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Assessment of feeding value of vegetable-carried pineapple fruit wastes to Red Sokoto goats in Ogbomoso, Oyo State of Nigeria

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This study compared the sun-drying characteristics of five blends each (w/w; 1:1, 1:1.5, 1:2, 1:2.5, 1:3) of wheat offal-carried pineapple waste (WO:PW) and brewers' dried grains-carried pineapple waste (BDG:PW), assessed the blends for their nutrient contents and the feeding value of the optimum blends with Red Sokoto (RS) goats. Moisture contents of all the blends were reduced to between 10.95 - 14.38% and 11.73 - 14.72%, respectively for WO:PW and BDG:PW blends within 7 h. Drying was observed to be optimum at 1WO:2PW and 1BDG:2PW and their respective proximate compositions suggest their potentials as an energy source and a protein source respectively in ruminant nutrition. Free choice intake, coefficient of preference and percentage preference of the optimum blends (1WO:2PW and 1BDG:2PW) and their respective equal mixtures (w/w) with a formulated conventional concentrate (CCON) by RS goats, were subsequently evaluated alongside the CCON in a cafeteria system. Results indicated that RS goats would opt for CCON in preference to other test feeds, but would readily accept WO-carried pineapple waste as an alternative to CCON.

Key words: Acceptability, feed processing, fruit-processing by-products, seasonal nutritional stress, small ruminants.

INTRODUCTION

Small ruminants represent between 63.7 and 75% of total grazing domestic livestock in Nigeria and are widely distributed in rural, urban and peri-urban areas (Ajala et al., 2008; FMA, 2008), hence their significance in livestock agriculture and human protein nutrition. The Red Sokoto (RS) and West African Dwarf (WAD) goats are the two most important goat breeds in the country (Yakubu et al., 2010). Even though natural pastures provide what is regarded as the "cheapest" feed for ruminants (Akinrinde and Olanite, 2014), it has long been

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recognized that they are incapable of sustaining the animals on a year-round basis as they are often deficient in nutritional quality for most of the year. In Nigeria, as observed by Bamigboye et al. (2013), rangelands only blossom in the rainy season while in dry season, they become standing hay. Thus, animals will have abundant feed in the wet season and a shortage of feed in the dry season.

Considerable research has been carried out to improve the quality and availability of feed resources, including works on sown forages, forage conservation, the use of multi-purpose trees, fibrous crop residues and strategic supplementation (Thornton, 2010) with promising results, but also with their attendant limitations. Many reasons have been adduced for the general non-adoption of sown forages in Nigeria, the most important of which is that most of the people involved are resource-poor; hence, they lack the needed financial resources to embark on improved pasture production (Akinrinde and Olanite, 2014). Other reasons (Akinrinde and Olanite, 2014), include lack of technical skills to manage such a system and relatively low prices for animal products. Although adequate levels of nutrients are retained in conserved feeds to merit their use in dry periods, the nutritive qualities differ from those of fresh materials (Asaolu et al., 2015). In Nigeria, two exotic species, *Gliricidia sepium* and *Leucaena leucocephala*, have shown appreciable forage potentials among multipurpose trees (Odeyinka et al., 2003; Fadiyimu et al., 2014). They have however been observed to have difficulty in adapting the local environment and are susceptible to pests and diseases, such as psyllid epidemic (*Heteropsylla cubana*) in *L. leucocephala* (Baumer, 1992). Furthermore, most native species shed their leaves during the dry season and majority of them possess physical structures and anti-nutritive chemical compounds, such as tannins, saponins, cyanogens, mimosine and coumarins (Leng, 1997), which are said to protect them against herbivores (Coley et al., 1985), but could reduce their palatability as well as limit their nutrient availability and digestibility (Barry, 1989). Kalio et al. (2015) identified a number of constraints to the utilization of fibrous crop residues as feed resources, including the lack of knowledge of where the crop residues could be gathered in reasonable quantities, the seasonality of their production, their alternative uses as composting and mulching materials by most crop farmers, the difficulty and expense of collecting, handling and storing large quantities of these bulky crop by-products and the lack of knowledge of the nutritive value of the materials as feed resources for ruminant livestock. Livestock have historically utilized large amounts of well-known and widely-available traditional by-products such as oil meals, bran, middlings, brewers' grains, distillers' grains, beet pulp and molasses in strategic supplementation strategies (Mirzaei-Aghsaghali and Maheri-Sis, 2008). Unfortunately, these supplements are often not fed due to their unavailability and high costs (Nouala et al., 2006). Additionally, as the world population increases relative to arable land, an increased demand for cereal grains and oilseed meals for direct use in human diets is expected in the long run (Knutson and Stoner, 2012). However, less conventional by-products have become available, such as vegetable- and fruit-processing residues, whey and culinary wastes (Mirzaei-Aghsaghali and Maheri-Sis, 2008). One of such by-products is pineapple waste.

