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Effect of fermentation on nutrients and phytonutrients content of potatoes (*Solanum tuberosum L.*)

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Abstract

The aim of this study was to investigate the effect of fermentation on potato nutrients and phytonutrients. Potatoes were washed, sliced and 140g were submerged in jars of 500ml containing 300ml of 2% brine solution. The jars were closed with lids and allowed to ferment spontaneously for 7 days. There was no interaction effect for moisture, starch and protein, while a significant effect was observed for phytonutrients and minerals at $P<0.05$. Moisture content ranged from 75.89 to 80.44%, starch from14.45 to 18.87% and protein ranged from 1.87% to 2.09%. Total phenols ranged from 11.98mg/100g for fermented Kinigi to 14.90mg/100g for non-fermented Kirundo, total anthocyanins ranged from 0.05mg/100g for fermented Mabondo to 0.92mg/100g for non-fermented Sangema. Vitamin C ranged from 1.29mg/100g for fermented Sangema to 12.14mg/100g for non-fermented Kinigi. There was a change in minerals during fermentation, calcium from 8.11mg/100g to 2.15mg/g, zinc from to 0.32 to 0.10 mg/100g, magnesium from 20.48 to 7.40mg/100g, iron from 0.86 to 0.17mg/100gram, potassium from 542.88 to 299.19mg/100gram, phosphorus from 69.77 mg/100g to 28.22 mg/100g. Fermentation reduced nutrients and phytonutrients in potatoes, potentially due to leaching into fermenting solution or utilization as substrates of fermenting microbes. However, fermentation may also generate bioactive compounds along with flavor that impart health benefits and enhance palatability for consumers.

Keywords : *Brine solution, Fermentation, Nutrients, Phytonutrients, Potato*

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Introduction

Fermentation is among the oldest methods used by people around the world to increase storage stability, palatability and bioavailability of nutrients in fermented products (Steinkraus, 2002; Ray & Sivakumar, 2009). It involves the process of converting food substrates into other compounds by microorganisms, which are often beneficial. Fermentation occurs in different forms, depending on the substrates and the end products produced. In alcoholic fermentation, sugars are converted into ethanol by yeast, which is also used in bread fermentation. Fermentation also includes the production of sour products through lactic acid bacteria and acetic acid bacteria. Molds are also used in the fermentation of cheese. Nowadays, fermentation is gaining popularity in various types of foods due to the numerous benefits associated with it, such as increased shelf life of food, improved palatability and health benefits. The highly perishable foods, like vegetables, are being fermented through lactic acid fermentation, which not only extends their storage stability but also enhances bioactive compounds and palatability of fermented food.

Fermented foods are food substrates that are subjugated to edible micro-organisms, whose enzymes especially amylases, proteases and lipases hydrolyze the polysaccharides, proteins and lipids to non-toxic products with flavors, aromas and textures that are pleasant and attractive to human consumers (Ray & Sivakumar, 2009). If the products of enzyme activities have unpleasant odors, unappealing flavors or toxic compounds detrimental to human, the foods are considered spoiled and unfit for human consumption (Ray&Sivakumar, 2009). Lactic acid bacteria (LAB) required for fermentation must be non-toxic, stable, capable of rapid acidification of the medium and resistant to bacteriocins and other processing conditions. They also require nutrients and conducive environment for effective fermentation (Montet *et al.*, 2014). Lactic acid fermentation is primarily carried out by LAB which are Gram –positive, anaerobic, non-spore forming bacteria, existing as cocci or rods. There are two types of lactic acid fermentation: homo-fermentation and hetero-fermentation. During fermentation, a glucose molecule is split into two molecules of pyruvate in the glycolysis process (Das *et al.*, 2016). In homo-fermentation, one molecule of glucose is converted into two molecules of lactic acid (Das *et al.*, 2016). For hetero-fermentation one molecule of glucose is converted into one molecule of lactic acid, one molecule of ethanol and one molecule of carbon dioxide (Das *et al.*, 2016). Lactic acid

fermentation can occur through dry salting, where fermentation is done on solid media or brine salting, where food is submerged in a solution. In both cases, the main byproduct of fermentation is lactic acid.

