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Proximate Composition and Mineral Profile of Some Agro-Allied By-Products Wastes in the Kingdom of Lesotho

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Abstract

The study was carried out to investigate the feed value of four agro-allied by-products consisting of two tubers wastes namely; Irish potato peel meal (IPPM) and sweet potato peel meal (SPPM) and two fruits wastes namely, sweet orange peel meal (SOPM) and banana peel meal (BPM) as feed ingredients in livestock and poultry production in a temperate environment. Fresh fruits of banana and sweet orange and fresh tubers of Irish potato and sweet potato were purchased from the Maseru District in Lesotho. The tubers were rinsed and peeled, the peels of the fruits were removed and all the peels were separately shade-dried to attain about 10% moisture. Drying of Irish potato, sweet potato, and sweet orange peels lasted 48 hours, while for banana peels it lasted 72 hours. The peels were milled and stored in sealed plastic bottles prior to chemical analyses. Chemical analyses were carried out in triplicate to determine the proximate constituents, energy content, and mineral profile. The results revealed significant ($P<0.05$) differences in the proximate composition and metabolisable energy, among the peels without any sequence of variation. The dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF), ash, nitrogen-free extract (NFE), and metabolisable energy varied between 88.83% - 93.67%, 5.72% - 14.26%, 0.77% -7.83%, 5.67% - 11.67%, 3.50% - 15.00%, 52.33% - 70.94% and 2782.28 kcal/kg - 2834.14 kcal/kg, respectively among the peels. The mineral elements profile showed significant ($P<0.05$) difference among the peels in phosphorus which ranged from 0.64 g/kg - 2.49 g/kg, calcium 0.24 g/kg - 3.32 g/kg, magnesium 1.35 g/kg - 2.07 g/kg, potassium 0.77 g/kg - 64.13 g/kg, sodium 0.08 g/kg - 1.43 g/kg and chloride 0.36 g/kg - 0.68 g/kg without a definite sequence of variation among the different peels. The results obtained showed that the peels of Irish potato, sweet potato, sweet orange, and banana peel can be utilised as unconventional feed resources in poultry and livestock nutrition in Lesotho.

Keywords: Agro-allied; Wastes; Evaluation; Feed.

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1. Introduction

There is increase in global demand for protein especially animal protein, in human diet to meet the need of the population and to mitigate the existing animal protein shortage. Knoema [1] reported that the animal protein daily intake per capita in Lesotho is 15.9 g (25.85%) of total protein supply of 61.5 g between 2010 - 2019. This shows a deficiency compared with the recommended per capita of animal protein daily intake of 35 g [2]. Animal protein is of paramount importance in human nutrition because of its biological significance due to the similarity of its amino acid profile to that of man [3]. Umutoni, *et al.* [4], stated that, livestock are very important assets to the rural people in developing countries as a source of food and income but the major challenge is the seasonal availability of feed because they depend largely on rangelands for feeds. Impact of the global climate change has precipitated ecological problems in many countries, Lesotho inclusive, causing degradation in rangelands and decline in productivity.

In developing countries, monogastric animals such as pigs, broiler and/or rabbit are a critical source of animal protein and mostly reared to provide fast meat protein because of their short production cycle, fecundity and ease of management compared to the large animals. However, high cost of feed is a major obstacle in rearing of these farm animals, hence the exorbitant prices of animal products such as meat, milk and eggs. Kpanja, *et al.* [5], reported nutrition as a main limitation in non-ruminant production. The major target of the farmer is to reduce the feed cost, which contributes 70-80% of the total cost of production [6] and yet get high output to increase profit margin. Therefore, there is need to find feed alternatives to replace the hitherto conventional feeds for farm animals.

