laboratory extruder (Brabender OHG, Duisburg, Germany) was also used to extrude the fermented samples. The samples were fed at a rate of 30 kg/hrs while being extruded at 100°C and 20 revolutions per minute. Following a 12 hrs air drying period, all of the extrudates were stored at 32°C in sterile polyethylene bags and labeled, airtight containers. Airtight containers held the control, which is made up of raw blends that were neither fermented nor extruded.

Analysis of the content of amino acids: Following the acid hydrolysis of the samples, the amino acid composition was ascertained by High-Performance Liquid Chromatography (HPLC)[11]. Standard amino acid solutions were utilized for calibration[12]. The results were expressed as grams of amino acids per 100 grams of the sample[13-15].

Fatty acid content analysis: Following lipid extraction and transesterification, gas chromatography (GC) was used to identify the fatty acid profiles[11]. Using standard chemicals, fatty acid methyl esters were isolated on a capillary column and identified[12]. The findings were presented as percentages of each type of fatty acid in the overall amount of lipids[16].

Data analysis using statistics: Every analysis was carried out three times. One-way Analysis of Variance (ANOVA) was performed on the collected data, and Duncan's New Multiple Range Test (DMRT) was used to determine mean differences at a significance level of 0.05. All data analyses were conducted using SPSS 22.0.

RESULTS

Essential amino acids (g/100 g) in unprocessed (raw) unripe plantain-soybean blends: The contents of essential amino acids in unprocessed (raw) blends of unripe plantain-soybeans are illustrated in Table 1. Unprocessed 50% unripe plantain: 50% soybeans (UF) have the highest values for leucine, phenylalanine, valine, lysine, isoleucine, histidine, methionine and threonine. Unprocessed 60% unripe plantain: 40% soybeans (UE) and unprocessed 50% unripe plantain: 50% soybeans (UF) show no significant difference in the values recorded for tryptophan. Furthermore, unprocessed 100% unripe plantain flour (UA) records the lowest values for leucine, phenylalanine, valine, isoleucine, histidine and methionine.

Non-essential amino acids (g/100 g) in raw unripe plantain-soybean blends: Table 2 revealed glutamic acid (7.23±0.01), aspartic acid (5.14±0.03), alanine (2.63±0.01), arginine (2.57±0.02), proline (2.24±0.03), serine (2.06±0.01), tyrosine (1.87±0.01), glycine (1.15±0.01) and cysteine (1.04±0.01) as the highest values for non-essential amino acid in unprocessed 50% unripe plantain: 50% soybean (UF). There was a decrease in the values for unprocessed 100% unripe plantain (UA) for glutamic acid, aspartic acid, alanine, arginine, proline, serine, tyrosine, glycine and cysteine.

Table 1: Essential amino acids (g/100 g) in raw unripe plantain-soybean blends

Amino acid	UA	UB	UC	UD	UE	UF
Leucine	1.54±0.01^{j}	2.89±0.01^{n}	3.68±0.01^{m}	5.14±0.01^{l}	6.26±0.02^{l}	6.52±0.01^{l}
Phenylalanine	1.83±0.01^{l}	2.05±0.01^{k}	2.24±0.01^{j}	2.67±0.01^{j}	2.97±0.02^{j}	3.13±0.01^{j}
Valine	1.67±0.01^{k}	2.13±0.01^{l}	2.47±0.01^{k}	2.52±0.01^{i}	2.63±0.01^{i}	2.74±0.01^{i}
Lysine	1.07±0.02^{f}	1.17±0.02^{f}	1.83±0.01^{h}	2.18±0.01^{g}	2.52±0.01^{h}	2.72±0.01^{i}
Isoleucine	1.08±0.01^{f}	1.34±0.01^{h}	1.64±0.01^{g}	1.72±0.01^{f}	2.16±0.01^{f}	2.23±0.02^{g}
Histidine	0.75±0.01^{d}	1.07±0.01^{e}	1.16±0.02^{e}	1.28±0.01^{d}	1.31±0.01^{d}	1.52±0.01^{d}
Methionine	0.82±0.01^{e}	0.96±0.01^{d}	1.02±0.01^{d}	1.03±0.01^{c}	1.06±0.01^{b}	1.15±0.01^{c}
Threonine	0.57±0.01^{b}	0.67±0.02^{b}	0.75±0.01^{b}	0.96±0.01^{b}	1.05±0.02^{b}	1.06±0.01^{b}
Tryptophan	0.49±0.01^{a}	0.50±0.03^{a}	0.50±0.01^{a}	0.51±0.01^{a}	0.52±0.01^{a}	0.52±0.01^{a}

Significant differences ($p \leq 0.05$) occur between values in the same column that are not superscripted with the same value, values are the three determinations' Mean±Standard Deviations, UA: 100% unripe plantain flour, UB: 90% unripe plantain: 10% soybeans, UC: 80% unripe plantain: 20% soybeans, UD: 70% unripe plantain: 30% soybeans, UE: 60% unripe plantain: 40% soybeans and UF: Unprocessed 50% unripe plantain: 50% soybeans

Table 2: Non-essential amino acids (g/100 g) in raw unripe plantain-soybean blends

Amino acid	UA	UB	UC	UD	UE	UF
Glutamic acid	2.67±0.01^{m}	3.47±0.01^{o}	5.33±0.01^{n}	6.53±0.01^{m}	7.15±0.01^{m}	7.23±0.01^{m}
Aspartic acid	1.19±0.01^{gh}	2.57±0.01^{m}	3.27±0.03^{l}	3.76±0.01^{k}	4.94±0.01^{k}	5.14±0.03^{k}
Alanine	1.57±0.01^{j}	1.97±0.01^{j}	2.18±0.01^{j}	2.27±0.01^{h}	2.34±0.02^{g}	2.63±0.01^{h}
Arginine	1.31±0.01^{i}	1.52±0.01i	1.92±0.01^{h}	2.25±0.02^{h}	2.34±0.01^{g}	2.57±0.02^{h}
Proline	1.24±0.03^{h}	1.94±0.03^{j}	2.07±0.01^{i}	2.13±0.02^{g}	2.21±0.01^{f}	2.24±0.03^{g}
Serine	1.15±0.01^{g}	1.24±0.02^{g}	1.33±0.01^{f}	1.53±0.01^{e}	1.86±0.01^{e}	2.06±0.01^{f}
Tyrosine	0.85±0.01^{e}	1.33±0.01^{h}	1.61±0.08^{g}	1.76±0.01^{f}	1.84±0.01^{e}	1.87±0.01^{e}
Glycine	0.65±0.01^{c}	0.77±0.02^{c}	0.88±0.01^{c}	1.05±0.01^{c}	1.13±0.01^{c}	1.15±0.01^{c}
Cysteine	0.47±0.01^{a}	0.71±0.01^{bc}	0.94±0.01^{cd}	1.00±0.01^{bc}	1.02±0.01^{b}	1.04±0.01^{b}

Values are the Mean±Standard deviations of three measurements, Significant differences ($p \leq 0.05$) occur between values in the same column that are not superscripted with the same value, UA: Unprocessed 100% unripe plantain flour, UB: Unprocessed 90% unripe plantain: 10% soybeans, UC: Unprocessed 80% unripe plantain: 20% soybeans, UD: Unprocessed 70% unripe plantain: 30% soybeans, UE: Unprocessed 60% unripe plantain: 40% soybeans and UF: Unprocessed 50% unripe plantain: 50% soybeans

Essential amino acids (g/100 g) in fermented unextruded unripe plantain-soybean blends: From the data in Table 3, fermented unextruded 50% unripe plantain: 50% soybeans (FFU) recorded increase in the following essential amino acids: Leucine (8.55±0.08), Phenylalanine (4.04±0.03), Valine (4.04±0.02), Lysine (3.31±0.29), and Isoleucine (3.18±0.03). There was no significant difference in the values recorded for Histidine (2.07±0.04) of FFU, Histidine (2.02±0.01) of FEU, and Histidine (2.02±0.01) of FEU, Histidine (1.85±0.03) of FDU and Histidine (1.25±0.05) of FBU. Fermented unextruded 100% unripe plantain (FAU) revealed a reduction in the value of Tryptophan (0.42±0.01), Histidine (0.35±0.04), Methionine (0.83±0.01), and Threonine (1.15±0.05). The value of Tryptophan (0.55±0.03) recorded for fermented unextruded 80% unripe plantain: 20% Soybean (FCU) was low.

