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Potential use of Tubers and Fruit Peels as Feed Ingredients in Livestock Ration Formulation in the Kingdom of Lesotho

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ABSTRACT

During the dry season, the shortage of quality feeds needed to sustain livestock production has been a major problem in many developing countries, including the kingdom of Lesotho. Agro-allied by-product wastes obtained from the processing of agricultural products can possibly be converted to unconventional sources of animal feed. Therefore, this study evaluated the fibre and anti-nutritional constituents of important agricultural wastes in Lesotho namely, Irish potato peel meal, sweet potato peel meal, sweet orange peel meal and banana peel meal, to determine their feed value because of the negative effect these nutrients can elicit in livestock and poultry at higher levels. Prior to chemical analyses, dried peels of each banana fruit (BF), sweet orange fruit (SOF), sweet potato (SP), and Irish potato (IP) were milled into a fine powder to pass through a 0.5 mm sieve screen by grinding machine (mrc-SM-450 L) and stored in labelled sealed laboratory plastic bottles. The determinations of fibre fractions and anti-nutritional factors in each sample were carried out in triplicates. The fibre fractions differed significantly ($p<0.05$) among the peels. NDF varied from 31.00% - 39.00%, ADF 15.33% - 24.33%, ADL 3.57% - 11.67%, hemicellulose 10.00% - 22.33% and cellulose 9.00% - 17.33%. Fruit peels had significantly ($p<0.05$) higher ADF than tuber peels and, lower ($p<0.05$) hemicellulose than tuber peels. Anti-nutritional factors differed significantly ($p<0.05$) among the peels, and varied between 1.35% - 5.65% in alkaloid, 0.06% - 0.44% in oxalate, 3.39% - 8.32% in flavonoid and 0.21% - 2.03% in tannin. Flavonoid is highest in all peels except sweet potato peel, while oxalate is lowest. The results showed that fibre constituents levels met ruminant requirements, and anti-nutritional factors were within safe limits for ruminant intake, therefore the peels could be incorporated into their feed as a source of roughage.

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Introduction

Farm animals' production in Lesotho contributes significantly to food security as a source of animal protein (meat, eggs, milk) which is an essential component of a balanced diet. Other important contributions of farm animals include income generation and employment generation across the value chain. However, during the dry season the scarcity of quality feed materials critical to sustaining livestock production has been a major problem in developing countries (Oluremi et al., 2007a). Furthermore, scarcity of animal feed manufacturing industries and reliance on externally procured ingredients and feeds, escalate animal production costs and reduce profit margin particularly in non-ruminants. Agro-allied by-product wastes which are generated from the processing of agricultural products have become potential environmental pollutants in Lesotho and can be transformed into alternative feed ingredients. According to Jobo & Oluremi (2023), this can reduce the feeding cost during production cycle. Therefore, the current study determines anti-nutritional factors and fibre fractions of agricultural by-product wastes in Lesotho as higher levels can have a negative impact, especially in monogastric animals.

Fibre is a complex carbohydrate found in plant based feed ingredients, mainly composed of cellulose, hemicellulose and lignin. Fibre fractions vary in their digestibility and can influence nutrient utilisation, gut health and overall performance. High-fibre fractions like cellulose and hemicellulose are less digestible than other nutrients such as starch and protein. Their presence in feed can reduce overall feed digestibility, especially in monogastric animals (pigs and poultry). However, ruminants can utilise fibre more efficiently through microbial fermentation in the rumen to produce VFAs as

an energy source. Ruminants use these fibrous materials to produce meat and milk, which are high in quality protein, vitamins, and minerals that are essential for human nutrition (Liu et al., 2021). The inclusion of an appropriate amount of dietary fibre in poultry diets stimulates gastrointestinal tract development, improves nutrient utilisation, growth response, and gut health indices such as beneficial microbiota and immune system, as well as avoiding overconsumption without impeding poultry growth (Jha & Mishra, 2021). To prevent obesity, high-fibre feeds can be used as a diluent to improve satiety in gestation sows (Chuang et al., 2021). Jha et al. (2019) found that dietary fibre can be used to improve gut health instead of antibiotic growth promoters, which were previously used in feeding programmes to boost production in monogastric animals.

