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Effects of Fermentation on the Proximate Composition of Irish (*Solanum tuberosum*) and Sweet Potato (*Ipomoea batatas*) Peels

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Abstract

Fermentation has been exploited to improve agricultural waste products. Fermentation of Sweet potato (*Ipomoea batatas*) and Irish potato (*Solanum tuberosum*) peels was carried out by soaking in clean water for 96 hours at room temperature during which samples were collected daily for microbial, physicochemical and proximate analysis. Microbial load of both peels ranged from 9.0×10^5 to 8.6×10^6 cfu/ml; 1.5×10^6 to 7.4×10^6 sfu/ml and 1.2×10^6 to 2.0×10^6 sfu/ml for bacteria, fungi and yeast respectively. The pH value of both peels decreased significantly ($P \leq 0.05$) with corresponding increase in the total titratable acidity (TTA) ($P \leq 0.05$) and temperature ($P \geq 0.05$) with time during fermentation. The percentage composition of moisture, ash, fat and protein content of both peels increased insignificantly ($P \geq 0.05$) with values ranging from $8.91^{ab} \pm 0.62$ to $12.19^{b} \pm 0.51$, $3.69^{a} \pm 0.41$ to $5.77^{a} \pm 0.58$, $1.86^{a} \pm 0.54$ to $4.57^{c} \pm 0.51$ and $4.55^{a} \pm 0.45$ to $7.74^{b} \pm 0.51$ respectively, while the crude fiber and carbohydrate composition decreased insignificantly ($P \geq 0.05$) with values ranging from $2.16^{a} \pm 0.43$ to $3.97^{bc} \pm 0.64$ and $41.83^{a} \pm 2.64$ to $70.05^{bc} \pm 2.55$ respectively, until the last day of fermentation as compared with the unfermented peels at 0 hour. However, there was no significant difference ($P \geq 0.05$) in the proximate composition of both peels. The results obtained from this study revealed that fermentation can bring about desirable changes in the nutrient composition of potato peels.

Keywords

Fermentation, Proximate Composition, Physicochemical Analysis, Microbial Load, Potato Peels

1. Introduction

Fermentation is one of the oldest applied biotechnological methods having been used in food processing for over 6000 years, and the fermentation processing of

staple foods thus serves as a means of providing a major source of nourishment for large rural population and contributes significantly to food security [1]. Fermentation therefore enhances the nutrient content of foods through the biosynthesis of vitamins, essential amino acids and protein by improving protein quality and fiber digestibility. It also enhances micro content bioavailability and aids degrading anti-nutritional factors [2].

Food processing is one of the most important industries over the globe, however, by-products of such industrial activity that are mainly organic material must be handled in appropriate manner to avoid any environmental violence. Also, sanitation and disposal problem of food processing by-products is a major concern; hence many approaches have been suggested including recycling of such ingredients and their utilization in several food and non-food applications [3]. By-product of food processing is an inexpensive, affordable, and valuable starting material for the extraction of value added products such as dietary fiber, natural antioxidants, biopolymers, and natural food additives [4]. However, the central dogma is still the stability, and economic feasibility of the processing development [5].

Potatoes, not only in terms of their easy preparations, combining the healthiness of cereals and delicacy and characteristic chemical composition of vegetables; therefore it is important that they are included in human diet. Nutritional value of potatoes is determined by the content of nutrients such as protein, starch, fat, minerals, and absence of toxins, as well as by a significant content of bioactive components from the group of polyphenols, which guarantee proper antioxidant activity of this vegetable [3].

Sweet potato (*Ipomoea batatas*) is a dicotyledonous plant that belongs to the family Convolvulaceae. The edible tuberous root is long and tapered with a smooth skin whose colour ranges between red, purple, brown and white. Its flesh ranges from white to yellow, orange and purple [6]. Although the leaves and shoots are also edible, the starchy tubers are by far the most important product in some tropical areas and have been utilized as staple food crop; such as "Amukeke" (sun-dried slices of storage roots) and "Inginyo" (sun-dried crushed storage roots) in north Eastern Uganda [7]. "Amukeke" is mainly for breakfast eaten with peanut source while Inginyo is mixed with cassava flour to make food called "Atapa" which is eaten cooked in peanut sauce.