In Lesotho there is scarcity of animal feed manufacturing industries because the conventional foodstuffs like maize, sorghum, soybean being produced are inadequate for human consumption, thereby resulting in heavy reliance on importation of animal feeds, which escalates total cost of production and consumer prices of animal products. The use of agro-allied by-product wastes that are cheap, easily accessible and have no direct nutritional value to man appears to be one of the solutions in solving this problem, especially in non-ruminant production [7]. Agro-allied by-product wastes namely sweet orange (*Citrus sinensis)* peels, irish potato (*Solanum tuberosum)* peels, banana (*Musa sapientum*) peels and sweet potato (*Ipomea batatas)* peels obtained from processing of agricultural products and, which have emerged as potential environmental pollutants in Lesotho can be possibly converted to unconventional sources of animal feed ingredients. This will help to mitigate the scarcity of feedstuffs which hitherto as produced negative effects on the productivity of farm animals and the income of farmers. Therefore, the aim of this study was to evaluate the feeding value of some agricultural by-product wastes in the Kingdom of Lesotho, a temperate country. Hence, the results of the study will help to determine which of these by-products can be employed for utilisation in formulating farm animal diets. The use of cheap feed resources will reduce feeding cost and the cost of animal products will also decrease, thus increasing consumer accessibility to animal protein.

2. Materials and Methods

2.1. Sample Collection and Preparation

Fresh fruits of banana and sweet orange, as well as irish potato and sweet potato tubers were purchased from the Maseru District in the Kingdom of Lesotho. They were rinsed and peeled, and the peels were separately shade dried; sweet orange peels (figure 1), irish potato peels (figure 2), banana peels (figure 3) and sweet potato peels (figure 4) until they attain about 10% moisture to grind them into powder easily and to avoid spoilage before analyses. Drying of irish potato, sweet potato and sweet orange peels lasted 48 hours, while for banana peels it was 72 hours due to their thickness. The peels were milled and stored in sealed plastic bottles prior to chemical analyses.

2.2. Proximate Analysis

Homogenous sample of each peel meal was taken after mixing, and analysed for proximate constituents to during which dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF) and ash were determined according to standard methods of A.O.A.C [8] and, nitrogen free extract was determined using equation:

% NFE= 100 - (% H_2O + % CP + % EE + % CF + % Ash)

Metabolisable energy was calculated using the equation:

ME (kcal/kg) = 37 x % CP + 81.8 x % EE + 35.5 x % NFE _ _ _ _ [9].

2.3. Determination of Mineral Composition

Homogenous sample of each peel meal was digested using the procedure described by Yahaya, *et al.* [10]. Magnesium (Mg), sodium (Na), calcium (Ca), and potassium (K) were determined by the Atomic Absorption Spectrophotometer (PinAAcle 500). Chloride was determined using [11] and phosphorus was determined by UV-Spectrophotometer (Spectro UV-11) using standard colorimetric technique [12].

2.4. Statistical Analysis

The data collected in the study were subjected to one-way Analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS) [13] version 20. Means found to be significantly different ($P<0.05$) were separated using Duncan's Multiple Range Test (DMRT).

3. Results and Discussion

3.1. Proximate Composition and Metabolisable Energy of Tubers and Fruits Peel Meals

The proximate composition and metabolisable energy of tubers and fruits peel meals is presented in Table 1. The dry matter of the peels differed significantly ($P<0.05$) and values were 88.83%, 92.33%, 93.00% and 93.67% for sweet orange peel meal (SOPM), irish potato peel meal (IPPM), banana peel meal (BPM) and sweet potato peel meal (SPPM), respectively. The SOPM dry matter content is in line with earlier finding by Sunmola, *et al.* [7] who reported dry matter content of 89.20% in *Citrus sinensis* peels. Similarly, BPM dry matter content compares favourably with 93.30% reported by Anhwange, *et al.* [14] in *Musa sapientum* peels but higher than 88.44% reported by Kabenge, *et al.* [15]. The irish potato peel meal dry matter content obtained is comparable to 93.21% observed by Wafar, *et al.* [16]. Sweet potato peel meal had the highest dry matter content in this study and is higher than 88.50% and 91.76% found by Agubosi, *et al.* [17]; Kwaido, *et al.* [18], respectively. The differences observed in the dry matter content of the various peels compared to the results of earlier studies could be due to the varieties used, stage of harvesting, the depth of peeling in the case of IPPM, SPPM and SOPM, and drying technique applied. The high dry matter content implies reduced susceptibility to mould growth and microbial spoilage, hence they will have long shelf life with proper storage.