Non-essential amino acids (g/100 g) in fermented unextruded unripe plantain-soybeans: Table 4 shows that there is a significant difference in the values recorded for Glutamic acid (11.44±0.11) of fermented unextruded 50% unripe plantain: 50% soybeans (FFU) and Glutamic acid (5.15±0.05) of fermented unextruded 100% unripe plantain (FAU). On the other hand, there was no significant difference in the values recorded for Proline (2.53±0.02) in FBU, Proline (2.93±0.02) in FCU, Proline (3.17±0.04) in FDU, and Proline (3.34±0.01) in FEU. Non-essential amino acids (Serine and Tyrosine) were highest in FEU and FFU. Furthermore, there was an increase in the values recorded for Glutamic acid (11.44±0.01), Aspartic acid (7.13+0.02), Alanine (3.95±0.01), and Arginine (4.21±0.01) in fermented unextruded 50% unripe plantain: 50% soybeans (FFU). The values of Glycine and Cysteine were relatively low in FAU, FBU, FCU, FDU, FEU, and FFU.

Essential amino acids (g/100 g) in unfermented-extruded unripe plantain-soybean: Extruded unfermented 50% unripe plantain: 50% soybeans (EUF) reveals highest values for Leucine (8.83±0.01),

Table 3: Essential amino acids (g/100 g) in fermented unextruded unripe plantain-soybean blends (g/100 g)

Amino acid	FAU	FBU	FCU	FDU	FEU	FFU
Leucine	3.12±0.03^{i}	4.34±0.02^{j}	6.88±0.01^{l}	7.14±0.04^{l}	8.36±0.02^{k}	8.55±0.08^{i}
Phenylalanine	1.15±0.05^{e}	1.91±0.01^{ef}	2.65±0.03^{g}	3.55±0.03^{i}	3.93±0.02^{hi}	4.04±0.03^{g}
Valine	1.26±0.01^{e}	1.56±0.03^{d}	2.94±0.01^{h}	3.62±0.01^{i}	3.87±0.04^{hi}	4.04±0.02^{g}
Lysine	2.03±0.04^{h}	2.75±0.05^{i}	3.13±0.02^{i}	3.22±0.01^{h}	3.29±0.25^{g}	3.31±0.29^{ef}
Isoleucine	1.91±0.05^{gh}	2.04±0.02^{fg}	2.25±0.03^{f}	2.77±0.01^{f}	3.16±0.02^{fg}	3.18±0.03^{e}
Histidine	0.35±0.04^{a}	1.25±0.05^{c}	1.75±0.02^{d}	1.85±0.03^{c}	2.02±0.01^{c}	2.07±0.04^{c}
Methionine	0.83±0.01^{d}	0.96±0.02^{b}	1.15±0.02^{c}	1.15±0.02^{b}	1.18±0.01^{b}	1.21±0.01^{b}
Threonine	1.15±0.05^{e}	1.81±0.08^{e}	2.34±0.02^{f}	2.73±0.02^{f}	3.02±0.02^{ef}	3.03±0.01^{de}
Tryptophan	0.42±0.01^{ab}	0.47±0.01^{a}	0.55±0.03^{a}	0.72±0.01^{a}	0.85±0.05^{a}	0.88±0.01^{a}

Values are the Mean±Standard Deviations of three measurements, Significant differences ($p \le 0.05$) occur between values in the same column that are not superscripted with the same value, FAU: Fermented unextruded 100% unripe plantain, FBU: Fermented unextruded 90% unripe plantain: 10% soybeans, FCU: Fermented unextruded 80% unripe plantain: 20% soybeans, FDU: Fermented unextruded 70% unripe plantain: 30% soybeans, FEU: Fermented unextruded 60% unripe plantain: 40% soybeans and FFU: Fermented unextruded 50% unripe plantain: 50% soybeans

Table 4: Non-essential amino acids (g/100 g) in fermented unextruded unripe plantain-soybean

Amino acid	FAU	FBU	FCU	FDU	FEU	FFU
Glutamic acid	5.15±0.05^{j}	5.95±0.02^{l}	6.27±0.03^{k}	7.85±0.11^{m}	10.68±0.02^{l}	11.44±0.11^{j}
Aspartic acid	5.35±0.05^{k}	5.81±0.02^{k}	6.37±0.03^{k}	6.75±0.03^{k}	7.06±0.04^{j}	7.13±0.02^{h}
Alanine	1.63±0.02^{f}	2.13±0.02^{g}	2.87±0.01^{h}	3.26±0.03^{h}	3.76±0.02^{h}	3.95±0.01^{g}
Arginine	1.23±0.02^{e}	2.72±0.01^{i}	3.44±0.04^{j}	3.82±0.01^{j}	4.03±0.02^{i}	4.21±0.01^{g}
Proline	1.84±0.03^{g}	2.53±0.02^{h}	2.93±0.02^{h}	3.17±0.04^{h}	3.34±0.01^{g}	3.33±0.04^{ef}
Serine	1.55±0.02^{f}	2.17±0.04^{g}	2.61±0.02^{g}	2.96±0.01^{g}	3.17±0.04^{fg}	3.58±0.09^{e}
Tyrosine	0.53±0.03^{bc}	1.86±0.03^{e}	2.24±0.04^{f}	2.42±0.01^{e}	2.86±0.04^{de}	3.08±0.02^{e}
Glycine	0.96±0.02^{d}	1.36±0.02^{c}	1.87±0.03^{e}	2.27±0.02^{d}	2.65±0.03^{d}	2.73±0.03^{d}
Cysteine	0.58±0.01^{c}	0.87±0.03^{b}	1.03±0.02^{b}	1.07±0.02^{b}	1.15±0.02^{b}	1.17±0.02^{ab}

Values are the Mean±Standard Deviations of three measurements, Significant differences ($p \le 0.05$) occur between values in the same column that are not superscripted with the same value, FAU: Fermented unextruded 100% unripe plantain, FBU: Fermented unextruded 90% unripe plantain: 10% soybeans, FCU: Fermented unextruded 80% unripe plantain: 20% soybeans, FDU: Fermented unextruded 70% unripe plantain: 30% soybeans, FEU: Fermented unextruded 60% unripe plantain: 40% soybeans and FFU: Fermented unextruded 50% unripe plantain: 50% soybeans

Table 5: Essential amino acids (g/100 g) in unfermented-extruded unripe plantain-soybean

Amino acid	EUA	EUB	EUC	EUD	EUE	EUF
Leucine	1.74±0.01^{g}	2.18±0.01^{g}	3.28±0.01^{i}	5.18±0.01^{n}	7.74±0.03^{i}	8.83±0.01^{l}
Phenylalanine	2.28±0.01^{i}	3.02±0.01^{l}	3.68±0.01^{j}	4.03±0.01^{l}	4.24±0.014^{fgh}	4.33±0.01^{h}
Valine	1.76±0.01^{g}	2.82±0.01^{k}	3.63±0.01^{j}	4.17±0.01^{m}	4.57±0.02^{h}	4.64±0.01^{i}
Lysine	1.14±0.01^{c}	2.22±0.01^{gh}	2.94±0.01^{h}	3.72±0.01^{k}	4.46±0.02^{gh}	4.73±0.01^{j}
Isoleucine	1.15±0.01^{c}	1.78±0.01^{de}	2.35±0.01^{f}	2.78±0.01^{e}	2.78±0.72^{bcd}	3.34±0.01^{e}
Histidine	1.14±0.01^{c}	1.32±0.01^{c}	1.73±0.01^{d}	2.14±0.01^{c}	2.21±0.01^{bc}	2.24±0.01^{c}
Methionine	0.82±0.01^{b}	1.14±0.02^{b}	1.64±0.01^{c}	1.88±0.01^{b}	2.18±0.01^{b}	2.25±0.01^{c}
Threonine	1.24±0.01^{d}	1.75±0.01^{d}	2.26±0.04^{e}	2.52±0.01^{d}	2.87±0.01^{cd}	3.07±0.01^{d}
Tryptophan	0.54±0.01^{a}	0.74±0.01^{a}	0.82±0.01^{b}	0.95±0.01^{a}	0.99±0.03^{a}	1.01±0.01^{a}

Values are Mean±Standard Deviations of three determinations, Values not followed by the same superscript in the same column are significantly different ($p \le 0.05$), EUA: Extruded unfermented 100% unripe plantain, EUB: Extruded unfermented 90% unripe plantain: 10% soybeans, EUC: Extruded unfermented 80% unripe plantain: 20% soybeans, EUD: Extruded unfermented 70% unripe plantain: 30% soybeans, EUE: Extruded unfermented 60% unripe plantain: 40% soybeans and EUF: Extruded unfermented 50% unripe plantain: 50% soybeans

Phenylalanine (4.33±0.01), Valine (4.64±0.01), Lysine (4.73±0.01), Isoleucine (3.34±0.01), and Threonine (3.07±0.01) Table 5. Samples EUA, EUB, and EUC reveal relatively low values for the essential amino acids. There is no significant difference in the values recorded for leucine (7.74±0.01) of EUE and leucine (8.83±0.01) of EUF. The values for histidine, methionine, and tryptophan were low in all the samples. Extruded unfermented 70% unripe plantain: 30% soybeans (EUD) and extruded unfermented 60% unripe plantain: 40% soybeans (EUE) show an increase in leucine, phenylalanine, valine, lysine, isoleucine and threonine.