Irish potato *(Solanum tuberosum*) is an edible tuber from the *Solanum tuberosum* plant which is actually native to South Africa. They can be referred to as "white potato" and their tubers are also rich source of starch worldwide [8]. They rank with wheat and rice as one of the most important staples in the human diet [9].

Potato peels have been exploited as natural antioxidants in food system due to its high content of polyphenols, antioxidants in biological systems, screened as low-cost solid substrates for microbial production of enzymes to be used either in food applications or in other industrial sectors [3]. They are excellent substrate for the production of thermostable alpha-amylase, a starch hydrolyzing

enzyme extensively used in different food industries and source of antimicrobial agents [6]. Thus, potato peels differ greatly from other agricultural by-products because of the presence of both nutritionally and pharmaceutically interesting constituents [3].

Potato peels have been explored in nutraceuticals [10], and the fermented peels utilized in ethanol production [11] and tested as biofertilizer [12]. However, the nutritional composition of fermented potato peels has not been fully investigated. Therefore, isolating and enumerating the microbial loads and nutritional composition of fermented *Solanum tuberosum* (Irish potato) and *Ipomoea batatas* (sweet potato) peels will give an insight into its nutritional quality which can serve as alternatives in food and or non/food applications.

2. Materials and Methods

2.1. Collection and Preparation of Potato Peels Samples

Apparently healthy corms of *Solanum tuberosum* (Irish potato), and *Ipomoea batatas* (sweet potato) used for this project work was obtained from Oja-Oba; a market in Akure, Ondo State, Nigeria. All samples were washed to remove sand and other debris, before they were peeled. Peels (100 g each) of each species were then soaked in eight clean containers separately *i.e.* four for each peel, covered and fermented at ambient temperature for four days. Samples were taken for both microbiological and proximate analyses.

2.2. Determination of Microbial Load of Fermented Potato Peels

This was carried out according to the pour plate method of isolation as described by [13]. Bacterial and fungal/yeast counts were expressed as colony forming unit (cfu/ml) and spore forming unit (sfu/ml) respectively.

2.3. Physicochemical Analysis of Fermented Potato Peels

The pH was determined using Jenway's pH meter (351-101 Model 3510, Kats Scientific, UK) which had been standardized with buffer solution of pH 7.0. The temperature was measured using thermometer and Total titratable acidity (TTA) carried out according to the method of [14].

2.4. Determination of Proximate Analysis of Fermented and Unfermented Potato Peels

The moisture, ash, protein, crude fibre, fat and carbohydrate contents were carried out according to the method of [15] and expressed in percentages.

2.5. Statistical Analysis

Values were recorded in triplicates, and statistical Analysis of data was carried out using analysis of variance (ANOVA) and Duncan's Multiple Range Test for the estimation of means. The "t" value was tested at 95% confidence interval.

3. Results

3.1. Microbial Load of Potato Peels during Fermentation

The microbial population ranged from 9.0×10^5 to 8.6×10^6 cfu/ml and 1.5×10^6 to 7.4×10^6 sfu/ml for bacteria and fungi respectively. Yeast survived within 48 hours of fermentation for both peels and it ranged from 1.2×10^6 to 2.0×10^6 sfu/ml. Microbial population in sweet potato peels was higher compared to Irish potato peels throughout the period of fermentation. The microbial count of both peels decreased initially until 48 hours and on the last day of fermentation. The Peak microbial load was observed in both peels at 72 hours of fermentation as shown in Table 1.