The crude protein content of tubers and fruits peels were 5.72%, 14.26%, 7.67% and 8.90% in SPPM, IPPM, BPM and SOPM, respectively, and varied significantly ($P<0.05$) among the peels. Agubosi, *et al.* [17]; Kalio, *et al.* [19] reported similar crude protein content of 5.63% and 6.07%, respectively in sweet potato peels. The crude protein content found in IPPM was comparable to 14.11% earlier reported by Kareem, *et al.* [20], and also within a range of 12.3% to 17.0% found by Ncobela, *et al.* [21] in potato peels. The crude protein content of 7.67% in this study agrees with the finding of Randa, *et al.* [22] who reported 7.94% CP in BPM. However, it is lower than 13.20% and 15.10% found by Salim, *et al.* [23] and Ahmed, *et al.* [24], respectively. Sweet orange peel meal had crude protein content of 8.90% slightly higher than 8.15% and 8.20% indicated by Oluremi, *et al.* [25] and Sunmola, *et al.* [7] in SOPM but markedly higher than 2.17% [26]. The variations observed may be due to varietal differences, processing techniques and/or the environment. Banana peel meal and SPPM are low in crude protein, but SOPM and IPPM can contribute plant protein in feeding ruminants because sheep and goats require 10% CP for maintenance [27].

The crude fat in the tubers and fruits peels significantly (P<0.05) differed and ranged from 0.77% to 7.83%. The tuber peels had lower fat content than the fruit peels. Crude fat of 0.77% in IPPM is higher than 0.32% found by Kpanja, *et al.* [5], but lower than 0.90% [28]. Sweet potato peel meal had a crude fat content of 1.03%, which is lower than 4.06% reported by Kwaido, *et al.* [18]. The BPM has a crude fat of 7.83% similar to the report of Hossain, *et al.* [28] who indicated 7.80%. The fat content of 4.17% in the SOPM is comparable to 4.51% obtained by Sunmola, *et al.* [7], but higher than 0.95% [29]. The observed variations in the crude fat might be attributed to the same reasons of differences in the sample preparation methods and the varieties used. While the low fat in IPPM and SPPM may result in low fat-soluble vitamins, however, this may increase the shelf life of the peels by reducing chances of rancidity. Fat content found in fruits peels may increase energy content of feeds when included in feed formulation.

The crude fibre content in the tubers and fruits peels varied significantly (P<0.05). Crude fibre of 5.67% in SPPM is higher than 3.68% and 3.80% reported by Agubosi, *et al.* [17] and Kwaido, *et al.* [18]. The crude fibre found in SOPM is close to 12.47% [30], however, lower than 13.30% [7]. The crude fibre content of 7.60% obtained in IPPM is comparable to 8.01% [16]. In contrast to the current study, Kareem, *et al.* [20] and Kairalla, *et al.* [31] found higher crude fibre values of 16.27% and 15.60%, respectively in IPPM. Banana peel meal has a crude fibre level of 10.17% and is within the range of 8.81% and 13.71% reported by Randa, *et al.* [22] and Salim, *et al.* [23]. The stage of maturity at harvesting has a significant influence on the crude fibre content in feedstuffs, and likewise the variety used. Low levels of crude fibre in IPPM and SPPM indicates that they can be included in poultry diets especially because of their low dietary fibre requirement.