Table 6: Non-essential amino acids (g/100 g) in unfermented-extruded unripe plantain-soybean

Amino acid	EUA	EUB	EUC	EUD	EUE	EUF
Glutamic acid	4.66±0.01^{k}	5.26±0.01^{n}	7.27±0.01^{l}	9.52±0.01^{p}	11.62±0.01^{j}	12.34±0.04^{m}
Aspartic acid	2.55±0.04^{j}	3.26±0.01^{m}	5.22±0.01^{k}	7.27±0.01^{o}	7.76±0.04^{i}	8.04±0.02^{k}
Alanine	1.73±0.01^{g}	2.86±0.03^{k}	3.27±0.01^{i}	3.52±0.01^{j}	3.72±0.01^{ef}	4.00±0.01^{g}
Arginine	1.59±0.00^{f}	2.32±0.01^{i}	2.72±0.01^{g}	3.52±0.01^{j}	4.47±0.01^{gh}	4.74±0.01^{j}
Proline	1.34±0.01^{e}	1.87±0.00^{f}	2.92±0.014^{h}	3.33±0.02^{h}	3.68±0.04^{ef}	3.86±0.01^{f}
Serine	1.15±0.01^{c}	1.83±0.02^{ef}	2.72±0.01^{g}	3.24±0.01^{g}	3.82±0.01^{efg}	4.05±0.03^{g}
Tyrosine	2.03±0.03^{h}	2.44±0.01^{j}	2.93±0.02^{h}	3.07±0.01^{f}	3.26±0.01^{de}	3.33±0.01^{e}
Glycine	1.36±0.02^{e}	2.28±0.01^{hi}	3.23±0.03^{i}	3.47±0.01^{i}	3.83±0.01^{efg}	4.04±0.01^{g}
Cysteine	0.56±0.01^{a}	0.71±0.01^{a}	0.74±0.01^{a}	0.92±0.01^{a}	1.18±0.01^{a}	1.21±0.01^{b}

Values are Means±Standard Deviations of three determinations, Values not followed by the same superscript in the same column are significantly different ($p \leq 0.05$), EUA: Extruded unfermented 100% unripe plantain, EUB: Extruded unfermented 90% unripe plantain: 10% soybeans, EUC: Extruded unfermented 80% unripe plantain: 20% soybeans, EUD: Extruded unfermented 70% unripe plantain: 30% soybeans, EUE: Extruded unfermented 60% unripe plantain: 40% soybeans and EUF: Extruded unfermented 50% unripe plantain: 50% soybeans

Table 7: Essential amino acids (g/100 g) in fermented-extruded unripe plantain-soybean

Amino acid	AFE	BFE	CFE	DFE	EFE	FFE
Leucine	6.57±0.02^{n}	6.75±0.03^{i}	7.14±0.01^{i}	7.33±0.01^{m}	7.75±0.04^{m}	9.35±0.05^{l}
Phenylalanine	3.05±0.03^{l}	3.28±0.01^{fg}	3.93±0.05^{g}	4.12±0.01^{i}	4.25±0.01^{i}	4.53±0.04^{g}
Valine	1.26±0.01^{e}	1.85±0.01^{cd}	2.45±0.04^{c}	3.36±0.01^{e}	3.67±0.02^{f}	4.76±0.03^{h}
Lysine	2.25±0.01^{h}	2.76±0.66^{ef}	3.75±0.02^{f}	4.34±0.04^{j}	4.79±0.01^{k}	4.870±0.08^{hi}
Isoleucine	1.32±0.02^{e}	1.66±0.02^{c}	2.57±0.01^{c}	2.95±0.01^{c}	3.42±0.01^{e}	3.54±0.04^{e}
Histidine	1.26±0.02^{e}	1.56±0.01^{bc}	1.97±0.02^{b}	2.07±0.02^{b}	2.16±0.01^{c}	2.34±0.03^{c}
Methionine	0.57±0.02^{b}	0.86±0.04^{a}	0.95±0.05^{a}	1.04±0.01^{a}	1.24±0.01^{e}	1.29±0.01^{b}
Threonine	1.24±0.01^{d}	1.75±0.01^{d}	2.26±0.04^{e}	2.52±0.01^{d}	2.87±0.01^{cd}	3.07±0.01^{d}
Tryptophan	1.01±0.01^{c}	1.01±0.01^{ab}	1.02±0.01^{a}	1.01±0.01^{a}	1.02±0.01^{e}	1.05±0.01^{a}

Values are Mean±Standard deviations of three determinations, Values not followed by the same superscript in the same column are significantly different ($p \leq 0.05$), AFE: Fermented extruded 100% unripe plantain, BFE: Fermented extruded 90% unripe plantain: 10% soybeans, CFE: Fermented extruded 80% unripe plantain: 20% soybeans, DFE: Fermented extruded 70% unripe plantain: 30% soybeans, EFE: Fermented extruded 60% unripe plantain: 40% soybeans and FFE: Fermented extruded 50% unripe plantain: 50% soybeans

Non-essential amino acids (g/100 g) in unfermented-extruded unripe plantain-soybean: The non-essential amino acid content in unfermented-extruded unripe plantain soybeans is shown in Table 6. The glutamic acid content of samples EUA to EUF ranged from 4.66±0.01 to 12.34±0.04. Glutamic acid content (12.34±0.04) of extruded unfermented 50% unripe plantain: 50% soybean increased significantly when compared with other samples. Other non-essential amino acids (Aspartic acid, Alanine, Arginine, Proline, Serine, Tyrosine, and Glycine) were significantly increased in samples EUC, EUD, EUE, and EUF. Extruded Unfermented 90% Unripe Plantain: 10% Soybeans (EUB) also show a slight relative increase in the contents of Aspartic acid, Alanine, Arginine, and Tyrosine. However, it is recorded that out of the non-essential amino acids, only Cysteine shows a significant reduction in all the samples.

Essential amino acids (g/100 g) in fermented-extruded unripe plantain-soybean: The values for essential amino acids in fermented-extruded unripe plantain-soybean blends are shown in Table 7. The results reveal an increase in Leucine content (9.35±0.05) of fermented extruded 50% unripe plantain: 50% soybean (FFE). There was no significant difference between the Leucine content of DFE (7.33±0.01) and EFE (7.75±0.04). Also, no significant difference was observed between the Leucine content of BFE (6.75±0.03) and CFE (7.14±0.01). Essential amino acids (Leucine and Phenylalanine) contents in AFE were significantly increased in all the samples. However, the values for valine and lysine were also increased in samples CFE, DFE, EFE, and FFE. The values recorded for Tryptophan and Methionine were very low in all the samples.

Non-essential amino acids (g/100 g) in fermented-extruded unripe plantain-soybean: Depicted in Table 8 is the significant decrease in alanine content (1.13±0.01) of fermented extruded 100% unripe

Table 8: Non-essential amino acids (g/100 g) in fermented-extruded unripe plantain-soybean

Amino acids	AFE	BFE	CFE	DFE	EFE	FFE
Glutamic acid	3.14±0.01^{m}	5.16±0.01^{h}	7.04±0.04^{i}	9.49±0.02^{n}	12.12±0.06^{n}	13.16±0.04^{m}
Aspartic acid	2.10±0.014^{g}	3.45±0.02^{g}	5.80±0.04^{h}	6.82±0.01^{l}	7.33±0.01^{l}	8.16±0.01^{k}
Alanine	1.13±0.01^{d}	1.87±0.01^{cd}	2.45±0.01^{c}	3.54±0.01^{g}	3.76±0.01^{fg}	4.11±0.02^{f}
Arginine	2.96±0.02^{l}	3.15±0.04^{fg}	3.83±0.02^{fg}	4.10±0.01^{i}	4.65±0.04^{j}	4.98±0.04^{ij}
Proline	2.74±0.02^{j}	3.43±0.02^{g}	3.75±0.02^{f}	3.94±0.01^{h}	4.03±0.03^{h}	4.11±0.02^{f}
Serine	2.83±0.03^{k}	3.05±0.03^{efg}	3.23±0.02^{e}	3.45±0.02^{f}	3.86±0.03^{g}	4.12±0.01^{f}
Tyrosine	2.55±0.03^{i}	2.96±0.01^{efg}	3.10±0.01^{e}	3.25±0.03^{d}	3.35±0.03^{e}	3.57±0.04^{e}
Glycine	2.04±0.01^{f}	2.75±0.04^{ef}	3.18±0.04^{e}	4.54±0.01^{k}	4.74±0.03^{jk}	5.02±0.01^{j}
Cysteine	0.35±0.02^{a}	0.73±0.03^{a}	0.91±0.01^{a}	1.03±0.02^{a}	1.22±0.01^{e}	1.24±0.01^{b}