Fermentation is responsible for chemical changes in fermented products. During fermentation, fermenting microorganisms utilize certain nutrients and produce new byproducts. For example, the fermentation of fufu flour using different starter cultures showed a reduction in nutrient content as result of fermentation. Protein content decreased from 1.65% to 1.14%, fat from 0.35% to 0.24%, fiber from 1.66% to 0.77%, ash from 1.31% to 0.54%, sugars from 5.21 to 4.41%, and starch from 76.86 to 70.28%, while amylose increased from 19.80 to 21.30% (Sobowale *et al*., 2007). A decrease in mineral content was also observed with the exception for calcium (Ca), which increased from 0.044 to 0.1%. magnesium (Mg) decreased from 0.054 to 0.007%, potassium (K) form 1.107 to 0.107%, sodium (Na) from 0.0094% to 0.00 61%, manganese (Mn) from 0.00038 to 0.002%, iron (Fe) from 0.002% to 0.0010%, zinc (Zn) from 0.0009 to 0.000 438% and phosphorus (P) from 0.06 to 0.01% (Sobowale *et al*., 2007). Similarly, the starch content of fermented potato pickles in brine solution for seven (7) days was reported to decrease attributed to the amylolytic activity of *L. plantum* used in the fermentation process. β-carotene levels also followed the trend (Panda *et al*., 2007). Furthermore, a decrease in sugar content was observed during fermentation of both sweet and bitter cassava after 24 and 96 hours of fermentation (Kakou *et al*., 2010). After 72 hours of fermentation, half of the reducing sugars in sweet cassava were degraded, while one fifth of the sugar in bitter cassava were consumed (Kakou *et al*., 2010). Reduction in some nutrients is related to their utilization by LAB during fermentation. At the same time LAB can induce production of other compounds that are beneficial to the human body.

Fermentation induces detoxification processes while simultaneously increasing the bioavailability of nutrients. Evans *et al*. (2013) reported reduction of anti-nutrients in cereals, legumes and tubers including compounds like phytates, tannins, cyanogenic glycosides, oxalates, saponins and lectins. These anti-nutrients can chelate minerals or inhibit digestive enzymes, thereby hindering nutrient bioavailability. The reduction of phytates during fermentation was reported to increase bioavailability of zinc, calcium, and iron (Das *et al*., 2016). Additionally, fermentation was found to decrease cyanide levels in the fermented cassava (Kakou *et al*.,2010).

Fermentation also increases protein content and the balance of amino acids, as well as vitamins such as thiamine, riboflavin, niacin, and folic acids, all of which have health benefits (Ray &Sivakumar, 2009; Steinkraus, 2002). Lactic acid fermentation was reported to preserve ascorbic acid, glutathione and antioxidant activity during storage (Montet *et al*., 2014). Fermented vegetables contain high level of vitamin C, fermented milk contains more vitamin B and fermented soya beans are rich in vitamin B12 (Evans, *et al*., 2013). Detoxification process in fermented food leads to an increase in nutrients and their bioavailability, thereby promoting good health.

Fermentation improves storability, healthiness and organoleptic properties of food. During fermentation, compounds like lactic acid, alcohol, acetic acid and high salt levels are produced, which inhibit the growth of harmful bacteria (Steinkraus, 2002). Furthermore, hydrogen peroxide and peroxides are generated, which have been reported to have bactericidal effect (Oyewole,1997). Lactic acid fermented products have also demonstrated antitumor effect (Anukam & Reid, 2009). Organic acids produced during fermentation, such as propionic acid, acetic acid and lactic acid, have been reported to inhibit fungal growth (Sauer *et al*., 2008). The byproducts of fermentation hinder the growth of Gram-negative bacteria, which are often pathogenic. Other antimicrobial compounds formed during lactic acid fermentation include bacteriocin, reuterin and reutericyclin (Chule *et al*., 2010). These compounds also contribute to the pleasant flavour, aroma and texture of fermented food (Steinkraus, 2002; Ray & Sivakumar, 2009). Most fermented roots and tubers are associated with lactic acid bacteria like *Lactobacillus, Leuconostoc, Streptococcus* and yeast like *Saccharomyces cerevisiae* which are considered as probiotics (Agrawal, 2005). In addition to the health benefits from probiotics, regular consumption of fermented lactic acid products enriched with pigments like anthocyanins, lutein and β-carotene can help combat various diseases such as night blindness, liver injury, aging and related ailment (Montet *et al*., 2014). Furthermore, bioactive compounds are linked to health benefits such as anti-aging, anti-cancer, protection against cataract, muscular degeneration and liver injury (Kaur & Kapoor, 2001). Fermented products are healthy, safe with pleasant organoleptic properties.