The ash content differed significantly (P<0.05) among the tubers and fruits peels. Sweet orange peel meal had the lowest value of 3.50% and BPM had the highest ash content of 15.00%. The BPM ash content is appreciably high like 15.97% [32], but higher than 9.85% reported by Salim, *et al.* [23]. The ash content in SOPM is comparable to 3.66% reported by Uzama, *et al.* [26] but lower than 7.92% [33]. The ash content of IPPM is similar to the reported literature values of 6.39% and 6.69% by Kareem, *et al.* [20]; Hassan, *et al.* [27]. The ash in SPPM is higher than 5.82% reported by Agubosi, *et al.* [17]. The variation could be as a result of varietal differences, geographical locations and soil conditions where cultivated. Ash is a measure of mineral content and high values obtained in SPPM and BPM indicate they have high content of minerals and may be a rich source of minerals for livestock.

The NFE contained in the peels was significantly (P<0.05) different. Sweet potato peel meal had the highest NFE value, followed by IPPM, SOPM and BPM. The observed NFE content in SPPM is comparable with 71.22% Agubosi, *et al.* [17] and 72.60% Kwaido, *et al.* [18], but lower than 82.44% [19]. Irish potato peel meal has NFE of 63.20% and higher than 41.48% [20]. The NFE in SOPM is comparable to 61.07% [34], while that in BPM is higher than 46.26% and 44.64% reported by Randa, *et al.* [22] and Ahmed, *et al.* [24], respectively. The variations obtained may arise from any or combinations of type of variety used, environment in which the fruits and tubers were planted and stage of maturity when harvested. With the exception of the SPPM with fairly high NFE, the nitrogen free extract in SOPM, IPPM and BPM was moderate.

Metabolisable energy content in the peel meals did not vary significantly (P>0.05). The ME of 2782.28 kcal/kg in BPM is within 2222.79 kcal/kg to 3346.14 kcal/kg reported by Diarra [35]. Sweet orange peel meal has 2821.43 kcal/kg ME and is lower than 2913.92 kcal/kg Oluremi, *et al.* [2] and 3079.61 kcal/kg [7], and also the ME in IPPM is lower than 3110.22 kcal/kg [5] and 3118.42 kcal/kg [16]. The metabolisable energy in SPPM is lower than 3100.5 kcal/kg and 3013.92 kcal/kg reported by Agubosi, *et al.* [17] and Kalio, *et al.* [19], respectively but higher than 2688.86 kcal/kg [35]. These variations observed, may be due to differences in the crop varieties, physiological stage when harvested, processing techniques adopted and/or region where cultivated, and analytical procedures for determining the proximate constituents. All the peels have high metabolisable energy (> 2700 kcal/kg) and can be useful as energy feeding stuffs in the preparation of farm animal diets.

3.2. Mineral Elements Profile of Tubers and Fruits Peel Meals

The result for mineral elements composition of the tubers and fruits peel meals is shown in Table 2. Significant (P<0.05) difference was observed in all the elements among the peel meals. Calcium content of tubers and fruits peels ranged from 0.24 g/kg to 3.32 g/kg. Calcium is highest in SOPM (3.32 g/kg) and lowest in IPPM (0.24 g/kg). Calcium level of 3.32 g/kg observed in SOPM differed from earlier reports which showed lower Ca of 133.73 mg/100g [26] and 134 mg/100g [36], and higher values of 490.5 mg/100g reported by Assa, *et al.* [37]Assa *et al.* [37] in SOPM. Irish potato peel meal contained 0.24 g/kg calcium which is lower than 115.00 mg/100g [27] and 0.66 g/kg to 1.10 g/kg [38]. The 1.14 g/kg calcium present in BPM is lower 246.0 mg/100g to 323.0 mg/100g [3], but higher than 70.38 mg/100g reported by Hassan, *et al.* [39]. Sweet potato peel meal had a calcium level of 2.47 g/kg, which is within the range of 0.17% to 0.57% in different varieties of sweet potato peels [40], but higher than 45.73 mg/100g in sun-dried SPPM Agubosi, *et al.* [17]. Sweet orange peel meal and sweet potato peel meal may be good sources of calcium for pregnant ewes because their Ca content are within the range of 0.20% to 0.40% considered adequate [41]. Banana peel and irish potato peel meals may require supplementation with sources of calcium if they must be used in formulating diet for pregnant ewes.