Anti-nutritional factors (ANFs) are substances that, when present in animal feed or water, reduce the availability of one or more nutrients either directly or through their metabolic products (Yacout, 2016). Most of the research on phytochemicals is concentrated on their toxic and anti-nutritional effects on livestock. They can interfere with nutrient digestion, absorption or utilisation, and also lower the bioavailability of minerals, protein digestibility and overall feed efficiency. ANFs can further interfere with the absorption of specific nutrients, leading to imbalances in the animal's nutrient status. For example, phytates can bind calcium, zinc and iron, reducing their bioavailability and potentially causing mineral deficiencies. Overall, reduced digestibility and absorption caused by anti-nutrients can result in low growth rates, poor feed efficiency and lower production performance in animals. Thus causing economic losses to poultry and livestock producers.

Materials and Methods

Sample Collection and Preparation

Four agro-allied by-products namely banana fruit (*Musa sapientum*) peels, sweet orange fruit (*Citrus sinensis*) peels, sweet potato tubers (*Ipomoea batatas*) peels and Irish potato tubers (*Solanum tuberosum*) peels were the test ingredients used for chemical assessment of feed value. Fresh fruits and tubers were sourced from the Maseru district in Lesotho. They were washed, mechanically peeled, thinly spread on a concrete flat surface and air dried separately to less than 12% moisture to facilitate the drying process for ease of grinding into powder and to avoid spoilage before nutrient analyses. Peels were milled and stored in sealed labelled plastic bottles prior to nutrient assay.

Determination of Fibre Fractions

A homogenous sample of each peel meal was analysed for the cell wall constituents. Both neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined using the Van Soest procedure described by Happi-Emaga et al. (2008). Hemicellulose and cellulose were calculated from the contents of NDF, ADF and ADL, as follows:

Hemicellulose = NDF-ADF
Cellulose = ADF-ADL

Determination Anti-nutritional Factors

Peel meal taken from each homogenous by-product sample was analysed for anti-nutrients. Oxalate and alkaloid were determined (Feumba et al., 2016), while flavonoid and tannin were determined using standard procedures (Ezeonu and Ejikeme, 2016).

Statistical Analysis

Data obtained were subjected to one-way Analysis of variance (SPSS, 2011) version 20. Means found to differ significantly ($p<0.05$) were separated using Duncan's Multiple Range Test (DMRT).

Results and Discussion

Fibre Fractions of Tubers and Fruits Peel Meals

The cell wall constituents all varied significantly ($p<0.05$) across the non-conventional feedstuffs (Table 1). The NDF content of 31.00% in SOPM was higher than 28.56% (Sanchez et al., 2014), but lower than 61.33% and 62.50% reported by Oluremi et al. (2007b) in two varieties of *Citrus sinensis* peels. The relatively high NDF of 39.00% in BPM was however lower than the range from 42.54% to 47.90% (Randa et al., 2017; Pimentel et al., 2017; Sanchez et al., 2014), but higher than 35.8% reported by Bakshi & Wadha (2013). Neutral detergent fibre of 37.67% in sweet potato peel meal (SPPM) was above 26.40% to 30.20% reported by Ukanwoko et al. (2020), while Kalio et al. (2013) reported a higher NDF of 45.50% in SPPM. The NDF of 37.67% in this study for Irish potato peel meal (IPPM) was between 25.10% and 41.00%, as reported by Negesse et al. (2009) and Ncobela et al. (2017). All peels were above 30%, which is the minimum NDF requirement for dairy cows (Moran, 2005). They can be used as a source of roughage which is important in maintaining milk fat in lactating animals and plays a key role in ensuring good rumen health. The values also fall within the range of 30% to 60% for all classes of adult cows (NRC, 2000). Low NDF content also implies higher digestibility, which could result in possibility of high consumption of the peel meals.