In today's world, people are increasingly confronted with lack of healthy food options, with junk foods predominate in many regions. Regular consumption of junk food is unhealthy and can lead to metabolic disorders.

There is a need to process our usual foods into healthier alternatives. In Rwanda, Potatoes are a starchy staple food that grows well in northwest of the country. Potatoes can be fermented to enhance its nutritional value. During fermentation some antinutrients are reduced, while useful compounds are produced due to the action of lactic acid bacteria. Moreover, the production of lactic acid, which has both bactericidal and bacteriostatic effect, increases the shelf life of the product. The fermentation process also contributes to the appealing flavor of fermented products. Apart from moisture content, potatoes are predominantly composed of starch, which accounts for more than 70% of total dry matter (Singh & Kaur (2009). Other, nutrients are present in small amounts and contribute minimally to health. Potato ranks the second source of energy after cassava with an average consumption of 125 kg per person per year (FAO, 2008). However, potatoes have a short shelf life and deterioration begins after harvesting. There is a need to extend their shelf life and make them available year –round. Given the high consumption of potatoes, transforming them into a healthier and more stable product would significantly benefit consumers health. Therefore, the purpose of this study is to transform potatoes into a healthier and more stable food and evaluate the change in nutrients during fermentation.

Materials and Methods

Sample preparation

The method used by Panda *et al.*(2007) was followed. Potatoes were washed, peeled and sliced into 1.2-1.3cm pieces, then washed in tap water to remove adhering starch. Thereafter, amount of 140g were put in a container of 500 ml and 300 ml of 2% brine solution was added. Jars were capped and allowed to stand at room temperature to ferment for seven days using spontaneous fermentation at room temperature. They were then sun dried and ground into powder, kept in clean dry containers and refrigerated at (4±2) ^{o} C for further analysis.

Determination of moisture content

CIP (2006) method was used for determination of moisture content. About 10 g of potatoes were weighed in a crucible with three replications and heated in forced air oven at 80^{o} C for 72 hours or until constant weight was obtained. The dry matter was calculated using the formula below

$$\text{Moisture content \%} = \frac{\text{weight of fresh sample} - \text{weight of dried sample}}{\text{Fresh weight}} \text{x}100 \ldots\ldots (1)$$

Determination of potato starch

The method of AOAC (2000) was used for determination of potato starch. About 3 g of samples were weighed into 250 ml volumetric flask. Amount of 200 ml of distilled water was added followed by 20 ml of concentrated HCl and 3 glass beads were added. The solution was refluxed until a clear solution was obtained. The solution was neutralized by adding 50% NaOH and 3 drops of phenolphthalein were used as indicator followed by filtration with Whatman no 541 with pore size of 22 µm into a 250 volumetric flask and diluted to the mark with distilled water. For the analysis of sugars Fehling solution was used following the method of Lane-Eynon.