3.2. Physicochemical Composition of Fermented and Unfermented Potato Peels

The pH value of both peels decreased significantly ($P \leq 0.05$) throughout the fermentation period as shown in Figure 1, with Irish potato peels having a higher pH value compared to Sweet potato peels. The pH values ranged between $5.03^a \pm 0.02$ and $6.93^e \pm 0.01$ before and during fermentation. The TTA increased significantly ($P \leq 0.05$) throughout the fermentation period also for both peels, as shown in Figure 2, with Sweet potato peels showing a higher TTA value compared to Irish potato peels. The TTA values ranges between $0.80^a \pm 0.02$ and $3.80^e \pm 0.04$ before and during fermentation. The Temperature of fermented potato peels increased insignificantly ($P \geq 0.05$) for both peels throughout fermentation period as shown in Figure 3, ranged from $22.00^a \pm 1.00$˚C to $30.00^c \pm 2.00$˚C before and during fermentation. However, the same initial and final temperature value was observed in both peels.

3.3. Proximate Composition of Irish and Sweet Potato Fermented Peels

The percentage composition of moisture, ash, fat and protein content of both peels increased insignificantly ($P \geq 0.05$) while the crude fiber and carbohydrate composition decreased insignificantly ($P \geq 0.05$) until the last day of fermentation

Table 1. Microbial load of fermented potato peels between 24 and 96 hours.

Time	Potato peels					
	Solanum tuberosum (Irish)			*Ipomoea batatas* (Sweet)		
	Bacteria (cfu/ml)	Fungi (sfu/ml)	Yeast (sfu/ml)	Bacteria (cfu/ml)	Fungi (sfu/ml)	Yeast (sfu/ml)
24 hours	9.0×10^5	1.5×10^6	1.6×10^6	2.0×10^6	3.0×10^6	1.2×10^6
48 hours	2.4×10^6	3.2×10^6	2.0×10^6	4.8×10^6	4.5×10^6	1.7×10^6
72 hours	7.2×10^6	6.0×10^6	ND	8.6×10^6	7.4×10^6	ND
96 hours	5.6×10^6	4.3×10^6	ND	5.3×10^6	5.5×10^6	ND

Key: ND—not detected.

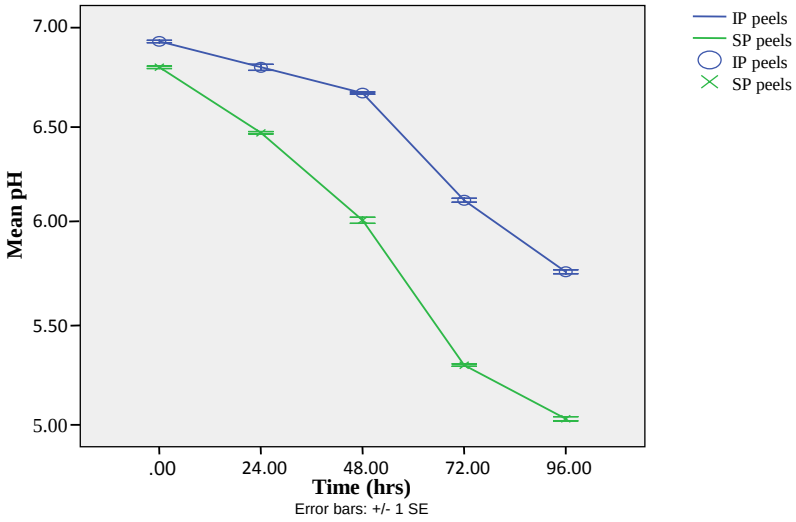

Figure 1. pH before fermentation (0 hr) and during fermentation of Irish potato (*Solanum tuberosum*) and sweet potato (*Ipomoea batata*) peels. IP is Irish potato, SP is Sweet potato.