Pineapple wastes, occurring mainly as pineapple peels and core (Buckle, 1989), are rich in fermentable sugars, organic acids, and fibre, have high digestibility potential (Jetana et al., 2009; Migwi et al., 2001). These characteristics make fruit by-products a potential feed resource for small ruminants (Pagan et al., 2014). Pineapple wastes account for approximately 40 to 50% of the fresh fruit weight (Buckle, 1989), and are mostly dumped with the attendant acceptable safe solid-waste disposal problems (Hepton and Hogson, 2003; Makinde et al., 2011). Incidentally, large quantities of fresh pineapple fruits are produced in Nigeria. Weight composition of a typical *Cayena lisa* pineapple is pulp (33%), core (6%), peel (41%) and crown (20%) (Medina and Garcia, 2005). Pineapple (*Ananas comosus*) is the third most important tropical fruit in the world after banana (Musa spp.) and Citrus spp. (Esiobu and Onubuogu, 2014). Nigeria is number six on the list of world pineapple producers (CADP Manuel, 2012), and the leading pineapple producer in Africa with an annual production of 1,400,000 metric tons (MT) of fresh pineapple (FAOSTAT, 2011). By extrapolation, Nigeria has a fresh pineapple waste generation potential of about 560,000 to 700,000 MT per annum. Such a huge yearly generation of residue constitutes a potential pollutant, and daily disposal of the residues is sure to increase the running cost of the fruit processing industry (Makinde and Sonaiya, 2007; Karkoodi et al., 2012). Fortunately, some research results have shown the benefits of utilizing such residues in ruminant feeding (Mokhtarpour, 1996). Feeding such residues to livestock has been considered not only to lessen environmental problems, diminish dependence of livestock on grains that can support human and eliminate the costly waste management programs (Grasser et al., 1995), but also to support sustainable development among the agricultural community (Suksathit et al., 2011).

Like other fresh fruit by-products, fresh pineapple cannery wastes are rich in water (about 90%) and soluble carbohydrates and decay very quickly (Ososanya et al., 2014). Therefore, there is the need for rapid utilization of the waste, but the canneries are often not located in areas of animal production and transportation of such bulky products is expensive and may require daily visits to the cannery (Nhan et al., 2009). Efforts toward proper processing and utilization of pineapple wastes by previous investigators in Nigeria involved sun-drying (Lamidi et al., 2008; Olosunde, 2010) and ensiling

(Ososanya et al., 2014), followed by the incorporation of the processed product in animal diets with satisfactory results (Makinde et al., 2011; Ososanya et al., 2014). Either way, the high moisture content of pineapple waste was a major problem. Drying which ought to be an easy way out has been reported to last between 5 and 14 days, depending on environmental conditions. Additionally, it reportedly (Ososanya et al., 2014) allows the soluble carbohydrates dispersed in water to be evaporated, hence, the need for the development of a quicker conversion method. Building upon earlier research efforts (Makinde and Sonaiya, 2007, 2010), it was found by Makinde et al. (2011) that pineapple wastes could be rapidly dried into a potential animal feed using wheat offal as a vegetable carrier/an absorbent.

The potential value of by-products in animal feeding depends on their nutritive characteristics and energy value with palatability also being an important feature (Mirzaei-Aghsaghali and Maheri-Sis, 2008). The significance of anti-oxidant contents of feed resources in the health and productivity management of livestock on an ecologically-sustainable basis (Shiau and Hsu, 2002) cannot be over-emphasized. This study was therefore designed to compare the sun-drying characteristics of different blends of pineapple waste with wheat offals and brewers' dried grains as moisture absorbents, assess these different blends for their proximate, fibre, mineral contents, and quantify the total polyphenols and other anti-oxidants present in the experimental pineapple waste. The intake and acceptability of the optimum blends of the two vegetable-carried pineapple wastes were also assessed relative to a conventional feed concentrate with Red Sokoto goats.

MATERIALS AND METHODS

Experimental site

The study was conducted during the dry season between February and March, 2015, at the Small Ruminant Unit (SRU) of Ladoke Akintola University of Technology Teaching and Research Farm (LAUTECH T&R F), Ogbomoso, Oyo State, located within the semi-arid zone where the major nutritional limitation of small ruminants is that of bridging the gap between wet and dry seasons (Onim et al., 1985). The area is located at 8°10' North latitude and 4°10' East longitude with annual rainfall of 1270 to 2030 mm, which occurs in 7 to 10 months with a peak between July and September of the year (Olaniyi, 2006). Ogbomoso is located within a 100-km radius of Ibadan, which is home to the Lafia Canning Factory of Fumman Agricultural Products Nigeria Ltd, Moor Plantation, Ibadan; one of the major generators of pineapple fruit wastes at commercial levels in Nigeria.