The phosphorus levels in the peels varied from 0.64 g/kg to 2.49 g/kg, and the peels of the tubers (IPPM and SPPM) have higher P content than the fruits peel (SOPM and BPM). The phosphorus content of 0.64 g/kg observed in SOPM is higher than 51.00 mg/100g [36], but lower than 0.20% reported by Fadda, *et al.* [29]. Irish potato peel meal contained 1.66 g/kg phosphorus which is higher than 130.70 mg/100g [27] but lower than a range of 2.90 g/kg to 4.54 g/kg [38]. The concentration of phosphorus in BPM is within the range 122.5 mg/100g to 167.30 mg/100g observed by Ogunlade, *et al.* [3] in different varieties of ripe BPM. Sweet potato peel meal has a relatively higher phosphorus level of 2.49 g/kg among the peels and it is lower than the range of 1.53% to 2.21% found in different varieties of SPPM [40] but higher than 20.45 mg/100g [17]. In feeding cattle, sweet potato peel meal, banana peel meal and irish potato peel meal can be used as a phosphorus feeding supplements because they contain phosphorus within a range of 1.0 g/kg to 3.8 g/kg [42].

Magnesium content in the peels varied from 1.35 g/kg to 2.07 g/kg. Magnesium level of 1.38 g/kg in SOPM is higher than 13.2 mg/100g reported by Czech, *et al.* [43]. Banana peel meal contained 1.45 g/kg Mg, which is close to 138.50 mg/100g in the William variety [44]. Much reduced Mg levels of 41.88 mg/100g and 44.50mg/100g were observed by Ahmed, *et al.* [24] and Hassan, *et al.* [39], respectively in BPM. The magnesium level of 1.35 g/kg in IPPM is within the range of 1.19 g/kg to 1.60 g/kg reported by Vaitkeviciene [38], but higher than 53.00 mg/100g [27]. Magnesium in SPPM is 2.47 g/kg, which is less than the range of 5.10% to 7.98% in different varieties of SPPM [40]. Sweet potato peel meal is a good source of magnesium as its concentration is within the range of 0.18% to 0.40% required by goats [45], while other peels will require supplementation when included in ruminant diet formulation.

Potassium content in the tubers and fruits peels varied widely from 0.77 g/kg to 64.13 g/kg, and BPM gave the highest concentration (64.13 g/kg) and IPPM the lowest (0.77 g/kg). The low potassium concentration in IPPM is comparable to 70 g/100g reported by Hassan, *et al.* [27], and lower than 24.3 g/kg to 33.3 g/kg K level in IPPM [38]. The potassium in BPM is within 3812.50 mg/100g and 7602.75 mg/100g reported in William and Maghrabi banana varieties peels, respectively [44]. Lower potassium levels ranging between 454.00 mg/100g to 476.5 mg/100g, were reported by Ogunlade, *et al.* [3] and Ahmed, *et al.* [24]. The concentration of K in SOPM, which was 21.46 g/kg, is higher than 1490.00 mg/100g reported by Assa, *et al.* [37]. The potassium in SPPM (47.70 g/kg) is lower than the range of 4.83% to 6.25% [40], and higher than 10.74 mg/100g [17]. The potassium levels in SOPM and IPPM were within the range required by ruminants, whereas BPM and SPPM have potassium concentrations above tolerable maximum level set at 3.00% in total ruminant's diet [46].