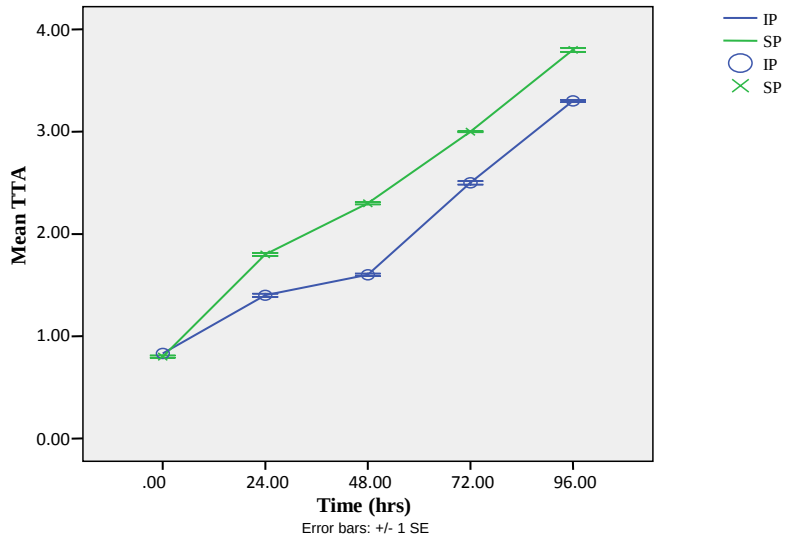

Figure 2. Total Titratable Acidity before fermentation (0 hr) and during fermentation of Irish potato (*Solanum tuberosum*) and sweet potato (*Ipomoea batata*) peels. IP is Irish potato, SP is Sweet potato.

as compared with the unfermented peels at 0 hour, as shown in Table 2. However, Crude fiber recorded the lowest % proximate content in both peels; ranging from $2.16^{a} \pm 0.43$ to $3.30^{bc} \pm 0.08$ and $2.34^{a} \pm 0.15$ to $3.97^{bc} \pm 0.64$ while Carbohydrate recorded the highest, ranging from $53.43^{a} \pm 3.65$ to $70.05^{bc} \pm 2.55$ and $41.83^{a} \pm 2.64$ to $65.80^{cd} \pm 4.68$ during fermentation for Sweet and Irish potato peels respectively.

4. Discussion

In this study, the microbial load and the effect of fermentation on the nutritional composition of Sweet and Irish potato peels were investigated. Peels often

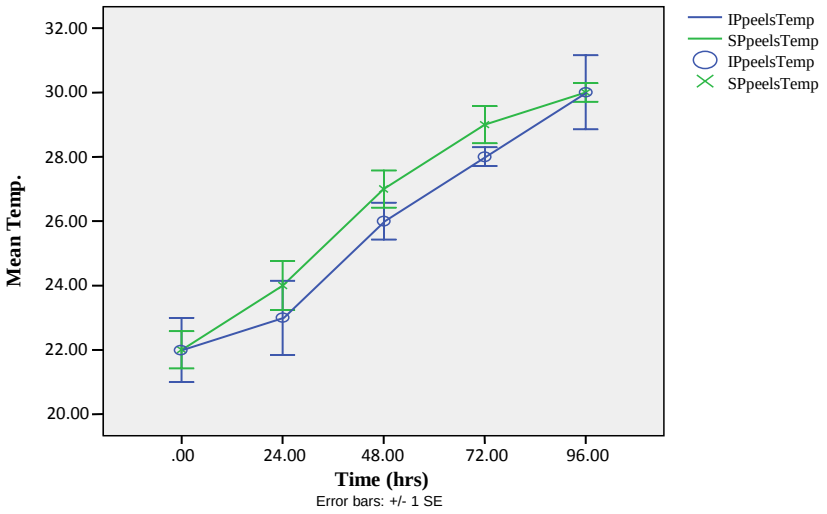

Figure 3. Temperature before fermentation (0 hr) and during fermentation of Irish potato (*Solanum tuberosum*) and sweet potato (*Ipomoea batata*) peels. IP is Irish potato, SP is Sweet potato Temp is Temperature.

Table 2. Proximate composition of Sweet and Irish potato peels before fermentation (0 hr) and during fermentation.