Procurement of fresh pineapple fruit waste, absorbents and other feed ingredients

Fresh wet pineapple wastes (the peelings and the pulp) were collected between 8.30 and 9.00 h from the Lafia Canning Factory of Fumman Agricultural Products Nigeria Ltd, Moor Plantation, Ibadan, Nigeria; and immediately transported to the SRU of LAUTECH T& R F, Ogbomoso. The moisture absorbents, that is, wheat offals and brewers' dried grains, as well as other as other experimental feed ingredients were obtained from a reliable feed ingredient store in Ogbomoso.

Table 1. Ingredient composition of a conventional feed concentrate for ruminant animal supplementation (Isah and Babayemi, 2010).

Ingredient	Levels (%)
Cassava peel	34.50
Wheat offal	24.00
Maize cob	15.00
Groundnut cake	10.00
Maize	6.00
Soybean	5.00
Bone meal	3.00
Oyster shell	2.00
Premix	0.25
Salt	0.25
Calculated analysis	
Crude protein (%)	15.92
Metabolizable energy (Mcal kg^{-1}DM)	2300.65

Formulation of a conventional feed concentrate

The formula of Isah and Babayemi (2010) for a conventional feed concentrate, as shown in Table 1, was adopted.

Determination of sun-drying characteristics of different blends of wheat offal- and brewers' dried grains-carried pineapple wastes

Five blends each of wheat offal-carried pineapple waste (WO:PW) and brewers' dried grains-carried pineapple waste (BDG:PW) were prepared. The blends (w/w), with each blend made in triplicates, were: wheat offal:pineapple waste blends (a) WO mixed with PW (1:1), (b) WO mixed with PW (1:1.5), (c) WO mixed with PW (1:2), (d) WO mixed with PW (1:2.5), (e) WO mixed with PW (1:3) and brewers' dried grains:pineapple waste blends (a) BDG mixed with PW (1:1), (b) BDG mixed with PW (1:1.5), (c) BDG mixed with PW (1:2), (d) BDG mixed with PW (1:2.5), (e) BDG mixed with PW (1:3).

For each of the blends, PW was thoroughly mixed with WO or BDG by hand until the fluid from pineapple waste was not superfluous (Makinde and Sonaiya, 2007). The blends were evaluated on the capacity to sun-dry to ≤10 to 12% in 7 h; as moisture content >12% is not desirable pertaining to good keeping quality (Rozis, 1997). The protocol of Makinde and Sonaiya (2007, 2010) was adopted for the drying of the blends but with a modification of the drying period from 4 to 7 h as reported by Asaolu (2013). The different blends were sun-dried by spreading thinly on polythene sheets (0.7 mm thickness) on a concrete floor, with each replicate weighing an average of 0.20 kg and covering an area of 1.42 m^2. Drying started at about 11.30 h and the mixtures were turned at about the first hour into drying. They were also turned about mid-way into the drying process. This involved rubbing handfuls together and spreading again. After the drying period, the blends were sampled for moisture contents and degrees of wetness. Wetness of each blend was estimated as the difference between its initial and final weight. The resultant blends were subsequently dried to constant moisture content and blended with a plate (burr) mill. Dried and cooled blends were stored in high-density polythene bags and then in a freezer for later chemical analyses.

Acceptability and preference evaluation of wheat offal- and brewers' dried grains-carried pineapple wastes relative to a conventional ruminant feed concentrate using Red Sokoto goats

The blends of WO and BDG with the highest PW contents (1WO:2PW and 1BDG:2PW), respectively that dried to ≤10 to 12% moisture content within 7 h were further produced and evaluated for free choice intake alongside equal mixtures of each blend with a formulated conventional concentrate (CCON as contained in Table 1); that is {50(1WO:2PW):50CCON} and {50(1BDG:2PW):50CCON}, respectively, relative to the sole conventional concentrate (CCON). Hence, there were five experimental supplements, namely, 1WO:2PW; 1BDG:2PW; {50(1WO:2PW):50CCON}; {50(1BDG:2PW):50CCON} and CCON, with the CCON serving as the reference supplement. Ten matured Red Sokoto goats, weighing 12.3±1.69 kg were used in a cafeteria style. The animals were housed together in a free stall with dwarf walls and concrete floors covered with wood shavings. All the animals were pre-conditioned to the experimental supplements for a period of 4 days after which the animals were offered 4 kg each (wet basis) of experimental supplements daily for a period of 10 days. Each 4 kg-serving was simultaneously presented in two separate feeding troughs, thus making a total of ten feeding troughs at a time. The positions of the feeding troughs were randomly changed on a daily basis to avoid any of the animals associating a particular experimental supplement to a particular position. Fresh water was also offered daily on a free choice basis. Intake of supplements was measured 2 h after they were offered by deducting remnants from the amount served and animals were subsequently allowed to graze for the rest of the day.