Values are Mean±Standard Deviations of three determinations, Values not followed by the same superscript in the same column are significantly different ($p \leq 0.05$), AFE: Fermented extruded 100% unripe plantain; BFE: Fermented extruded 90% unripe plantain: 10% Soybeans, CFE: Fermented extruded 80% unripe plantain: 20% soybeans, DFE: Fermented extruded 70% unripe plantain: 30% soybeans, EFE: Fermented extruded 60% unripe plantain: 40% soybeans and FFE: Fermented extruded 50% unripe plantain: 50% soybeans

plantain (AFE). Furthermore, no significant difference was observed in the reduced contents of cysteine in samples AFE, BFE, CFE, and DFE. Fermented extruded 50% unripe plantain: 50% soybeans (FFE) revealed the highest value (13.16±0.04) in glutamic acid. There was no significant difference between the Aspartic acid content of DFE (6.82±0.01) and EFE (7.33±0.01). Fermented extruded 50% unripe plantain: 50% soybeans (FFE) record a significant increase in the value of arginine (4.98±0.04). The values of tyrosine in samples EFE (3.35±0.03) and FFE (3.57±0.04) were of no significant difference.

Fatty acid composition of raw unripe plantain-soybean blends: The fatty acid composition of unprocessed (raw) unripe plantain-soybean blends is displayed in Table 9. A small amount of fat contents primarily made up of saturated fatty acids Palmitic acid [C16:0] (15.10±0.00) is observed in unprocessed 100% unripe plantain (UA). The major fatty acids in unprocessed 50% unripe plantain and 50% soybeans (UF) are polyunsaturated fatty acids (PUFA). Specifically, linolenic acid [C18:4] (26.33±0.00) and γ-linolenic acid [C18:3] (27.94±0.00) along with smaller amounts of oleic acid [C18:1] (22.03±0.00)-monounsaturated fatty acid and saturated fatty acids like palmitic acid [C16:0] (24.24±0.00) and stearic acid [C18:0] (20.71±0.00) were respectively observed in unprocessed 50% unripe plantain: 50% soybeans.

Fatty acid composition of fermented-unextruded unripe plantain-soybean blends: Table 10 shows the variation of fatty acid composition in fermented-unextruded unripe plantain-soybean blends. Fermented unextruded 50% unripe plantain: 50% soybeans (FFU) had the highest Butyric acid [C4:0] (0.83±0.00). Fermented unextruded 60% unripe plantain: 40% soybeans (FEU) records the highest increase in Caproic acid [C6:0] (1.52±0.00). The lowest saturated fatty acid (SFA) content (80.34±0.01) was observed in fermented unextruded 100% unripe plantain while the highest saturated fatty acid (SFA) content (158.18±0.01) was observed in fermented unextruded 50% unripe plantain: 50% soybean. Monounsaturated fatty acid (Oleic acid [C18:1] was highest in Fermented unextruded 50% unripe plantain: 50% soybeans (FFU). There was a decrease in the summation of polyunsaturated fatty acid (PUFA) contents (77.02± 0.00) in fermented unextruded 100% unripe plantain (FAU). Linolenic acid [C18:3] content (22.32±0.00) was highest in fermented unextruded 50% unripe plantain: 50% soybeans.

Fatty acid composition of extruded-unfermented unripe plantain-soybean blends: The trend in the fatty acid composition of extruded unfermented unripe plantain-soybeans blends is shown in Table 11. Monounsaturated fatty acid (heneicosanoic acid) [C24:0] showed the highest increase in extruded unfermented 50% unripe plantain: 50% soybeans (25.06±0.00). Polyunsaturated fatty acid (linolenic acid) [C18:4] records the lowest content in extruded unfermented 100% unripe plantain (10.85±0.00). Summation of saturated fatty acid (SFA) was highest in Extruded unfermented 50% unripe plantain: 50% soybeans (144.79±0.01). Palmitic acid [C16:0] and stearic acid [C18:0] were present but in small

Table 9: Composition of fatty acids in unprocessed, unripe plantain-soybean blends

Fatty acid components (%)	UA	UB	UC	UD	UE	UF
Butyric acid methyl ester (SFA) [C4:0]	0.27±0.00^{a}	0.27±0.00^{a}	0.31±0.00^{b}	0.65±0.00^{c}	0.87±0.00^{d}	0.94±0.00^{e}
Caproic acid methyl ester (SFA) [C6:0]	0.05±0.01^{a}	0.51±0.00^{b}	0.90±0.00^{c}	1.09±0.00^{d}	1.67±0.00^{e}	2.24±0.00^{f}
Caprylic acid methyl ester (SFA) [C8:0]	1.01±0.01^{a}	1.01±0.00^{a}	1.96±0.00^{b}	2.53±0.00^{c}	3.85±0.00^{d}	4.51±0.00^{e}
Capric acid methyl ester (SFA) [C10:0]	1.29±0.01^{a}	3.27±0.00^{b}	4.13±0.00^{c}	5.27±0.00^{d}	7.36±0.00^{e}	8.64±0.00^{f}
Lauric acid methyl ester (SFA) [C12:0]	5.23±0.00^{a}	7.35±0.00^{b}	7.91±0.00^{c}	8.95±0.00^{d}	11.20±0.00^{e}	12.75±0.00^{f}
Tridecanoic acid methyl ester (SFA) [C13:0]	8.21±0.00^{a}	11.35±0.00^{b}	11.91±0.00^{c}	12.96±0.00^{d}	15.21±0.00^{e}	16.24±0.00^{f}
Myristic acid methyl ester (SFA) [C14:0]	9.38±0.00^{a}	12.04±0.00^{b}	12.63±0.00^{c}	13.18±0.00^{d}	16.17±0.00^{e}	17.84±0.00^{f}
Palmitic acid methyl ester (SFA) [C16:0]	9.81±0.00^{a}	13.93±0.00^{b}	14.33±0.00^{c}	15.87±0.00^{d}	18.24±0.00^{e}	19.26±0.00^{f}
Palmitoleic acid methyl ester (MUFA) [C16:1]	11.07±0.00^{a}	14.36±0.00^{b}	15.25±0.00^{c}	16.74±0.00^{d}	19.31±0.00^{e}	20.71±0.00^{f}
Heptadecanoic acid methyl ester (SFA) [C17:0]	14.24±0.00^{a}	17.23±0.00^{b}	18.11±0.00^{c}	19.51±0.00^{d}	22.32±0.00^{e}	23.22±0.00^{f}
Stearic acid methyl ester (SFA) [C18:0]	15.10±0.00^{a}	18.42±0.00^{b}	19.07±0.00^{c}	20.33±0.00^{d}	23.87±0.00^{e}	24.24±0.00^{f}
Behenic acid methyl ester (SFA) [C22:0]	23.59±0.00^{a}	26.53±0.00^{b}	27.11±0.00^{c}	28.88±0.00^{d}	31.30±0.00^{e}	32.17±0.00^{f}
∑SFA (sum of saturated fatty acids)	99.27±0.03^{a}	126.27±0.03^{b}	133.63±0.02^{c}	145.96±0.01^{d}	171.39±0.00^{e}	182.78±0.01^{f}
Myristoleic acid methyl ester (MUFA) [C14:1]	6.64±0.00^{a}	8.38±0.00^{b}	9.19±0.00^{c}	10.74±0.00^{d}	12.61±0.00^{e}	14.58±0.00^{f}
Oleic acid methyl ester (MUFA) [C18:1]	13.31±0.00^{a}	16.82±0.00^{b}	17.08±0.00^{c}	18.70±0.00^{d}	21.02±0.00^{e}	22.03±0.00^{f}
Cis-11-Eicosenoic acid methyl ester (MUFA) [C20:1]	19.49±0.00^{a}	22.16±0.00^{b}	23.31±0.00^{c}	24.72±0.00^{d}	27.51±0.00^{e}	28.35±0.00^{f}
Heneicosanoic acid methyl ester (MUFA) [C21:0]	21.00±0.00^{a}	23.65±0.00^{b}	24.70±0.00^{c}	25.62±0.00^{d}	28.73±0.00^{e}	29.98±0.00^{f}
∑MUFA (sum of monounsaturated fatty acids)	60.45±0.00^{a}	71.02±0.01^{b}	74.29±0.00^{c}	79.78±0.00^{d}	89.87±0.00^{e}	94.95±0.00^{f}
Linolenic acid methyl ester (PUFA) [C18:2] n–6)	16.79±0.00^{a}	19.47±0.00^{b}	20.32±0.00^{c}	21.69±0.00^{d}	25.71±0.00^{e}	26.33±0.00^{f}
γ-Linolenic acid methyl ester (PUFA) [C18:3] n–6	16.88±0.00^{a}	19.71±0.00^{b}	20.57±0.00^{c}	21.71±0.00^{d}	25.80±0.00^{e}	26.62±0.00^{f}
α-Linolenic acid methyl ester (PUFA) [C18:3] n–3	17.92±0.00^{a}	20.55±0.00^{b}	21.85±0.00^{c}	23.51±0.00^{d}	26.05±0.00^{e}	27.94±0.00^{f}
Arachidonic acid methyl ester (PUFA) [C20:4] n–6	19.70±0.01^{a}	22.36±0.00^{b}	23.53±0.00^{c}	24.80±0.00^{d}	27.81±0.00^{e}	28.83±0.00^{f}
Cis-11,14-Eicosadienoic acid methyl ester (PUFA) [C20:2]	21.97±0.01^{a}	24.80±0.00^{b}	25.21±0.00^{c}	26.91±0.00^{d}	29.44±0.00^{e}	30.89±0.00^{f}
∑PUFA	93.27±0.02^{a}	106.89±0.00^{b}	111.48±0.01^{c}	118.63±0.00^{d}	134.82±0.00^{e}	140.62±0.01^{f}