The current study revealed higher ADF content in fruit peels than in tubers peels. The ADF of 19.33% in SPPM was close to 20.39% to 20.81% reported by Ukanwoko et al. (2020) in different varieties of SPPM. However, Kalio et al. (2013) reported a lower ADF value of 7.64% in SPPM. The ADF content of 21.00% in SOPM was higher than 14.10% (Sanchez et al., 2014) but lower than 39.71% and 41.39% reported by Oluremi et al. (2007b) in two varieties of *Citrus sinensis* peels. Banana peel meal had ADF of 24.33% which was lower than 29.83% (Pimentel et al., 2017) and 32.84% (Randa et al., 2017) but higher than 21.27% reported by Sanchez et al. (2014). With the exception of IPPM, all the peels met the minimum ADF requirement of 19% in cattle (Moran, 2005). As a result, the peels can be used in ruminants feeding to maintain optimum rumen fermentation and as a source of energy because they are easily digestible and thereby increase energetic efficiency of use. On the other hand, Irish potato peel meal has lower ADF content and can be included in the rabbit diet, a monogastric herbivore that has caecum, which contain special microbes that break down and digest various fibres to obtain energy.

Table 1. Cell wall constituents of tubers and fruits peel meals

Fibre fractions (%)	Non-conventional feedstuffs				
	SOPM	IPPM	BPM	SPPM	SEM
NDF	31.00^{b}	37.67^{a}	39.00^{a}	37.67^{a}	1.18
ADF	21.00^{b}	15.33^{d}	24.33^{a}	19.33^{c}	1.00
ADL	3.67^{c}	6.33^{b}	11.67^{a}	5.33^{b}	0.92
Hemicellulose	10.00^{c}	22.33^{a}	14.67^{bc}	18.33^{ab}	1.56
Cellulose	17.33^{a}	9.00^{c}	12.67^{b}	14.00^{b}	0.92

$^{a, b, c, d}$ Means in the same row with different superscripts differ significantly (P<0.05); SOPM= Sweet orange peel meal; IPPM= Irish potato peel meal; BPM= Banana peel meal; SPPM= Sweet potato peel meal; NDF= Neutral detergent fibre; ADF= Acid detergent fibre; ADL= Acid detergent lignin; SEM = Standard error of means