Coefficient of preference (CoP) was used as an index of acceptability while percentage preference (PP) was used as a preference index. The CoP was calculated as the ratio of individual test supplement intake to average intake of all the supplements while PP was calculated as the ratio of individual intake to total intake multiplied by 100. Test supplements were considered acceptable when the CoP was greater than one while ranking was based on PP (Ososanya and Olorunnisomo, 2015).

Chemical analyses

Proximate analyses of all the test supplements were carried out according to the methods of AOAC (2000), while the fibre components were determined according to Van Soest et al. (1991). For mineral analysis, samples were dry-ashed at 550°C for 4 h, followed by wet digestion of the resulting ash. Calcium concentration was estimated by using the Jenway Digital Flame Photometer (PFP7 Model), while phosphorus and magnesium contents were estimated using the Atomic Absorption Spectrophotometer (model Bulk 221CGP).

Beta carotene content was determined as described by Rodriguez-Amaya and Kimura (2004) and AOAC (2000). Total anthocyanins were determined by the pH deferential method (Lee et al., 2005) using a spectrophotometer (Unicam UV/VIS ATI UNICAM, Cambridge, UK). Total polyphenols were determined by the Folin-Ciocalteu method (Makkar, 2003). Ascorbic acid was determined using 2,4,6-dichloroindositol method of AOAC (2000) while total sugars were measured using Spectrophotometric method of AOAC (2000). pH was measured by a pH meter (model: PHS-25), and this was followed by the measurement of titratable acidity with NaOH as described by Garner et al. (No date) using the equation:

Titratable acidity = (ml of NaOH used) × (Normality of NaOH used) × MF × 100 / Weight of sample (g)

where MF = Milliequivalent factor, which is taken to be 0.067 for malic acid; the predominant acid in apples.

All analyses were done in triplicates.

Data analyses

The sun-drying characteristics data were analyzed with the 2-way analysis of variance using the General Linear Model (GLM) procedure of SAS (2001) in a completely randomized block design, with vegetable carrier as the main treatment effect and mixing ratios as the block. Significant differences between means were separated using the Duncan's New Multiple Range Test (DNMRT) of the same package. Data on acceptability and preference study were subjected to 1-way analysis of variance using the GLM of SAS (2001). Significant differences between means were also separated using the DNMRT of the same package.

RESULTS AND DISCUSSION

Chemical compositions of pineapple waste, wheat offals and brewers' dried grains

The chemical compositions of PW, WO and BDG are contained in Table 2. Wheat offals and BDG contained high dry matter contents while PW contained a considerable amount of moisture. Brewers' dried grains were relatively higher in crude protein and ether extract, respectively followed by WO and PW. Total ash was least for BDG and highest for WO. Crude fibre values appeared comparable for the three feedstuffs; while nitrogen free extract was the highest for PW followed by WO and BDG, respectively. Calcium and magnesium levels were highest in WO followed by BDG and PW, respectively. Wheat offals and BDG contained comparable amounts of phosphorus which were both higher than the level in PW. The proximate components of each of the three test feeds fell within the respective reported literature values (Wondifraw and Tamir, 2013; Hemalatha and Ambuselvi, 2013). Unlike BDG and WO, PW was observed to be very high in moisture content, which compares with 80% reported by Makinde et al. (2011). Hemalatha and Ambuselvi (2013) reported an even higher moisture value of 91.35%. Such high moisture contents make pineapple waste a highly perishable material. A low energy value could also be implied in this high moisture state (Muller and Tobin, 1980). In order to optimize the energy potential of this waste therefore, treatments to minimize its moisture content becomes expedient. Additionally, its shelf life will be significantly increased. Only BDG contained a crude protein content that is higher than the range of 15 to 18% requirement for growing lambs (Aruwayo et al., 2009). Brewers' dried grains have been reported (Wondifraw

Table 2. Chemical compositions of pineapple waste, wheat offals and brewers' dried grains.