Sodium content in the tubers and fruits peels ranged from 0.08 g/kg to 1.43 g/kg. Sodium was highest in SPPM. The SPPM content in the present study is lower than a range of 0.63% to 0.87% in different varieties of SPPM [40], but earlier report by Agubosi, *et al.* [17] showed lower sodium content of 1.52 mg/100g. Banana peel meal contained 0.11 g/kg sodium which is lower than 15.50 mg/100g and 54.92 mg/100g [44]. Irish potato peel meal had lowest Na content (0.08 g/kg), which is lower than 460 mg/100g Hassan, *et al.* [27]. Sodium level of 0.15 g/kg in SOPM is lower than 55.56 mg/100g and 55 mg/100g reported by Uzama, *et al.* [26] and Abdelazem, *et al.* [36], respectively but higher than 0.54 mg/100g Czech, *et al.* [43]. With the exception of SPPM, sodium in the peels seems lower than normal dietary range of 0.10% to 0.40% [47] for farm animals, thus its utilisation must be in combination with other feed materials.

Chloride content in the tubers and fruits peels varied significantly from 0.36 g/kg in SOPM to 0.68 g/kg in BPM. Chloride level of 0.36 g/kg in SOPM is comparable to 33.87 mg/100g Assa, *et al.* [37]. Chloride concentrations in the peels were lower than 0.12% to 0.40% [47] as it was observed for sodium. The chloride levels in IPPM, BPM and SPPM may serve as baseline values because of the dearth of information in literature.

The significant variations in the levels of calcium, phosphorus, magnesium, potassium, sodium and chloride in the peels can be attributed to the physiological differences in the crops, soil environment under which they were cultivated and varietal differences.

4. Conclusion and Recommendations

The peels of irish potato and sweet potato tubers, sweet orange and banana fruits contained significantly varied amounts of crude protein 5.72% to 14.26%, crude fibre 5.67% to 11.67%, ether extract, ash and nitrogen free extract which are important nutrients in animal nutrition. The metabolisable energy of all the different peels was high, greater than 2700 kcal/kg) and can all contribute to the dietary energy requirement of farm animals. There was significant presence of phosphorus, calcium, magnesium and potassium, which are essential mineral elements required for several metabolic and biochemical reactions, and low levels of sodium 0.08 g/kg to 1.43 g/kg and chloride 0.36 g/kg to 0.68 g/kg which are necessary to maintain homeostasis in the animal body. Therefore, the peels can be used as unconventional feed ingredients in livestock and poultry farming and this will help to mitigate the scarcity of feedstuffs which hitherto has produced negative effects on the productivity of farm animals and the income of farmers.

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Figure-1. Sweet orange peels before and after drying