Values are Mean±Standard deviations of three determinations, values not followed by the same superscript in the same column are significantly different ($p \leq 0.05$), SFA: Saturated fatty acid, PUFA: Polyunsaturated fatty acid, MUFA: Monounsaturated fatty acid, UA= Unprocessed 100% unripe plantain flour, UB: Unprocessed 90% unripe plantain: 10% soybeans, UC: Unprocessed 80% unripe plantain: 20% soybeans, UD: Unprocessed 70% unripe plantain: 30% soybeans, UE: Unprocessed 60% unripe plantain: 40% soybeans and UF: Unprocessed 50% unripe plantain: 50% soybeans

Table 10: Fatty acid composition of fermented-unextruded unripe plantain-soybean blends

Fatty acid components (%)	FAU	FBU	FCU	FDU	FEU	FFU
Butyric acid methyl ester (SFA) [C4:0]	0.13 ± 0.00^{a}	0.15 ± 0.00^{b}	0.20 ± 0.00^{c}	0.40 ± 0.00^{d}	0.75 ± 0.00^{e}	0.83 ± 0.00^{f}
Caproic acid methyl ester (SFA) [C6:0]	0.08 ± 0.00^{a}	0.31 ± 0.00^{b}	0.57 ± 0.00^{c}	0.78 ± 0.00^{d}	1.52 ± 0.00^{e}	1.24 ± 0.00^{f}
Caprylic acid methyl ester (SFA) [C8:0]	0.09 ± 0.00^{a}	0.43 ± 0.00^{b}	1.24 ± 0.00^{c}	1.37 ± 0.00^{d}	1.88 ± 0.00^{e}	3.47 ± 0.00^{f}
Capric acid methyl ester (SFA) [C10:0]	1.41 ± 0.00^{a}	2.17 ± 0.00^{b}	3.39 ± 0.00^{c}	4.11 ± 0.00^{d}	6.53 ± 0.00^{e}	7.63 ± 0.00^{f}
Tridecanoic acid methyl ester (SFA) [C13:0]	3.27 ± 0.00^{a}	4.39 ± 0.00^{b}	5.76 ± 0.00^{c}	7.29 ± 0.00^{d}	9.37 ± 0.00^{e}	11.75 ± 0.00^{f}
Lauric acid methyl ester (SFA) [C12:0]	5.37 ± 0.00^{a}	7.00 ± 0.00^{b}	8.19 ± 0.00^{c}	10.36 ± 0.00^{d}	11.11 ± 0.00^{e}	14.87 ± 0.00^{f}
Palmitoleic acid methyl ester (MUFA) [C16:1]	6.43 ± 0.00^{a}	7.93 ± 0.00^{b}	9.83 ± 0.00^{c}	11.75 ± 0.00^{d}	13.22 ± 0.00^{e}	15.26 ± 0.00^{f}
Heptadecanoic acid methyl ester (SFA) [C17:0]	9.35 ± 0.00^{a}	10.41 ± 0.00^{b}	11.68 ± 0.00^{c}	13.92 ± 0.00^{d}	15.31 ± 0.00^{e}	16.26 ± 0.00^{f}
Stearic acid methyl ester (SFA) [C18:0]	9.79 ± 0.00^{a}	11.17 ± 0.00^{b}	12.35 ± 0.00^{c}	13.40 ± 0.00^{d}	14.18 ± 0.00^{e}	17.16 ± 0.00^{f}
Myristic acid methyl ester (SFA) [C14:0]	11.10 ± 0.00^{a}	12.80 ± 0.00^{b}	15.25 ± 0.00^{c}	16.00 ± 0.00^{d}	17.50 ± 0.00^{e}	20.35 ± 0.00^{f}
Palmitic acid methyl ester (SFA) [C16:0]	13.58 ± 0.00^{a}	15.29 ± 0.00^{b}	17.73 ± 0.00^{c}	16.22 ± 0.00^{d}	18.05 ± 0.00^{e}	21.24 ± 0.00^{f}
Behenic acid methyl ester (SFA) [C22:0]	19.74 ± 0.00^{a}	21.61 ± 0.00^{b}	23.39 ± 0.00^{c}	25.79 ± 0.00^{d}	27.49 ± 0.00^{e}	28.11 ± 0.00^{f}
∑SFA	80.34 ± 0.01^{a}	93.66 ± 0.01^{b}	109.58 ± 0.01^{c}	121.39 ± 0.01^{d}	136.91 ± 0.01^{e}	158.18 ± 0.01^{f}
Myristoleic acid methyl ester (MUFA) [C14:1]	2.10 ± 0.00^{a}	3.74 ± 0.00^{b}	5.40 ± 0.00^{c}	7.41 ± 0.00^{d}	8.20 ± 0.00^{e}	13.57 ± 0.00^{f}
Oleic acid methyl ester (MUFA) [C18:1]	10.22 ± 0.00^{a}	12.33 ± 0.00^{b}	13.47 ± 0.00^{c}	15.83 ± 0.00^{d}	17.11 ± 0.00^{e}	19.03 ± 0.00^{f}
Cis-11-Eicosenoic acid methyl ester (MUFA) [C20:1]	17.87 ± 0.00^{a}	19.21 ± 0.00^{b}	21.10 ± 0.00^{c}	22.41 ± 0.00^{d}	23.13 ± 0.00^{e}	26.34 ± 0.00^{f}
Heneicosanoic acid methyl ester (MUFA) [C21:0]	15.16 ± 0.00^{a}	16.35 ± 0.00^{b}	19.37 ± 0.00^{c}	21.25 ± 0.00^{d}	24.83 ± 0.00^{e}	26.28 ± 0.00^{f}
∑MUFA	46.16 ± 0.00^{a}	51.63 ± 0.00^{b}	59.34 ± 0.00^{c}	66.90 ± 0.00^{d}	73.27 ± 0.00^{e}	85.23 ± 0.00^{f}
Linolenic acid methyl ester (PUFA) [C18:2] n-6	12.41 ± 0.00^{a}	14.74 ± 0.00^{b}	16.39 ± 0.00^{c}	17.93 ± 0.00^{d}	21.32 ± 0.00^{e}	22.32 ± 0.00^{f}
Arachidonic acid methyl ester (PUFA) [C20:4] n-6	15.00 ± 0.00^{a}	16.17 ± 0.00^{b}	17.26 ± 0.00^{c}	19.45 ± 0.00^{d}	21.48 ± 0.00^{e}	24.11 ± 0.00^{f}
γ-Linolenic acid methyl ester (PUFA) [C18:3] n-6	15.59 ± 0.00^{a}	17.44 ± 0.00^{b}	18.87 ± 0.00^{c}	20.38 ± 0.00^{d}	22.01 ± 0.00^{e}	23.00 ± 0.00^{f}
α-Linolenic acid methyl ester (PUFA) [C18:3] n-3	16.33 ± 0.00^{a}	17.10 ± 0.00^{b}	20.51 ± 0.00^{c}	22.34 ± 0.00^{d}	23.75 ± 0.00^{e}	24.33 ± 0.00^{f}
Cis-11,14-Eicosadienoic acid methyl ester (PUFA) [C20:2]	17.69 ± 0.00^{a}	19.47 ± 0.00^{b}	21.72 ± 0.00^{c}	23.37 ± 0.00^{d}	25.20 ± 0.00^{e}	25.81 ± 0.00^{f}
∑PUFA	77.02 ± 0.00^{a}	84.92 ± 0.00^{b}	94.75 ± 0.00^{c}	103.47 ± 0.00^{d}	113.76 ± 0.00^{e}	119.57 ± 0.00^{f}