Parameter	Fresh pineapple waste	Wheat offals	Brewers' dried grains
Dry matter	21.84	89.99	90.10
% of DM			
Crude protein	5.08	13.76	31.08
Ether extract	1.18	4.65	8.20
Ash	6.21	9.43	4.88
Crude fibre	11.57	16.45	13.10
Nitrogen free extract	67.00	55.72	42.75
Calcium	0.18	0.35	0.20
Phosphorus	0.10	0.50	0.58
Magnesium	0.09	0.38	0.19
Total sugars	26.28	Nd	Nd
Total polyphenols	0.60	Nd	Nd
Total anthocyanins	0.05	Nd	Nd
Total titratable acidity	0.71	Nd	Nd
Vitamin C (mg/100g)	7.42	Nd	Nd
β-Carotene (µg/100g)	378.59	Nd	Nd
pH	4.40	Nd	Nd

nd: Not determined.

and Tamir, 2013) as valuable sources of crude protein, metabolizable energy, many of the B-vitamins, phosphorus but relatively low in calcium. They are also considered as good sources of rumen undegradable protein, fibre and water-soluble vitamins (Westendorf and Wohlt, 2002; Vasso and Winfried, 2007). The crude protein content of WO was however higher than the range of 11.00 to 13.00% known to be capable of supplying adequate protein for maintenance and moderate growth performances in goats (NRC, 1981), while PW contained even less than range of 7.00 to 8.00% recommended for efficient functioning of rumen microorganisms (Van Soest, 1994). The observed crude protein was comparable to the value of 5.11% (Adeyemi et al., 2010) for pineapple peels alone, but higher than the value of 3.69% reported by Omwago et al. (2013) for the waste. It was however lower than 6.12% reported by Aboh et al. (2013) for pineapple peels. With the crude fibre content observed in this study, Omole et al. (2011) opined that PW could be a veritable source of fibre in livestock diets. Ether extract and ash values as obtained in this study have earlier been described (Omole et al., 2011) as low and rich, respectively. The nitrogen free extract values reflect higher concentration of energy in PW than in WO and BDG in that order. Aside from compositional differences between the wastes, Aboh et al. (2013) attributed the observed chemical variations in PW to pineapple varietal differences and supply of fertilizers.

Pineapple waste was observed to be acidic with moderately low pH, titratable acidity, total polyphenols and anthocyanidins, but relatively high contents of ascorbic acid (vitamin C), total sugars and β-carotene. A pH range of 2.5 to 7.0 has been reported (Ambuselvi and Muthumani, 2014), implying that pineapple wastes are usually acidic in nature. Hemalatha and Ambuselvi (2013) reported a titratable acidity of 1.86% for PW while the value for the whole fruit ranged from 0.80 to 1.50%. Titratable acidity levels as observed in this study have been described (Hemalatha and Ambuselvi, 2013) as moderate. The acidity found in the pineapple and citrus by-products is typical of ripen fruits and results from the presence of organic acids, mainly citric, malic, ascorbic and tartaric (Falade et al., 2003). The ascorbic acid content reported for PW in this study was higher than the range of 2.50 to 3.50 mg/100 g reported by Ambuselvi and Muthumani (2014). Vitamin C has been described (Adebowale et al., 2011) as an indispensable and multifunctional micronutrient substance that is essential in minute amounts for the proper growth and metabolism of a living organism. It is the body's primary water soluble antioxidant against free radicals that attack and damage normal cells (Hossain et al., 2015). A powerful antioxidant, vitamin C supports the formation of collagen in bones, blood vessels, cartilage and muscle, as well as the absorption of iron. Vitamin C also retards the development of urinary tract infections during pregnancy (Debnath et al., 2012). Sugar is a major biochemical component of pineapple fruit and its concentration will determine the quality of the fruit (Siti Roha et al., 2013). This assertion could rightly apply to the wastes of the fruit as Correia et al. (2004) reported that PW still retains a

Table 3. Drying characteristics of different blends of wheat offal-carried pineapple waste (WO:PW) and brewers' dried grains-carried pineapple waste (BDG:PW).

Mixing ratio	Vegetable carrier/SEM	Wetness	Moisture
1:1	WO:PW	0.06	10.95
	BDG:PW	0.13	11.61
	SEM	0.01	0.07
1:1.5	WO:PW	0.17	11.59
	BDG:PW	0.18	11.73
	SEM	0.01	0.17
1:2.	WO:PW	0.22	11.88
	BDG:PW	0.23	11.90
	SEM	0.01	0.12
1:2.5	WO:PW	0.27	14.36
	BDG:PW	0.28	14.50
	SEM	0.01	0.05
1:3	WO:PW	0.33	14.38
	BDG:PW	0.38	14.72
	SEM	0.01	0.18

[abc]Triplicate mean values in each column for the same parameter at different mixing ratios with different superscripts are significantly different at P<0.05. Drying surface temperature range = 45 to 52°C; Ambient temperature range = 32 to 35°C; Fresh pineapple waste average % moisture = 78.16%, WO: Wheat offals; BDG: brewers' dried grains; PW: pineapple waste, SEM: standard error of the mean.