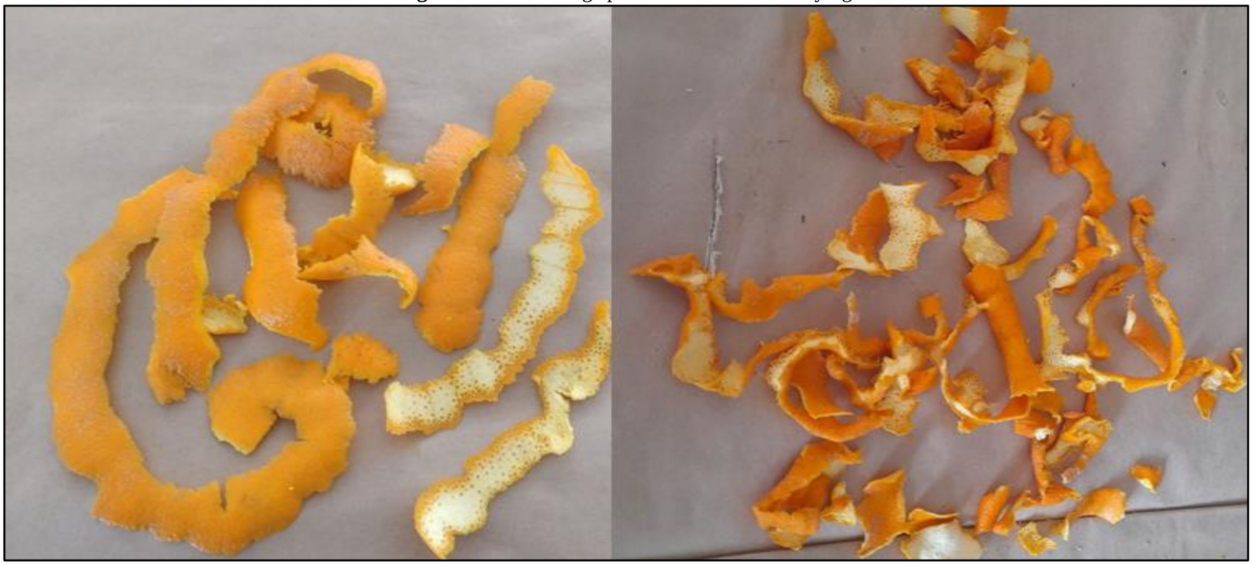

Figure-2. Irish potato peels before and after drying

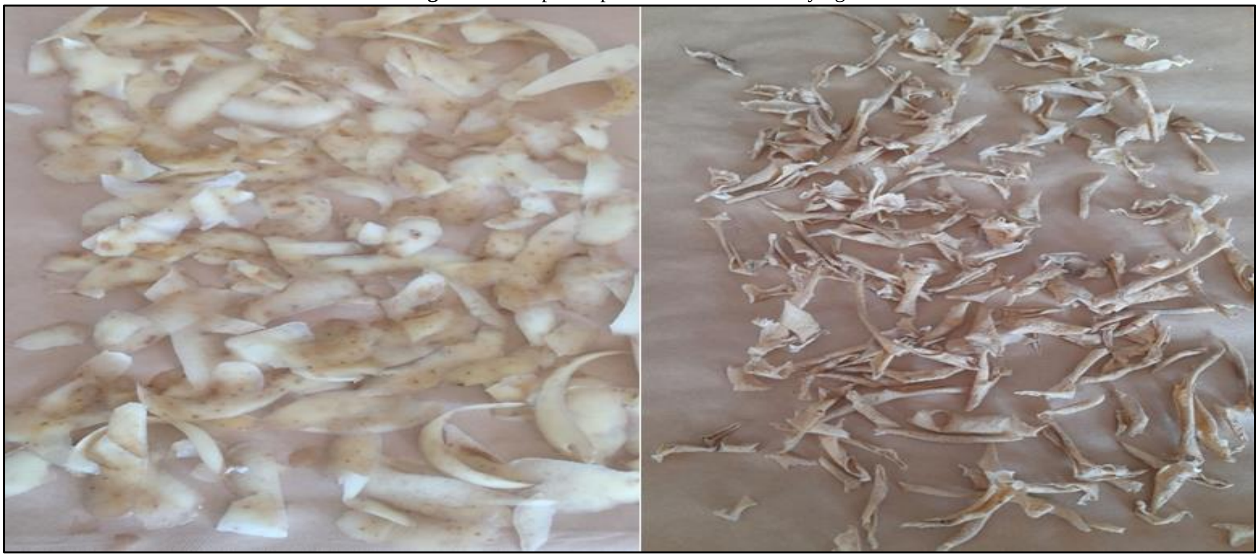

Figure-3. Banana peels before and after drying

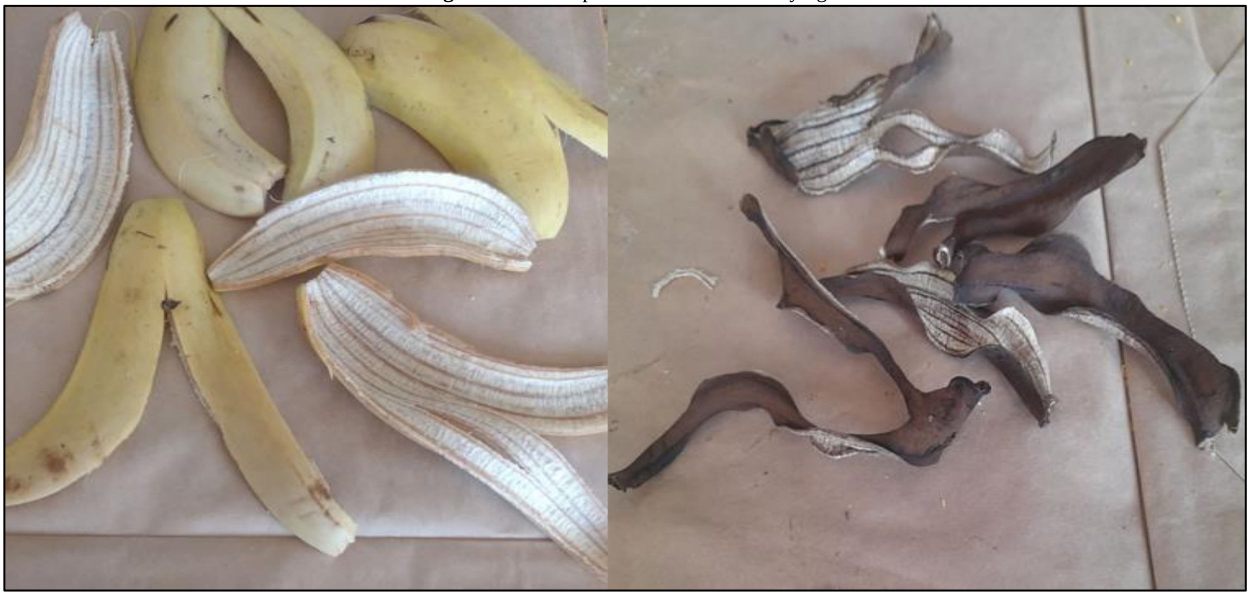

Figure-4. Sweet potato peels before and after drying

Table-1. Proximate Composition and Metabolisable Energy of Fruits and Tubers Peel Meals

Proximate Composition (%)	Fruits and Tubers Peel Meals				
	SOPM	IPPM	BPM	SPPM	SEM
Dry matter	88.83[c]	92.33[b]	93.00[ab]	93.67[a]	0.59
Crude protein	8.90[b]	14.26[a]	7.67[c]	5.72[d]	0.96
Crude fat	4.17[b]	0.77[c]	7.83[a]	1.03[c]	0.86
Crude fibre	11.67[a]	7.60[c]	10.17[b]	5.67[d]	0.71
Ash	3.50[d]	6.50[c]	15.00[a]	10.33[b]	1.30
NFE	60.60[c]	63.20[b]	52.33[d]	70.94[a]	2.02
ME (kcal/kg)	2821.43	2834.14	2782.28	2814.41	11.15[NS]

[a, b, c, d]Means in the same row with different superscripts are significantly different ($P<0.05$), [NS]= Not significantly different ($P>0.05$)