Values are Mean±Standard Deviations of three determinations, values not followed by the same superscript in the same column are significantly different ($p\leq0.05$), SFA: Saturated fatty acid, PUFA: Polyunsaturated fatty acid, MUFA: Monounsaturated fatty acid, FAU: Fermented unextruded 100% unripe plantain, FBU: Fermented unextruded 90% unripe plantain: 10% soybeans, FCU: Fermented unextruded 80% unripe plantain: 20% soybeans, FDU: Fermented unextruded 70% unripe plantain: 30% soybeans, FEU: Fermented unextruded 60% unripe plantain: 40% soybeans, FFU: Fermented unextruded 50% unripe plantain: 50% soybeans

Table 11: Fatty acid composition of extruded-unfermented unripe plantain-soybean blends

Fatty acid components (%)	EUA	EUB	EUC	EUD	EUE	EUF
Butyric acid methyl ester (SFA) [C4:0]	0.07±0.00^{a}	0.08±0.00^{b}	0.14±0.00^{c}	0.33±0.00^{d}	0.51±0.00^{e}	0.73±0.00^{f}
Caproic acid methyl ester (SFA) [C6:0]	0.05±0.00^{a}	0.52±0.00^{b}	0.59±0.00^{c}	0.72±0.00^{d}	0.08±0.00^{e}	0.24±0.00^{f}
Caprylic acid methyl ester (SFA) [C8:0]	0.03±0.00^{a}	0.07±0.00^{b}	0.09±0.00^{c}	0.11±0.00^{d}	0.13±0.00^{e}	2.35±0.00^{f}
Capric acid methyl ester (SFA) [C10:0]	0.71±0.00^{a}	1.41±0.00^{b}	2.15±0.00^{c}	3.37±0.00^{d}	4.35±0.00^{e}	6.51±0.00^{f}
Tridecanoic acid methyl ester (SFA) [C13:0]	3.44±0.00^{a}	4.29±0.00^{b}	4.69±0.00^{c}	5.94±0.00^{d}	7.29±0.00^{e}	10.11±0.00^{f}
Lauric acid methyl ester (SFA) [C12:0] (Corrected from C12:1)	4.75±0.00^{a}	6.88±0.00^{b}	7.72±0.00^{c}	9.18±0.00^{d}	10.43±0.00^{e}	13.25±0.00^{f}
Myristic acid methyl ester (SFA) [C14:0]	5.61±0.00^{a}	8.35±0.00^{b}	9.51±0.00^{c}	11.41±0.00^{d}	12.20±0.00^{e}	13.01±0.00^{f}
Palmitic acid methyl ester (SFA) [C16:0]	8.38±0.00^{a}	9.37±0.00^{b}	11.83±0.00^{c}	13.06±0.00^{d}	13.95±0.00^{e}	15.11±0.00^{f}
Heptadecanoic acid methyl ester (SFA) [C17:0]	8.85±0.00^{a}	10.47±0.00^{b}	9.61±0.00^{c}	11.84±0.00^{d}	13.63±0.00^{e}	16.75±0.00^{f}
Stearic acid methyl ester (SFA) [C18:0]	10.27±0.00^{a}	15.06±0.00^{b}	15.75±0.00^{c}	16.40±0.00^{d}	17.35±0.00^{e}	19.10±0.00^{f}
Behenic acid methyl ester (SFA) [C22:0]	12.36±0.00^{a}	14.11±0.00^{b}	14.94±0.00^{c}	15.83±0.00^{d}	17.18±0.00^{e}	20.28±0.00^{f}
Butyric acid methyl ester (SFA) [C4:0]	19.10±0.00^{a}	20.87±0.00^{b}	23.57±0.00^{c}	25.39±0.00^{d}	26.18±0.00^{e}	27.35±0.00^{f}
∑SFA	73.62±0.01^{a}	91.48±0.01^{b}	100.59±0.01^{c}	113.58±0.01^{d}	123.28±0.01^{e}	144.79±0.01^{f}
Myristoleic acid methyl ester (MUFA) [C14:1]	3.59±0.00^{a}	4.06±0.00^{b}	5.08±0.00^{c}	5.51±0.00^{d}	6.71±0.00^{e}	12.31±0.00^{f}
Palmitoleic acid methyl ester (MUFA) [C16:1]	9.49±0.00^{a}	12.10±0.00^{b}	15.33±0.00^{c}	16.19±0.00^{d}	16.87±0.00^{e}	18.31±0.00^{f}
Oleic acid methyl ester (MUFA) [C18:1]	16.55±0.00^{a}	18.39±0.00^{b}	21.44±0.00^{c}	22.38±0.00^{d}	22.73±0.00^{e}	25.06±0.00^{f}
Cis-11-Eicosenoic acid methyl ester (MUFA) [C20:1]	14.57±0.00^{a}	15.68±0.00^{b}	21.69±0.00^{c}	22.93±0.00^{d}	23.69±0.00^{e}	25.47±0.00^{f}
∑MUFA	44.20±0.00^{a}	50.20±0.00^{b}	63.54±0.00^{c}	67.01±0.00^{d}	70.00±0.00^{e}	81.15±0.00
Linolenic acid methyl ester (PUFA) [C18:2] n–6	10.85±0.00^{a}	14.28±0.00^{b}	17.82±0.00^{c}	18.59±0.00^{d}	19.82±0.00^{e}	21.41±0.00^{f}
Arachidonic acid methyl ester (PUFA) [C20:4] n–6	14.69±0.00^{a}	16.03±0.002^{b}	19.13±0.00^{c}	19.74±0.00^{d}	21.00±0.00^{e}	23.17±0.00^{f}
γ-Linolenic acid methyl ester (PUFA) [C18:3] n–6	14.92±0.00^{a}	16.10±0.00^{b}	19.04±0.00^{c}	19.69±0.00^{d}	20.59±0.00^{e}	22.09±0.00^{f}
α-Linolenic acid methyl ester (PUFA) [C18:3] n–3	15.38±0.00^{a}	16.59±0.00^{b}	19.72±0.00^{c}	21.00±0.00^{d}	22.11±0.00^{e}	23.29±0.00^{f}
Cis-11,14-Eicosadienoic acid methyl ester (PUFA) [C20:2]	16.46±0.00^{a}	18.65±0.00^{b}	19.88±0.00^{c}	20.57±0.00^{d}	22.41±0.00^{e}	23.31±0.00^{f}
∑PUFA	72.30±0.00^{a}	81.65±0.00^{b}	95.59±0.00^{c}	99.59±0.00^{d}	105.93±0.00^{e}	113.27±0.00^{f}

Values are Mean±Standard Deviations of three determinations, values not followed by the same superscript in the same column are significantly different ($p \le 0.05$), SFA: Saturated fatty acid, PUFA: Polyunsaturated fatty acid, MUFA: Monounsaturated fatty acid, EUA: Extruded unfermented 100% unripe plantain, EUB: Extruded unfermented 90% unripe plantain: 10% soybeans, EUC: Extruded unfermented 80% unripe plantain: 20% soybeans, EUD: Extruded unfermented 70% unripe plantain: 30% soybeans, EUE: Extruded unfermented 60% unripe plantain: 40% soybeans and EUF: Extruded unfermented 50% unripe plantain: 50% soybeans

Table 12: Fatty acid composition of fermented-extruded unripe plantain-soybean blends