considerable amount of sugars that are contained within the fruit. The sugar content of PW was detected by Siti Roha et al. (2013) to comprise of fructose, glucose and sucrose, with sucrose being the main sugar. Of the three major components of PW (crown, peels and core), pineapple core extract has been found (Siti Roha et al., 2013) to have the highest amounts of the three sugars, irrespective of the stage of maturity. It was further reported by Siti Roha et al. (2013) that sucrose is the major sugar found in pineapple core and peel extracts. Hence, sucrose is likely to constitute the bulk of the sugars that were detected in this study. Muller (1978) reported that PW, because of its high sugar content, has long been exploited in cattle rations as a source of readily available carbohydrates. These sugars, which are principally non-reducing in nature, in association with other carbohydrates and proteins, are used as a nutrient medium for growth of microbes and fermentation using yeast to produce ethanol and single cell protein (Hemalatha and Ambuselvi, 2013). The experimental PW was also very high in provitamin A (β-Carotene) relative to the values reported by Nzeagwu and Onimawo (2010) for the popular black currant drink (1.24 mg/100 g) and juice made from *Eugenia uniflora* L. (pitanga) fruits (15.85 mg/100 g), although lower than the value of 926.55 μg/100 g reported by Asaolu (2013) for cashew apple. This suggests that PW may probably be a very good source of provitamin A. Beta-carotene has been described as the carotenoid with the most vitamin A activity, and because of its chemical nature, it has been suggested that β-carotene may be an antioxidant within tissues protecting them from damage from free radicals (Wardlaw et al., 2004). The whole pineapple fruit is known to be high in both vitamin C and vitamin A (Joy, 2010). Even though apparently low total polyphenols and total anthocyanins were detected in this study, high amounts of phenolic compounds have been reported (Rudra et al., 2015) in PW with high antioxidant activities.

Sun-drying characteristics of different blends of wheat offal-carried pineapple waste and brewers' dried grains-carried pineapple waste

The sun-drying characteristics of the different blends of WO:PW and BDG:PW after a 7 h drying period, and the observed effects of the two vegetable carriers and different mixing ratios on these characteristics are shown in Tables 3, 4 and 5 respectively. In contrast to the reports of Lamidi et al. (2008) and Olosunde (2010) where sun drying-periods for pineapple waste ranged between 5 and 14 days, the three tables show that sun-

Table 4. Effects of vegetable carriers on the wetness and moisture contents of different blends of wheat offal-carried pineapple waste (WO:PW) and brewers' dried grains-carried pineapple waste (BDG:PW).

Vegetable carrier	Wetness (kg)	Moisture (%)
Brewers' dried grains	0.23	12.89^{a}
Wheat offals	0.22	12.63^{b}
SEM	0.02	0.27

^{abc}Mean values in each column for the same parameter with different superscripts are significantly different at P<0.05. WO: Wheat offals; BDG: brewers' dried grains; PW: pineapple waste, SEM: standard error of the mean.

Table 5. Effects of mixing ratios on the wetness and moisture contents of different blends of wheat offal-carried pineapple waste (WO:PW) and brewers' dried grains-carried pineapple waste (BDG:PW).

Mixing ratio	Wetness (kg)	Moisture (%)
1:1	0.09^{e}	11.34^{c}
1:1.5	0.18^{d}	11.50^{bc}
1:2	0.22^{c}	11.89^{b}
1:2.5	0.28^{b}	14.43^{a}
1:3	0.35^{a}	14.55^{a}
SEM	0.01	0.11

^{abc}Mean values in each column for the same parameter with different superscripts are significantly different at P<0.05. WO: Wheat offals; BDG: brewers' dried grains; PW: pineapple waste, SEM: standard error of the mean.