Time	Mean Proximate compositions (%)											
	Moisture content		Ash content		Fat content		Protein content		Crude fibre		Carbohydrate content	
	Sp	Ip	Sp	Ip	Sp	Ip	Sp	Ip	Sp	Ip	Sp	Ip
O hr	8.24^{a} ± 0.34	9.96^{a} ± 0.41	4.56^{a} ± 1.15	3.65^{a} ± 0.41	2.02^{a} ± 0.22	1.63^{a} ± 0.54	4.64^{a} ± 0.51	4.42^{a} ± 0.45	3.79^{c} ± 0.67	4.81^{c} ± 0.07	72.60^{c} ± 1.58	73.79^{d} ± 3.02
24 hrs	8.91^{ab} ± 0.62	10.33^{a} ± 0.33	4.92^{a} ± 0.41	3.69^{a} ± 0.41	2.31^{ab} ± 0.17	1.86^{a} ± 0.54	4.66^{a} ± 0.49	4.55^{a} ± 0.45	3.30^{bc} ± 0.08	3.97^{bc} ± 0.64	70.05^{bc} ± 2.55	65.80^{cd} ±4.68
48 hrs	9.40^{b} ± 0.29	10.61^{a} ± 0.66	4.63^{a} ± 0.69	4.11^{a} ± 0.20	2.73^{b} ± 0.17	2.23^{a} ± 0.15	5.15^{a} ± 0.19	5.28^{a} ± 0.64	3.68^{c} ± 0.41	3.54^{abc} ± 1.15	68.17^{bc} ± 3.16	57.81^{bc} ± 9.19
72 hrs	10.60^{c} ± 0.29	11.89^{b} ± 0.06	5.20^{a} ± 0.07	5.03^{b} ± 0.29	4.15^{c} ± 0.51	3.10^{b} ± 0.27	6.16^{b} ± 0.25	7.01^{b} ± 0.51	2.89^{ab} ± 0.15	3.11^{ab} ± 1.01	63.29^{b} ± 6.62	49.62^{ab} ± 1.89
96 hrs	11.21^{c} ± 0.59	12.19^{b} ± 0.51	5.77^{a} ± 0.58	5.43^{b} ± 0.07	4.57^{c} ± 0.51	3.47^{b} ± 0.09	6.66^{b} ± 0.84	7.74^{b} ± 0.51	2.16^{a} ± 0.43	2.34^{a} ± 0.15	53.43^{a} ± 3.65	41.83^{a} ± 2.64

Values are mean zone of inhibition (mm) ± Standard deviation of three replicate $^{a-d}$means in the same column not sharing a common letter are significantly different (P = 0.05) by Duncan's multiple range test. IP is Irish potato while SP is Sweet potato.

constitute wastes and have been found to contain heavy microbial load as they make up 10% of the root and undergo fermentation which results in environmental pollution [16]. The occurrence of aerobic organisms during fermentation showed that they grew in close association with the substrate and increased the production of extracellular enzymes [17]. *Acinetobacter calcolaceticus* has constantly been isolated during fermentation of sweet potato peels, it is aerobic and commonly found in soil and water while some strains utilizes a restricted amount of sugar [18]. Species of *Aspergillus* and *Rhizopus* observed is related with their amylolytic activity [19]. Presence of yeast indicates that they are capable of growing and surviving in an acidic and alcoholic medium [20].

Titratable acidity measures total organic acid that is present in the potato peels since acidification plays a key role during fermentation. Decrease in pH

($P \leq 0.05$) could result in the hydrolysis of available carbohydrate being converted into lactic acid by microorganisms associated with the fermentation process while the TTA increased ($P \leq 0.05$) with fermentation time [21]. The pH range observed during fermentation is favourable for cellulases which are responsible for cellulose degradation during acidification. The rise in temperature ($P \geq 0.05$) indicates the release of energy as a result of active microbial activities caused by increased microbial biomass due to ample availability of nutrients that resulted from primary metabolism. Mesophilic temperature ranges observed during fermentation was responsible for the survival of acid producing organisms, as lower temperature range within 48 hours of fermentation favoured the growth of yeast. This temperature is also able to support the growth of organisms that are producers of extracellular enzymes during fermentation [22]. Moisture content is a notable factor in fermentation due to its influence on growth, biosynthesis and secretion of various metabolites [23]. Low moisture content can cause reduction in solubility of nutrients from the substrate, low degree of swelling and high water tension. Thus, water content is a very significant factor in the fermentation process. High water activity can lead to the decrease in porosity of the substrate, thereby reducing the exchange of gases. On the other hand, low water activity may result in the reduction of microbial growth and consequent lower production of enzyme [24].