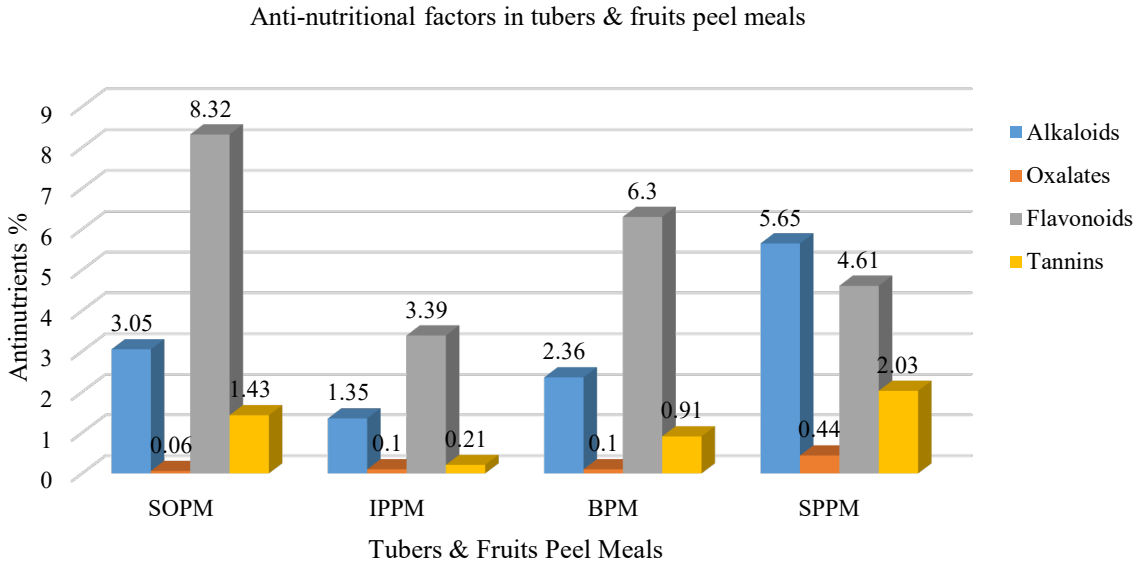

Figure 1. Anti-nutritional factors in tubers and fruits peel meals

The ADL content in the peels ranged from 3.67% to 11.67%. The ADL levels in tubers and fruit peels varied significantly (p<0.05). The ADL content in SOPM was higher than 2.10% (Ververis et al., 2007), but lower than 5.64% and 6.10% reported by Oluremi et al. (2007b) in different varieties of *Citrus sinensis* peels. The observed ADL content of 6.33% in IPPM was higher than 3.80% (Ncobela et al., 2017). Higher ADL values of 10.00% and 20.00% have been observed in IPPM by Osorio et al. (2021) and Javed et al. (2019), respectively. Banana peel meal had the highest value of ADL (11.67%) which is comparable to 10.25% (Pimentel et al., 2017) but higher than the 8.90% reported by Kabenge et al. (2018). Whereas, ADL found in SPPM was lower than 12.03% to 19.00% (Ukanwoko et al., 2020), but higher than 1.95% (Kalio et al., 2013). With the exception of BPM, other peels had low ADL content and this means they can easily be digested by rumen microbes and utilised as a source of energy in livestock feeding. Lignin combines with cellulose and hemicellulose, limiting their digestion by microbes, hence reducing the digestible energy of a feedstuff (Moore and Jung, 2001). High ADL in BPM can be possibly reduced by applying physical or chemical treatments to improve the availability of carbohydrates for microbial fermentation (Srivastava et al., 2012).

Hemicellulose content ranged from 10.00% to 22.33% in the tubers and fruit peels, with tubers peels having significantly (p<0.05) higher content compared to fruit peels. Sweet orange peel meal had the lowest hemicellulose content of 10.00%, and was within the range from 6.10% to 21.62% reported earlier (Sanchez et al., 2014; Oluremi et al., 2007b; Ververis et al., 2007). Banana peel meal had hemicellulose content of 14.67% and was higher than 10.5% (Bakshi & Wadha, 2013). However, Kabenge et al. (2018), Ragab et al. (2016) and Sanchez et al. (2014) reported higher hemicellulose values ranging from 25.52% to 41.3% in BPM. Hemicellulose in IPPM in the current study was comparatively lower than 39.00% (Osorio et al., 2021). The hemicellulose content in the present study for SPPM and IPPM were 18.33% and 22.33%, respectively. There is a paucity of literature on hemicellulose levels in the tubers peel meals. Hemicellulose in these peels can be a source of energy for ruminants since it will be accessible for microbial degradation in the rumen due to low levels of ADL in the peels.

The cellulose present in tubers and fruit peels ranged from 9.00% to 17.33%. The cellulose content of 12.67% in BPM is comparable to 11.45% (Sanchez et al., 2014) and higher than 6.4% to 9.9% (Kabenge et al., 2018; Happi Emaga et al., 2008). In contrast, higher contents ranging from 18.2% to 30.46% were previously documented (Ragab et al., 2016; Bakshi & Wadha, 2013). Irish potato peel meal had a cellulose content of 9.00%, higher than 2.5% (Ncobela et al., 2017). The cellulose content of 14.00% for SPPM in the current study was lower than 49.80% (Ebabhi et al., 2018). Sweet orange peel meal had a comparatively higher cellulose level of 17.33% than

11.90% (Sanchez et al., 2014), but lower than the range from 34.07% to 35.29% reported by Oluremi et al. (2007b) for different varieties of *Citrus sinensis* peels. The differences between current results and the values in literature can be attributed to any or combinations of differences in the varieties of tubers (SPPM and IPPM) and fruits (SOPM and BPM), stage of maturity at harvesting, processing techniques adopted and environmental conditions for cultivation. The peels have appreciable amount of cellulose, which is a major source of glucose, and can be fed as source of energy in ruminants. Digestible energy may also be high because of low ADL content in the peels.