drying period in this study was significantly reduced. This observation compares with the report of Asaolu (2013) with fresh cashew apples, but the drying period was slightly longer than what was reported by Makinde et al. (2011) for pineapple waste with wheat offal. Shorter drying times have been attributed (Sonaiya, 1988; Rozis, 1997) to increased air to product surface exchange area. Table 4 shows that while there was no vegetable carrier effect (P>0.05) on the wetness of the vegetable-carried feedstuffs, it exerted a significant (P<0.05) effect on the moisture contents of these vegetable-carried feedstuffs, with the BDG-carried pineapple wastes having higher moisture contents. This is in agreement with the findings of Makinde and Sonaiya (2007) that BDG absorbed more water than WO but had lower water absorbency than WO. These observations were found to conform to the general observation that lower bulk density feedstuffs have higher water holding capacities (Sundu et al., 2005). Makinde and Sonaiya (2007) reported that BDG had a higher bulk density than WO. Mixing ratio was however observed to have significant (P<0.05) effects on both wetness and moisture contents of the two vegetable-carried feedstuffs (Table 5). Wetness and moisture levels were observed to increase with increasing levels of fresh PW in the different blends. Blends with PW of 2.5 and 3.0 parts had comparable (P>0.05) moisture levels, but their moisture levels were significantly (P<0.05) higher than in blends containing ≤2.0 parts of PW. In line with the criterion of selecting blends that dried to ≤10 to 12% moisture in 7 h, the blend ratio with PW of 2.0 parts appeared to be the optimum for both WO and BDG to effectively dry PW, with an edge in favour of WO in view of the effect of vegetable carrier on moisture content as observed in Table 4. This confirms in part the report of Makinde et al. (2011) on the optimum drying combination of WO and PW. The high moisture level of fresh PW would most likely have been responsible for the observed trend of the effect of mixing ratio on wetness and moisture levels of the different blends. It must have exerted a high pressure by increasing the absolute amount of water (g of water) that had to be absorbed by each vegetable carrier and the corresponding absorbency (g of water/g of feed) at every higher level of PW.

Nutrient compositions of different blends of wheat offal- and brewers' dried grains-carried pineapple wastes

Tables 6, 7 and 8 show the nutrient compositions of the different blends of WO- and BDG-carried PW and the effects of the two vegetable carriers as well as the mixing ratios of these vegetable carriers with PW on the chemical compositions of the resultant blends. It can be seen from Table 6 that dry matter contents of the blends were not significantly affected (P>0.05) by the vegetable carriers at each mixing ratio, although the WO:PW blends contained slightly higher dry matter contents. The table further shows that BDG-containing blends contained significantly higher (P<0.05) levels of crude protein and ether extract at each mixing ratio while the reverse was observed with crude fibre, ash, nitrogen free extract and the analyzed fibre components. In summary, the two vegetable carriers had no significant (P>0.05) effect on the dry matter contents of the different blends of WO- and BDG-carried PW while significant (P<0.05) effects were observed in the trends for other analyzed nutrients (Table 7). These trends were as observed in Table 6. The mixing ratios of the two vegetable carriers with PW were however observed to exert significant (P<0.05) effects on all the nutrient parameters that were measured (Table 8). It can be seen from the table that with the exception of nitrogen free extract, the dry matter and all the other nutrient contents that were measured were observed to decrease significantly (P<0.05) with increasing levels of PW in the different blends. On the contrary, however, the nitrogen free extract values increased with increasing levels of pineapple waste, implying higher energy concentrations of the blends with increasing pineapple

Table 6. Nutrient compositions of different blends of wheat offal- and brewers' dried grains-carried pineapple wastes.

Mixing ratio	Veg. C./SEM	DM	CP	EE	CF	ASH	NFE	NDF	ADF	ADL
	WO:PW	89.05	11.91[b]	3.42[b]	13.54[a]	6.77[a]	53.42[a]	46.15[a]	29.76[a]	11.57[a]
1:1	BDG:PW	88.27	22.73[a]	6.01[a]	9.32 [b]	4.85[b]	45.37[b]	35.08[b]	21.70[b]	6.16[b]
	SEM	0.07	0.09	0.04	0.11	0.03	0.09	0.10	0.06	0.07
	WO:PW	88.41	9.86[b]	2.60[b]	12.09[a]	6.07[a]	57.51[a]	44.22[a]	28.82[a]	10.64[a]
1:1.5	BDG:PW	88.13	22.06 [a]	5.67 [a]	9.51[b]	4.54[b]	46.62[b]	33.60[b]	21.09[b]	5.67[b]
	SEM	0.17	0.24	0.05	0.18	0.05	0.43	0.39	0.08	0.05
	WO:PW	88.13	9.15[b]	2.50[b]	11.75[a]	5.90[a]	57.75[a]	43.50[a]	28.10[a]	10.44[a]
1:2	BDG:PW	88.10	20.75[a]	5.33[a]	9.15[b]	4.24[b]	48.65[b]	33.38[b]	20.30[b]	5.09[b]
	SEM	0.12	0.73	0.01	0.19	0.06	0.47	0.11	0.10	0.05
	WO:PW	85.64	8.48[b]	2.36[b]	11.22[a]	5.66[a]	57.93[a]	42.72[a]	27.71[a]	10.13[a]
1:2.5	BDG:PW	85.50	19.47[a]	4.92[a]	8.60[b]	3.89[b]	48.62[b]	32.89[b]	19.38[b]	4.70[b]
	SEM	0.05	0.10	0.04	0.04	0.04	0.16	0.06	0.09	0.05
	WO:PW	85.62	7.53[b]	2.09[b]	10.58[a]	5.32[a]	60.11[a]	42.11[a]	26.76[a]	9.34[a]
1:3	BDG:PW	85.28	18.91[a]	4.50[a]	8.24[b]	3.51[b]	50.12[b]	32.28[b]	18.68[b]	4.11[b]
	SEM	0.18	0.17	0.05	0.11	0.05	0.16	0.10	0.11	0.07