Fatty acid components (%)	AFE	BFE	CFE	DFE	EFE	FFE
Butyric acid methyl ester (SFA) [C4:0]	0.00±0.00^{a}	0.05±0.00^{b}	0.07±0.00^{c}	0.11±0.00^{d}	0.32±0.01^{e}	0.51±0.00^{f}
Caproic acid methyl ester (SFA) [C6:0]	0.00±0.00^{a}	0.17±0.00^{b}	0.09±0.00^{c}	0.53±0.00^{d}	0.05±0.00^{e}	0.11±0.00^{f}
Caprylic acid methyl ester (SFA) [C8:0]	0.00±0.00^{a}	0.83±0.00^{b}	0.03±0.00^{c}	0.07±0.00^{d}	0.08±0.00^{e}	1.01±0.00^{f}
Capric acid methyl ester (SFA) [C10:0]	0.31±0.00^{a}	0.71±0.00^{b}	1.13±0.00^{c}	2.19±0.00^{d}	3.19±0.00^{e}	5.63±0.00^{f}
Tridecanoic acid methyl ester (SFA) [C13:0]	2.37±0.00^{a}	3.29±0.00^{b}	3.96±0.00^{c}	5.41±0.00^{d}	6.41±0.00^{e}	7.74±0.00^{f}
Lauric acid methyl ester (SFA) [C12:0]	3.73±0.00^{a}	5.57±0.00^{b}	5.48±0.00^{c}	8.28±0.00^{d}	9.11±0.00^{e}	11.10±0.00^{f}
Palmitoleic acid methyl ester (MUFA) [C16:1]	5.29±0.00^{a}	7.29±0.00^{b}	8.83±0.00^{c}	9.56±0.00^{d}	10.71±0.00^{e}	11.32±0.00^{f}
Heptadecanoic acid methyl ester (SFA) [C17:0]	7.11±0.00^{a}	7.93±0.00^{b}	11.19±0.00^{c}	11.83±0.00^{d}	13.18±0.00^{e}	13.25±0.00^{f}
Stearic acid methyl ester (SFA) [C18:0]	8.38±0.00^{a}	9.11±0.00^{b}	8.74±0.00^{c}	10.37±0.00^{d}	13.38±0.00^{e}	14.38±0.00^{f}
Myristic acid methyl ester (SFA) [C14:0]	9.30±0.00^{a}	14.05±0.00^{b}	14.36±0.00^{c}	15.16±0.00^{d}	15.91±0.00^{e}	16.20±0.00^{f}
Palmitic acid methyl ester (SFA) [C16:0]	11.17±0.00^{a}	13.17±0.00^{b}	13.81±0.00^{c}	14.58±0.00^{d}	16.17±0.00^{e}	18.61±0.00^{f}
Behenic acid methyl ester (SFA) [C22:0]	17.88±0.00^{a}	19.83±0.00^{b}	22.17±0.00^{c}	23.74±0.00^{d}	25.37±0.00^{e}	25.19±0.00^{f}
∑SFA	65.56±0.01^{a}	82.00±0.01^{b}	89.86±0.01^{c}	101.83±0.01^{d}	113.88±0.01^{e}	125.04±0.00^{f}
Myristoleic acid methyl ester (MUFA) [C14:1]	3.10±0.00^{a}	2.85±0.00^{b}	3.74±0.00^{c}	4.75±0.00^{d}	5.27±0.00^{e}	10.57±0.00^{f}
Oleic acid methyl ester (MUFA) [C18:1]	7.53±0.00^{a}	11.38±0.00^{b}	13.55±0.00^{c}	15.49±0.00^{d}	15.59±0.00^{e}	15.02±0.00^{f}
Cis-11-Eicosenoic acid methyl ester (MUFA) [C20:1]	15.95±0.00^{a}	17.41±0.00^{b}	20.07±0.00^{c}	21.39±0.00^{d}	21.47±0.00^{e}	20.93±0.00^{f}
Heneicosanoic acid methyl ester (MUFA) [C21:0]	13.59±0.00^{a}	14.76±0.00^{b}	20.51±0.00^{c}	21.81±0.00^{d}	22.94±0.00^{e}	19.97±0.00^{f}
∑MUFA	40.17±0.00^{a}	46.40±0.00^{b}	57.87±0.00^{c}	63.44±0.00^{d}	65.27±0.00^{e}	66.50±0.00^{f}
Linolenic acid methyl ester (PUFA) [C18:2] n-6 (Incorrect notation in original: [C18:4] should be [C18:2])	9.65±0.00^{a}	12.64±0.00^{b}	17.13±0.00^{c}	17.73±0.00^{d}	18.31±0.00^{e}	19.31±0.00^{f}
Arachidonic acid methyl ester (PUFA) [C20:4] n-6	13.81±0.00^{a}	15.39±0.00^{b}	17.65±0.00^{c}	19.27±0.00^{d}	20.18±0.00^{e}	18.81±0.00^{f}
γ-Linolenic acid methyl ester (PUFA) [C18:3] n-6	13.37±0.00^{a}	15.50±0.00^{b}	18.49±0.00^{c}	18.63±0.00^{d}	19.71±0.00^{e}	19.72±0.00^{f}
α-Linolenic acid methyl ester (PUFA) [C18:3] n-3	14.14±0.00^{a}	15.15±0.00^{b}	19.88±0.00^{c}	20.26±0.00^{d}	20.65±0.00^{e}	21.82±0.00^{f}
Cis-11,14-Eicosadienoic acid methyl ester (PUFA) [C20:2]	15.71±0.00	17.55±0.00^{b}	18.55±0.00^{c}	19.58±0.00^{d}	20.51±0.00^{e}	21.38±0.00^{f}
∑PUFA	66.68±0.00^{a}	76.23±0.00^{b}	91.70±0.00^{c}	95.47±0.00^{d}	99.36±0.00^{e}	101.04±0.00^{f}

Values are Mean±Standard Deviations of three determinations, values not followed by the same superscript in the same column are significantly different ($p \leq 0.05$), SFA: Saturated fatty acid, PUFA: Polyunsaturated fatty acid, MUFA: Monounsaturated fatty acid, AFE: Fermented extruded 100% unripe plantain, BFE: Fermented extruded 90% unripe plantain: 10% soybeans, CFE: Fermented extruded 80% unripe plantain: 20% soybeans, DFE: Fermented extruded 70% unripe plantain: 30% soybeans, EFE: Fermented extruded 60% unripe plantain: 40% soybeans, FFE: Fermented extruded 50% unripe plantain: 50% soybeans proportions in extruded unfermented 100% unripe plantain (EUA). The values of summation of saturated fatty acid (SFA) in extruded unfermented unripe plantain-soybeans blends ranged between 73.62±0.01 to 144.79±0.01. Summation of the values of monounsaturated fatty acid (MUFA) in extruded unfermented unripe plantain-soybeans blends ranged between 44.20±0.00 to 81.15±0.00. The result of the summation of PUFA in extruded unfermented unripe plantain-soybeans blends ranged between 72.30±0.00 to 113.27±0.00.

Fatty acid composition of fermented-extruded unripe plantain-soybean blends: The result shown in Table 12 revealed the fatty acid composition of fermented-extruded unripe plantain-soybean blends. Saturated fatty acid (tridecanoic acid) [C13:0] content ranged between 2.37±0.00 to 7.74±0.00 in fermented extruded unripe plantain-soybean blends. Fermented extruded 50% unripe plantain: 50% soybeans (FFE) records the highest value (25.19±0.00) of behenic acid [C22:0]. Monounsaturated fatty acid (oleic acid) [C18:1] reveals the highest value in fermented extruded 60% unripe plantain: 40% soybeans (EFE). The Cis-11-Eicosanoic acid and Heneicosanoic acid show the highest values in fermented extruded 60% unripe plantain: 40% soybeans. Polyunsaturated fatty acid (Linolenic acid) [C18:4] was lowest in AFE. The summation of saturated fatty acid (SFA) in fermented extruded unripe plantain-soybean blends ranged between 65.56±0.01 to 125.04±0.00. Monounsaturated fatty acid (MUFA) content summation in fermented extruded unripe plantain-soybean blends ranged between 40.17±0.00 to 66.50±0.00. Fatty acid composition of fermented extruded unripe plantain-soybean blends records summation of Polyunsaturated Fatty Acid (PUFA) content that ranged between 66.68±0.00 to 101.04±0.00.

DISCUSSION

According to the study's findings, unripe plantain and soybean blends' amino acid content was greatly impacted by both fermentation and extrusion. The samples' amino acid profile increased as a result of fortifying unripe plantain with soybean. The outcome showed that the amino acid content of plantain was considerably raised by combining unripe plantain with soybeans before fermentation and extrusion. Mukherjee *et al.*[17] had previously found a similar rise in the amino acid content of rice flour enriched with amaranth. Proteins were broken down into amino acids during fermentation processes, which were probably aided by lactic acid bacteria and proteolytic activity RR[18]. Glutamic acid, leucine, and aspartic acid are among the amino acids that have increased. This could indicate that during fermentation, free amino acids were released, which could improve the blend's flavor and nutritional value[19].

However, the reduction in vital amino acids, such as methionine and lysine, raises questions regarding the possible loss of nutritive value during fermentation. Further research is necessary to maximize the conditions for fermentation and reduce the breakdown of amino acids.

Essential amino acids are shown to be reduced in raw plantain soybean mixtures. Protein binding, antinutritional factors, and poor digestibility may be the primary causes of the decrease in essential amino acids in raw blends; in contrast, fermentation increases amino acid availability, decreases antinutritional factors, and improves protein digestibility[20]. There could be several reasons for the rise in non-essential amino acids in raw blends of unripe plantains and soybeans. The body can produce non-essential amino acids on its own, and based on the biochemical reactions taking place in the raw materials, their concentrations can change[21]. Plant metabolic activity, natural enzyme breakdown, precursor availability, and possible microbial activity could all contribute to the rise in non-essential amino acids in raw blends of unripe plantains and soybeans[8]. The observed rise may be explained by the raw soybeans and unripe plantains' increased metabolic capacity to either release stored amino acids from proteins or manufacture non-essential amino acids. These alterations are also influenced by processing methods, environmental variables, and protein degradation[22]. Several fermentation-related biochemical and microbiological processes allow fermented, unextruded blends of unripe plantains and soybeans to contain more essential amino acids than raw blends. The availability and content of proteins, particularly significant amino acids, are drastically changed by these processes. Microorganisms break down proteins enzymatically, reduce antinutritional factors, synthesize amino acids, release bound amino acids, and improve the digestibility and bioavailability of proteins during fermentation[23]. These processes are responsible for the increase in essential amino acids in fermented, unextruded blends of unripe plantain and soybeans[24]. These elements work together to increase the content of important amino acids in the finished fermented product and to make them easier to obtain[5].