SOPM = Sweet orange peel meal
IPPM = Irish potato peel meal
BPM = Banana peel meal
SPPM = Sweet potato peel meal
SEM = Standard error of means
NFE = Nitrogen free extract
ME = Metabolisable energy = 37 x % CP + 81.8 x % EE + 35.5 x % NFE _ _ _ _ [9].

Table-2. Mineral Elements Profile of Fruits and Tubers Peel Meals

Minerals (g/kg)	Fruits and Tubers Peel Meals				
	SOPM	IPPM	BPM	SPPM	SEM
Calcium	3.32[a]	0.24[d]	1.14[c]	2.47[b]	0.36
Phosphorus	0.64[d]	1.66[b]	1.26[c]	2.49[a]	0.20
Magnesium	1.38[c]	1.35[c]	1.45[b]	2.07[a]	0.09
Potassium	21.46[c]	0.77[d]	64.13[a]	47.70[b]	7.33
Sodium	0.15[b]	0.08[b]	0.11[b]	1.43[a]	0.17
Chloride	0.36[d]	0.41[c]	0.68[a]	0.53[b]	0.04

[a, b, c, d]Means in the same row with different superscripts are significantly different ($P<0.05$)
SOPM = Sweet orange peel meal
IPPM = Irish potato peel meal
BPM = Banana peel meal
SPPM = Sweet potato peel meal
SEM = Standard error of means