Determination of crude protein

Crude protein was determined using a standard method AOAC (2000). Crude protein content was computed by multiplying percentage of nitrogen with a factor of 6.25.

$$\text{Total sugars } \% = \frac{4.95\ (\text{factor}) \times 250\ (\text{Dilution}) \times 2.5 \times 100}{\text{Weight of the sample} \times \text{Titre} \times 1000} \quad \ldots \ldots \ldots (2)$$

$$\text{Starch, g per } 100\text{g} = \%\ \text{Total sugar} \times 0.9 \ldots \ldots \ldots (3)$$

Determination of minerals

Minerals were determined using AOAC (2000). One gram of sample was weighed accurately in a Teflon cup with screw cap. Thereafter, 5 ml concentrated HNO_3 and 1ml concentrated $HClO_4$ were added and closed. The mixture was allowed to stand overnight at room temperature to predigest the sample. They were then placed in oven at 100°C for 8 hours and cooled to room temperature in fume hood. The digests were filtered with Whatman filter and transferred into 100 ml volumetric flasks, which were filled to the mark with distilled water. Calibration curves was made using standards of 0, 0.4, 0.8, 1.2, 1.6, 2.0 ppm. Specific lamps were used for every element and wavelength used were 422.7 nm for calcium, 285.2 nm for magnesium, 248.4 nm for iron, 213.9 nm for zinc. Atomic Absorption Spectrophotometer (Thermo Jarrell Ash Corporation model 6, Forge Parkway Franklin, USA) was used. Flame spectrophotometer (Corning Flame photometer model 410, Cambridge, United Kingdom) was used for determination of potassium and standard curve was plotted against concentrations of 0, 1, 2, 4, 6, 8, 10 ppm.

Phosphorus was determined by pipetting 10 ml of aliquot prepared previously for minerals into 100 ml conical flask. To each flask 10 ml of 6N HNO_3 was added. Thereafter, 10 ml 0.25% ammonium monovanadate was added and 10 ml 5% ammonium molybdate. It was diluted to the mark, mixed and allowed to stand for 15 minutes. The absorbance was read at 400 nm with spectrophotometer (JENWAY 7315, Staffordshire, United Kingdom). Standard was prepared by dissolving 0.4390 g KH_2PO_4 in 1L of water to obtain 10 mg phosphorus per 100 ml. Standard curve was plotted with 0, 0.2, 0.4, 0.6, 0.8, 1.0 and 1.2 ppm. Ammonium monovanadate 0.25% was prepared by dissolving 0.25 g of ammonium monovanadate in 2 ml conc. HNO_3 and diluted to 100 ml with deionized water. The 5% (w/v) ammonium molybdate solution was prepared by dissolving 5 g of ammonium molybdate in deionized water to a final volume of 100 ml conical flask.

Determination of total phenols

The method used by Sun *et al.* (2015) was adopted for determination total phenols. Amount 1 g of potato flour was solubilized into 20 ml of distilled water, shaken for 5 hours at 80 x g subjected to centrifugation (HERMLE Labnet, model Z382K, Wehingen, Germany) at 400 x g for 5 minutes. Amount of 0.5 ml of potato powder extract was homogenized with 2 N 0.5 ml of Folin-Ciocalteu reagent for 6 min. Subsequently, 1.5 ml 20% Na_2CO_3 was added followed by distilled water to make total volume of 10 ml and incubation was 10 minutes in dark at room temperature. Reading of absorbance was done at 765 nm with spectrophotometer (JENWAY 7315, Staffordshire, United Kingdom). Standard curve of absorbance against 0, 0.2, 0.4, 0.6, 0.8 and 1 mg/100g gallic acid was plotted and total phenol was expressed as milligram of gallic acid equivalent per 100 grams of potato (mg GAE/100 g).

Determination of total anthocyanins

Total anthocyanin was determined using the method of Tokusoglu and Yildirim (2012). Amount of 0.2 g of potato powder was extracted with 10 ml of 80% ethanol solution. It was then centrifuged (HERMLE Labnet, model Z382K, Wehingen, Germany) at 4000 xg for 5 minutes at 4^o C. Afterward, 1ml of extract was diluted with 20 ml of distilled water. From diluted aliquot, 0.5 ml was pipetted and mixed with 4 ml of 10% formic acid (1:9v/v). The absorbance was done at 530 nm in spectrophotometer (JENWAY 7315, Staffordshire, United Kingdom). The amount of anthocyanin was computed

using the equation below and expressed as cyanidin-3-glucose equivalent.