Anti-nutritional factors of Tubers and Fruits Peel Meals

The quantitative result of the anti-nutritional factors in tubers and fruits peel meals are shown in Fig. 1. The alkaloid content of tubers and fruits peels differed significantly ($p<0.05$) between the treatments and ranged from 1.35% in IPPM to 5.65% in SPPM. Alkaloid toxicity levels in livestock and poultry feeding can vary widely depending on the specific alkaloid and the animal species involved. With the exception of the alkaloid in IPPM which was within toxicity level range of 0.5% to 2.2% for pyrrolizidine alkaloid (Cortinovis & Caloni, 2015), the SOPM, BPM and SPPM had alkaloid concentrations above the upper toxic level of 2.2%. This suggests the need to for feed processing techniques that can reduce its level in the crops to improve their feed value potential in ruminant and non-ruminant feeding, especially in the latter. It has earlier been found that the high content of alkaloid in BPM, SOPM and SPPM can be reduced by microwave drying (Abu-Arab & Abu-Selam, 2017). There was significant difference ($p<0.05$) in the oxalate content among the peels of the tubers (IPPM and SPPM) and fruits (BPM and SOPM). Although SPPM had a comparatively high oxalate content compared to SOPM, IPPM and BPM, its concentration was lower than 0.5% and 2.0% established as toxicity levels for non-ruminants and ruminants, respectively (Rahman et al., 2013). This suggests that this level of oxalate is safe for livestock and poultry. A higher oxalate concentration in the diet disrupts normal microbe degradation, and the excess oxalates combine with calcium in feed to form insoluble calcium oxalate, hence calcium becomes unavailable for absorption. Flavonoid content of tubers and fruits peels studied varied significantly ($p<0.05$) from 3.39% in IPPM to 8.32% for SOPM. The flavonoid concentrations of all the peels were above the range of 0.049% to 0.19% provided to poultry to improve carcass and egg quality (Narth & Aravindkumar, 2021). The peels have to be processed to reduce flavonoid content before being used in poultry rations. According to North et al. (2019), flavonoids have beneficial effects on growth and feed efficiency in stressed animals, reduce morbidity and mortality rates due to both infectious diseases and metabolic disorders. It has been found that supplementation of dairy cows with plant flavonoids during the transition period increased milk yield, reduced inflammatory markers, and improved liver health (Olagaray & Bradford, 2019). Tannin content of tubers and fruits peel meals were 0.211%, 0.911%, 1.430% and 2.030% for IPPM, BPM, SOPM and SPPM respectively, and differed significantly ($p<0.05$) across the peels. Atiku et al. (2016) reported that dietary tannin levels of 2% and 5% in sheep and cattle respectively, have negative effect on digestibility. They bind to protein, reducing its availability to animals, lower cellulose activity, and hence reduce crude fibre digestion. The peels in the current study can be included in ruminant's ration as their tannin content is lower than 2% except in SPPM, which is slightly higher.

Conclusion

The peels of Irish potato and sweet potato tubers and banana and sweet orange fruits contained fibre constituents that met minimum requirement for ruminant animals and can therefore be incorporated in their feed as a source of roughage for dietary energy supply. The peels also contained alkaloids, oxalates, flavonoids and tannins, which were within safe limits for exclusive consumption of ruminants. However, the peels require further processing to reduce alkaloids and flavonoids levels to improve their feed value, especially for non-ruminant animals.

Declarations

Author Contribution Statement

T.J.: Conducted the field work, interpreted data and wrote the original manuscript

O.I.: Atanda Oluremi: Designed, supervised the research, corrected and approved the manuscript

Conflict of Interest

Authors declare no conflict of interest.

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