An improvement in the ash content of the fermented peels might be due to the non-leakage of the soluble minerals into the fermenting liquid during fermentation [25]. Ash content represents the total mineral content in foods. Although minerals represent a small proportion of dry matter, often less than 7% of the total, they play an important role from a physicochemical and nutritional composition of food.

The % carbohydrate content observed in the fermented peels is in line with the observation of [9], on the effect of cooking and extrusion on potato peels. It was observed that starch content of potato peels depends on the peeling process: while steam peels contains approximately 28% starch, abrasion peels have about twice as much starch (58%), since more potato flesh is removed during the abrasion process. However, the reduction in the carbohydrate content during fermentation might be due to the utilization of some sugars as carbon source by fermentative organisms for growth and other metabolic activities. The general reduction in carbohydrate contents may be as a result of respiratory activities of hydrolytic enzymes [26].

Crude fiber content decreased which is an indication of softening of the fibrous tissues during fermentation. This could also be due to the activities of microorganisms which are known for the bioconversion of carbohydrates and lignocelluloses into protein, while the increase in the moisture content might lead to the decrease in the carbohydrate during fermentation. This agrees with the findings of [19], in the study of the nutritional improvement of cassava products using microbial techniques for animal feeding, also, [27] who attributed this to the fact that fermenting temperatures were responsible for the breakdown of the starch or carbohydrate into sugar by the enzyme amylase which hydrolyses

starch granules for the growth of the fermenting organisms, in their work on Quality assessment of starter-produced weaning food subjected to different temperatures and pH.

The increase observed in the fat content during fermentation is a clear evidence on the use of potato peels in feeding of multi-gastric animals, as milk fat from cows fed with potato peels were reported to be 3.3 g/kg higher than that of control as reported by [28], where the milk fat was varied with the amount of starch in a total mixed diet fed to dairy cows. This increase could also be due to extensive breakdown of large fat molecule to simpler fatty acids units due to the high activity of lipolytic enzymes which could have resulted in fat increase during fermentation [29].

During fermentation, an increase in microbial biomass can cause an extensive hydrolysis of protein molecules to amino acid and other simple peptides and enzymatic hydrolysis of some protease inhibitors. It may be due to structural proteins that are integral part of the microbial cells [30]. The occurrence of fungal and yeast load during fermentation might also be responsible for the increase in the protein content of the peels. Fungi are also able to produce extracellular enzymes such as amylases from the fungal mycelia and thus secreted into the fermenting system in an attempt to make use of the starch content of the peel as a source of carbon [31]. Moreover, potato peels are capable of being used to produce single cell protein with a high biomass [32].

Agricultural food processing industries such as potato processors yield a huge amount of by-products which need to be discarded. Disposal of these by- products is an economic and environmental problem. In this study, the proximate composition of both Sweet (*Ipomoea batatas*) and Irish (*Solanum tuberosum*) potato was observed to improve during fermentation with time, as compared to the unfermented peels. Potato as a major staple food could play an important role to combat mineral deficiencies through its relative high nutritional content. Therefore, potato by-products based silage may be used as a substitute for concentrates as an energy source in growing and finishing diets for livestock.

5. Conclusion

Potato peels as a by-product from potato processing are available in large amount and their utilization may eliminate a substantial pollution problem. Thus, several tonnes of sweet and Irish potato peels, if properly fermented and incorporated into animal feed can reduce the cost of animal feeds thereby alleviating financial problem faced by many farmers in developing countries in feeding animals.

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