Anthocyanin content (mg/100g of dry matter) = A x MWxDF x100 / (ε x W) (as Cyanidin 3-glucoside, mg/l)

Where A = absorbance

MW = molecular weight of Cyanidin 3-glucoside ($C_{21}H_{21}ClO_{11}$, 449.2),
DF = dilution factor, ε = molar absorptivity of Cyanidin 3-glucoside (26900), W= weight of the sample.

Determination of total carotenoids

Total carotenoid was analyzed using the method of Robles-ramírez *et al*. (2016). Amount of 10 g of potato powder was extracted with 100 ml of 80% ethanol at room temperature overnight in orbital shaker at 80 x g. It was then centrifuged (HERMLE Labnet, model Z382K, Wehingen, Germany), at 6182×g for 15 minutes at 4^{o} C and the residues were re-extracted in the similar conditions and the two extracts were mixed. The amount of 10 ml of extract was added in assay tube wrapped with aluminium foil containing 10 ml of hexane. The tubes were allowed to stand in ice bath and shaken in an orbital shaker at 80 x g for 15 minutes. Subsequently, 3 ml of deionized water were added in each tube and homogenized for 5 more minutes. Thereafter, the tubes were allowed to stand at room temperature to allow phases separation. The reading of absorbance for hexane top layer (A) was at 450 nm in spectrophotometer (JENWAY 7315, Staffordshire, United Kingdom). The total carotenoids (TC) concentration was computed using the formula below: TC (mg/kg) = (A x V x 104) / (A1% x W); where A is the absorbance at 450 nm, V is the hexane volume, A1% is the extinction coefficient for total carotenoids (2500), and W is the mass of the sample in the extract.

Determination of ascorbic acid content

Ascorbic acid was analyzed using spectrophotometric method described by Grudzińska *et al.* (2016). Amount of 2 g of potato tuber were extracted with a solution of 40 ml of 0.4% oxalic acid and homogenized at 6750 x g for 3 minutes. Filtration of extract was done using filter paper and topped up to 100 ml with the same extracting solution. Subsequently, 5 ml of the extracts were allowed to react with 2 ml of 2, 6-dichloroindophenol (1.6%) for 2 minutes. The absorbance was read at 500 nm using a spectrophotometer (JENWAY 7315). The blank consisted of oxalic acid and 2 ml of 2, 6-dichloroindophenol (1.6%). The ascorbic acid concentration was quantified using a standard curve of 0, 0.2, 0.5, 0.8 and 1 mg/ 100 ml of ascorbic acid. Ascorbic

acid content was reported as milligrams per 100 grams.

Statistical analysis

Analysis of variance (ANOVA) was conducted using Statistical Analysis System (SAS version 9.2) with General Linear Model (GLM) procedure and means were separated using Tukey's test at 5% level of significance (SAS institute Inc., 2008).

Results and Discussion

Moisture content of fermented potatoes

Potato fermentation was conducted in brine solution and changes in nutrients were evaluated. Moisture content was analyzed and was not significantly influenced by fermentation. There was no statistically significantly difference among fermented and non-fermented potatoes at ($P < 0.05$). The moisture content ranged from 75.89% for non-fermented Kirundo to 80.44% for fermented Sangema as presented in the Table 1. In other words, there was no interaction effect. Fermentation increased moisture content of potatoes to insignificant level. The increase in moisture content might have been caused by the extended period potatoes stayed in fermenting solution. Lister & Munro (2000) reported a range of moisture content of potatoes to be 63% to 87%. The moisture absorbed during fermentation did not exceed an unacceptable level, as potatoes with moisture content of 80% or below are suitable for fried and dehydrated products, while those with high moisture content are reserved for canning and salads (Marwaha *et al*., 2010). The increase in moisture content is related to the length of time the potatoes were submerged in the fermenting solution. Since moisture content of fermented potatoes is not statistically significantly different from non-fermented ones, fermented potatoes can be used in manufacturing of various potato products, provided that moisture content does not reach unacceptable levels. Potatoes with low moisture content require less energy to evaporate water and absorb less oil, resulting in a crispier texture for fried products (Marwaha *et al*., 2010).