Fermented, unextruded blends of unripe plantains and soybeans have higher quantities of non-essential amino acids than raw blends for several important reasons. Firstly, microbial synthesis is part of their metabolic activities, microorganisms (such as lactic acid bacteria and fungus) can produce non-essential amino acids during fermentation, which raises their concentration in fermented blends[25]. Secondly, proteins are broken down into smaller peptides and free amino acids by proteolytic enzymes, which are activated by the fermentation process and found naturally in the components[26]. Non-essential amino acids that might have been incorporated into intricate protein structures in the raw blend are released during this breakdown, increasing their availability in the fermented blend. Thirdly, a decrease in antinutritional factors inhibitors and phytates, two antinutritional factors found in raw soybeans, can restrict the availability of amino acids[27]. Better availability of amino acids, especially non-essential ones, is made possible by fermentation, which lessens or deactivates these inhibitors[28].

There are several reasons why extruded unfermented blends of unripe plantains and soybeans have a marginally higher amount of essential amino acids than fermented blends. These considerations include both the fermentation and extrusion processes.

Proteins may become denatured by the high temperatures and mechanical shear pressures used in the extrusion process[29]. The proteins may degrade into smaller peptides and amino acids as a result of this denaturation, which could liberate more important amino acids[30]. This technique may lead to a modest increase in the bioavailability of significant amino acids, but it does not hydrolyze proteins as thoroughly as fermentation[31]. Furthermore, microbial enzymes may break down or transform some amino acids especially important ones into other molecules during fermentation[5]. For instance, during fermentation, microbial degradation may impact tryptophan and lysine, resulting in a reduction in their concentrations[32]. Nevertheless, because extrusion is more concerned with physical alterations than biochemical ones, it might preserve a greater percentage of the original essential amino acids even after heat treatment[33].

The extrusion technique and its impact on protein breakdown, amino acid synthesis, and bioavailability are some of the reasons why extruded, unfermented unripe plantain-soybean blends have higher quantities of non-essential amino acids than raw and fermented blends.

Extruded, unfermented unripe plantain-soybean blends have higher quantities of non-essential amino acids than raw and fermented blends for several reasons. Firstly, extrusion causes heat-induced protein degradation, releasing more non-essential amino acids[33]. Secondly, antinutritional elements that prevent amino acids from being available in raw blends, such as trypsin inhibitors and phytates, are inactivated[34]. Thirdly, non-essential amino acids that could be changed or consumed during fermentation are preserved by the absence of microbial changes during extrusion[35]. Fourthly, disruption of the cell wall and other mechanical processes during extrusion increases the release and solubility of amino acids.

The combined effects of fermentation and extrusion, which complement each other to improve the essential amino acid profile, are responsible for the highest levels of essential amino acids in fermented-extruded unripe plantain-soybean blends as compared to raw, fermented, and extruded-only blends. In addition to decreasing antinutritional factors and increasing protein breakdown, fermentation may result in the microbial production of important amino acids[36]. When proteins are broken down and important amino acids are further released, extrusion increases the bioavailability and digestibility of the released amino acids[27]. When combined, these procedures guarantee that essential amino acids are as readily available and bioavailable as possible, producing a blend with the maximum concentration of essential amino acids. Fermentation and extrusion work in concert to produce fermented-extruded unripe plantain-soybean blends that have a notable increase in non-essential amino acids such as glutamic acid, aspartic acid, and arginine. Fermentation increases the production of non-essential amino acids and decreases antinutritional factors by promoting microbial synthesis and proteolysis[37]. Extrusion inactivates any residual anti-nutritional components while further breaking down proteins and increasing the availability of these amino acids[38]. During fermentation, precursors are transformed into non-essential amino acids by microbial metabolic activity[39]. These amino acids are subsequently liberated and rendered more accessible during the extrusion process[40].

Several factors related to the fermentation process and its effects on the composition and stability of fatty acids in the raw ingredients can be attributed to the increase in total saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA) in raw unripe plantain-soybean blends as compared to fermented unripe plantain-soybean blends. Due to microbial fat degradation and fermentation-induced oxidation of unsaturated fatty acids (PUFA and MUFA), raw unripe plantain-soybean blends have higher levels of total saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA) than fermented blends[41].

The increase in the fatty acids contents of the raw blends as compared with the fermented blends is due to alterations in the composition of fatty acids brought about by the preferential consumption or conversion of unsaturated fatty acids by microbial enzymes during fermentation[42]. Saturated fatty acids are more stable and so have a higher relative concentration in fermented blends than in raw blends, but unsaturated fatty acids, particularly PUFAs, tend to have lower levels during the fermentation process[43]. The main reason fermented unripe plantain-soybean blends have less fatty acid than raw, unfermented blends is due to factors such as; fatty acid consumption and microbial lipolysis by fermenting microbes[44]; fermentation-induced oxidation of unsaturated fatty acids, particularly PUFA[45]; lipids undergo hydrolysis and degradation, producing volatile fatty acids and other byproducts that lower the overall fatty acid level[45]; alterations in the fatty acid composition brought on by microbial metabolism, which may result in a decrease in MUFAs and PUFAs[46]; depletion of volatile fatty acids as a result of fermentation output[47] and acidic fermentation environment-induced fatty acid inactivation and modification[48].

Fatty acid concentration in unripe plantain-soybean blends is lower after extrusion processing than in raw, unextruded blends because: of fatty acid oxidation and thermal breakdown, especially of unsaturated fatty acids (MUFA and PUFA)[49]; triglycerides are hydrolyzed and broken down into free fatty acids, then further degraded by heat[50]; fatty acid structures are broken down by physical pressure and shear, which results in a loss of volatile fatty acids[51]; possible binding or displacement of fatty acids during extrusion, as well as the creation of new chemical compounds[52]; and steam and evaporation during the extrusion process cause the loss of fatty acids[53].

The fatty acid content of fermented-extruded unripe plantain-soybean blends was much lower than that of raw, fermented, and extruded unripe plantain-soybean blends. This can be ascribed to several reasons of both the extrusion processing and the fermentation process. The combined impacts of heat, oxidation, microbial activity, and other chemical reactions may cause a larger loss of fatty acids in the fermentation-extrusion process than in either step alone. Additionally, compared to raw, fermented, and extruded blends, fermented-extruded unripe plantain-soybean blends significantly reduced their fatty acid content.

This can be attributable to the production of fermentation byproducts, including alcohols and organic acids, which have the potential to bind or displace fatty acids; fatty acid oxidation and thermal degradation during the high-heat extrusion process; and the combined impact of extrusion and fermentation, which results in increased fatty acid loss and degradation[54].

Additionally, the results of this study reveal new information regarding how fermentation and extrusion affect the amino and fatty acid composition of blends of unripe plantains and soybeans. Comprehending these impacts is pivotal in enhancing food processing methodologies and creating nutrient-dense and appetizing food materials.

CONCLUSION

The evaluation of the effects of extrusion and fermentation on the fatty acid and amino acid compositions of unripe plantain-soybean blends shows that extrusion significantly degrades polyunsaturated fatty acids, especially linolenic acid, arachidonic acid, and γ-linolenic acid while fermentation has little effect on amino acids of fermented unextruded 100% unripe plantain but may result in minor alterations in fatty acids. Most fatty acids are found in 50% unripe plantain: 50% soybeans of unprocessed, fermented, extruded, and fermented-extruded blends. To reduce the breakdown of important fatty acids and maintain the amino acid profile, future studies should concentrate on improving the conditions for fermentation and extrusion. Furthermore, investigating different processing methods and the results of different plantain-to-soybean ratios may improve the blends' nutritional value.

SIGNIFICANCE STATEMENT

This study highlights the potential of fermentation and extrusion to enhance the nutritional quality of unripe plantain and soybean blends by improving their amino acid and fatty acid profiles. These processing techniques could create more balanced, nutrient-dense plant-based foods, especially in regions reliant on soybeans and plantains. The findings offer valuable insights for developing sustainable, affordable, high-protein food products to address nutritional deficiencies and combat hunger.

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