Starch content of fermented potatoes

The Starch content of analyzed potato cultivars was not significantly affected by fermentation ($P < 0.05$) as presented in the Table1. Starch content ranged from 14.43% for fermented Sangema to 18.87% for non-fermented Kirundo. Starch is an important compound which determines processing quality of potatoes. Starch contributes 75% of the dry matter (Lister & Munro,2000;Bandana *et al*.,2016). Ganga

&Kulkarni (2014) reported that the starch content of potatoes ranges from 52.55% to 85.67% across ten varieties on dry weight basis. A study done on fermentation of boiled and non-boiled sweet potatoes with *L. plantarum* showed reduction in starch from 14.1% to 8.4 % for boiled and 14.5% to 9.8 % for non-boiled sweet potatoes (Panda & Ray, 2007) which aligns with the results of this study. Starch content was lower in fermented compared to non-fermented ones. Moreover, it was reported that during fermentation starch content can reduce from 14.80% to 2.35%, with reduction attributed to amylolactic bacteria (Panda *et al.*, 2007). Hydrolyzed starch can be used as an energy source by fermenting bacteria. Potatoes with starch content of 15% and above are suitable for starch production, while those with 16-20% starch content are suitable for chips, 15%-18% for French fries and 15-19% of starch content for dehydrated products (Lisiěska *et al.*, 2009). Kirundo and Kinigi had starch content above 15% after fermentation, while other cultivars had reduced starch content below 15%. Continuous fermentation can reduce starch content to unacceptable levels, potentially due to leaching or their utilization as source of energy by fermenting microorganisms.

Table 8. ***Moisture, starch and protein of fermented and non-fermented potatoes in percentage***

Cultivars	**Fermented and non-fermented potatoes**	**Moisture content** %	**Starch content** %	**protein content** %
Kinigi	Non-Fermented	77.23 ± 1.55[a]	17.82 ± 0.18[a]	1.92 ± 0.07[a]
	Fermented	79.51 ± 1.14[a]	16.28 ± 0.21[a]	1.87 ± 0.23[a]
Kirundo	Non-Fermented	75.89 ± 1.55[a]	18.87 ± 0.06[a]	2.31 ± 0.06[a]
	Fermented	76.88 ± 1.36[a]	17.16 ± 0.31[a]	2.05 ± 0.01[a]
Mabondo	Non-Fermented	77.11 ± 1.71[a]	16.98 ± 0.16[a]	2.08 ± 0.12[a]
	Fermented	80. 38 ± 0.68[a]	14.65 ± 0.28[a]	1.97 ± 0.03[a]
Sangema	Non-Fermented	78.17 ± 1.63[a]	16.35 ± 0.25[a]	2.02 ± 0.16[a]
	Fermented	80. 44 ± 0.76[a]	14.43 ± 0.43[a]	2.09 ± 0.07[a]
CIP393251.6	Non-Fermented	78. 11 ± 1.74[a]	16.14 ± 0.13[a]	2.13 ± 0.10[a]
4	Fermented	80.06 ± 1.19[a]	14.87 ± 0.29[a]	1.96 ± 0.07[a]
CV		1.85	3.09	9.43
MSD		4.2423	1.359	0.5631

MSD: Minimum significant difference at 5% Tukey; Means followed by the same letter in a column do not differ by Tukey's test at 5%

Crude protein content of potatoes

Potato protein of different potato cultivars was not statistically significantly affected by fermentation at ($P < 0.05$) as depicted in the Table 1. Protein content ranged from 1.87% for fermented Kinigi to 2.43% for non-fermented Sangema. Fermentation led to a reduction in protein content. Fermentation of potato with *L. plantarum* has been shown to reduce free amino acids (Baardseth *et al.*, 2006). Amino acids are utilized by bacteria for their growth. Potato protein varies from one cultivar to another, and during fermentation, protein may be reduced, potentially due to utilization by microorganisms for growth or leached in fermenting solution. Reduction of protein might be linked to a decrease in free amino acids, which are undesirable during manufacturing of fried potato products as they react with reducing sugars during frying, resulting in darkened products.

Mineral content of potato

The mineral content of fermented potato cultivars was significantly affected by fermentation ($P < 0.05$) for calcium and zinc, while it was not statistically significant for iron, magnesium, potassium and phosphorus as presented in Table 2. Calcium varied from 2.15 mg/100g for fermented Sangema to 8.21 mg/100g for non-fermented Mabondo, zinc varied from 0.10 mg/100g for fermented Sangema to 0.32mg/100g for non-fermented Kinigi. Magnesium levels ranged from 7.40 mg/100g for fermented CIP393251.64 to 20.48 mg/100g for non-fermented Kirundo. Iron levels ranged from 0.17 mg/100g for fermented Mabondo to 0.86 mg/100g for non-

fermented Kinigi. Potassium levels ranged from 299.19 for fermented CIP393251.64 to 542.88 mg/100g for non-fermented Kirundo. Phosphorus levels ranged from 28.22 for fermented Sangema to 69.77 mg/100g for non-fermented Kirundo. Variability in the mineral content of different potato cultivars has also been reported by other authors (Pal *et al.*, 2008; Furrer *et al.*, 2018). The reduction in minerals might be due to their utilization by bacteria during growth or leaching into the fermenting solution due to their solubility in aqueous solutions. During fermentation, microorganisms utilize minerals, leading to their reduction, or the reduction might result from leaching into the fermenting medium.

Table 2. *Effect of potato fermentation on minerals in mg/100g*

Cultivars	Fermented and non- fermented potatoes	Calcium	Magnesium	Iron	Zinc	Potassium	Phosphorus
Kinigi	Non-Fermented	4.47 ± 0.02^{bc}	17.59 ± 0.71^{a}	0.81 ± 0.03^{a}	0.32 ± 0.01^{a}	466.55 ± 11.05^{a}	47.86 ± 2.94^{a}
	Fermented	2.99 ± 0.08^{de}	12.59 ± 0.56^{a}	0.55 ± 0.02^{a}	0.24 ± 0.00^{b}	323.32 ± 55.52^{a}	36.96 ± 1.95^{a}
Kirundo	Non-Fermented	3.71 ± 0.07^{cd}	20.48 ± 1.47^{a}	0.67 ± 0.04^{a}	0.30 ± 0.01^{a}	542.88 ± 2.95^{a}	69.77 ± 2.59^{a}
	Fermented	2.19 ± 0.10^{e}	15.70 ± 1.59^{a}	0.43 ± 0.03^{a}	0.23 ± 0.01^{b}	435.68 ± 2.95^{a}	48.92 ± 3.42^{a}
Mabondo	Non-Fermented	8.21 ± 0.31^{a}	19.59 ± 0.60^{a}	0.34 ± 0.02^{a}	0.23 ± 0.01^{b}	519.61 ± 12.34^{a}	40.52 ± 1.55^{a}
	Fermented	5.34 ± 0.42^{b}	14.03 ± 0.48^{a}	0.17 ± 0.01^{a}	0.16 ± 0.01^{c}	431.92 ± 10.6^{a}	31.91 ± 1.30^{a}
Sagema	Non-Fermented	3.43 ± 0.04^{cd}	19.68 ± 0.77^{a}	0.66 ± 0.03^{a}	0.12 ± 0.01^{d}	372.71 ± 11.43^{a}	36.12 ± 1.53^{a}
	Fermented	2.15 ± 0.04^{e}	13.06 ± 0.30^{a}	0.42 ± 0.02^{a}	0.10 ± 0.00^{d}	304.72 ± 9.81^{a}	28.22 ± 1.28^{a}
CIP393251.64	Non-Fermented	4.51 ± 0.07^{bc}	11.32 ± 0.35^{a}	0.36 ± 0.01^{a}	0.14 ± 0.01^{cd}	365.83 ± 11.10^{a}	39.88 ± 3.40^{a}
	Fermented	2.92 ± 0.16^{de}	7.40 ± 0.28^{a}	0.19 ± 0.01^{a}	0.11 ± 0.01^{d}	299.19 ± 9.71^{a}	32.21 ±3.26 ^{a}
CV		9.40	8.33	6.91	6.52	9.05	9.84
MSD		1.0984	3.6924	0.0932	0.0372	107.67	11.879

MSD: Minimum significant difference at 5% Tukey; Means followed by the same letter in a column do not differ by Tukey at 5%level of significance.

Total phenols, anthocyanins and vitamin C content of potatoes

Fermentation significantly affected the phytonutrients content of potato cultivars ($P < 0.05$) as presented in Table 3. Total phenols ranged from 11.98 mg/100g in fermented Kinigi to 14.90 mg/100g in non-fermented Kirundo. The total anthocyanins varied from 0.05 mg/100g in fermented Mabondo to 0.92 mg/100g in non-fermented Sangema. Vitamin C ranged from 1.29 mg/100g in fermented Sangema to 12.14 mg/100g in non-fermented Kinigi. Fermentation reduced phytonutrients content of potatoes. For example, vitamin C in raw cabbage was reported to decrease from 27.5 mg/100g to 17.5 mg/100g after 90 days of fermentation(Pandey & Garg, 2015). On the other hand, lactic acid fermentation has been shown to increase anti-oxidant activity, anthocyanin content and sensory characteristics in fermented sweet cherries (Montet *et al*., 2014). Phytonutrients are often utilized by bacteria during their growth. During fermentation, the reduction in phytonutrients may be due to their utilization by fermenting microorganisms or their leaching into the fermenting solution. However, fermentation also induces production of various bioactive compounds that are beneficial to consumers.

Table 3. ***Effect of potato fermentation on total phenols, anthocyanins and vitamin C in mg/100g***

Cultivars	Treatments	Total phenols mg/100g	Total anthocyanins mg/100	Vitamin C mg/100g
Kinigi	Non-Fermented	13.90 ± 0.40^{abcd}	0.79 ± 0.05^{a}	12.14 ± 0.27^{a}
	Fermented	11.98 ± 0.36^{f}	0.27 ± 0.01^{b}	6.72 ± 0.33^{b}
Kirundo	Non-Fermented	14.90 ± 0.18^{a}	0.24 ± 0.02^{bc}	6.35 ± 0.38^{bc}
	Fermented	13.01 ± 0.15^{cdef}	0.13 ± 0.01^{bcd}	4.02 ± 0.51^{de}
Mabondo	Non-Fermented	13.15 ± 0.28^{bcde}	0.79 ± 0.04^{a}	6.93 ± 0.80^{b}
	Fermented	12.56 ± 0.28^{ef}	0.05 ± 0.01^{d}	4.52 ± 0.27^{cde}
Sagema	Non-Fermented	13.45 ± 0.04^{bcde}	0.92 ± 0.04^{a}	2.87 ± 0.42^{ef}
	Fermented	12.86 ± 0.04^{def}	0.09 ± 0.01^{cd}	1.29 ± 0.08^{f}

Cultivars	Treatments	Total phenols mg/100g	Total anthocyanins mg/100	Vitamin C mg/100g
CIP393251.64	Non-Fermented	14.29 ± 0.26^{ab}	0.90 ± 0.07^{a}	5.04 ± 0.25^{bcd}
	Fermented	14.06 ± 0.45^{abc}	0.20 ± 0.01^{bcd}	2.80 ± 0.13^{ef}
CV		2.94	13.91	13.53
MSD		1.1533	0.1787	2.0857

MSD: Minimum significant difference at 5% Tukey; Means followed by the same letter in a column do not differ by Tukey's test at 5%

Conclusion

Fermentation is one of the oldest technologies used to preserve food and enhance its palatability. During fermentation, substrates are transformed in other compounds that have preservative and health benefits. The fermentation of five potato cultivars revealed that nutrients, anti-nutrients and phytonutrients were reduced. This reduction might be due to the conversion of nutrients into fermentation byproducts or their leaching into the brine solution used during fermentation. Therefore, fermentation has an effect on the reduction of chemical compounds of potatoes. The byproducts formed during lactic acid fermentation are believed to be beneficial to human health. There is a need to investigate and quantify byproducts of potato fermentation to further assess their potential uses.

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