[abc]Mean values in each column for the same parameter at different mixing ratios with different superscripts are significantly different at P<0.05, Veg. C. = Vegetable carrier, SEM = Standard Error of the Mean, DM = Dry Matter, CP = Crude Protein, EE = Ether Extract, CF = Crude Fibre, NFE = Nitrogen Free Extract, NDF = Neutral Detergent Fibre, ADF = Acid Detergent Fibre, ADL = Acid Detergent Lignin, WO = Wheat Offal, PW = Fresh Pineapple Waste.

Table 8. Effects of vegetable carriers on the nutrient compositions of different blends of wheat offal-carried pineapple waste (WO:PW) and brewers' dried grains-carried pineapple waste (BDG:PW).

Veg. C	DM	CP	EE	CF	ASH	NFE	NDF	ADF	ADL
WO	87.37	9.82[b]	2.70[b]	12.11[a]	6.06[a]	56.69[a]	44.11[a]	28.46[a]	10.46[a]
BDG	87.11	20.78[a]	5.28[a]	8.96[b]	4.21[b]	47.88[b]	33.45[b]	20.23[b]	5.14[b]
SEM	0.07	0.08	0.02	0.06	0.20	0.12	0.10	0.04	0.03

[abc]Mean values in each column for the same parameter at different mixing ratios with different superscripts are significantly different at P<0.05. Veg. C.: Vegetable carrier, SEM: standard error of the mean, DM: dry matter, CP: crude protein, EE: ether extract, CF = crude fibre, NFE: nitrogen free extract, NDF: neutral detergent fibre, ADF: acid detergent fibre, ADL: acid detergent lignin, WO: wheat offal, PW: fresh pineapple waste.

Table 8. Effects of mixing ratios on the nutrient compositions of different blends of wheat offal-carried pineapple waste (WO:PW) and brewers' dried grains-carried pineapple waste (BDG:PW).

Mixing ratio	DM	CP	EE	CF	ASH	NFE	NDF	ADF	ADL
1:1	88.66[a]	17.32[a]	4.71[a]	11.43[a]	5.81[a]	49.40[d]	40.62[a]	25.73[a]	8.86[a]
1:1.5	88.40[a b]	16.69[b]	4.35[b]	11.31[a]	5.51[b]	50.54[c]	39.38[b]	25.17[b]	8.40[b]
1:2	88.11[b]	15.30[c]	3.96[c]	10.62[b]	5.16[c]	53.08[b]	38.91[c]	24.56[c]	7.86[c]
1:2.5	85.57[c]	13.97[d]	3.64[d]	9.91[c]	4.78[d]	53.27[b]	37.80[d]	23.55[c]	7.41[d]
1:3	85.45[c]	13.22[c]	3.30[e]	9.41[d]	4.41[e]	55.11[a]	37.20[d]	22.72[d]	6.73[e]
SEM	0.12	0.13	0.03	0.09	0.03	0.20	0.16	0.07	0.04

[abc]Mean values in each column for the same parameter with different superscripts are significantly different at P<0.05. DM: Dry matter, CP: crude protein, EE: ether extract, CF: crude fibre, NFE: nitrogen free extract, NDF: neutral detergent fibre, ADF: acid detergent fibre, ADL: acid detergent lignin, WO: wheat offal, PW: fresh pineapple waste, SEM: standard error of the mean.

waste levels. All the observations on the trends of nutrient contents of the vegetable-carried PW could be attributed to the nutrient compositions of the individual feed ingredients as contained in Table 2. Although WO and BDG had comparable dry matter contents, BDG were comparatively higher in crude protein and ether extract but lower in ash and crude fibre contents. The increasing concentration of nitrogen free extract in the different blends of vegetable-carried PW with increasing proportion of PW would most likely have been due to the higher concentration of nitrogen free extract in PW relative to both WO and BDG.

The ADF and NDF contents of all the vegetable carried-PW blends at the various mixing ratios (Table 6) were low to moderate when compared with low quality roughages which ruminants effectively degrade (Okoli et al., 2003). NDF is a measure of cellulose, hemicellulose, and lignin fractions of feeds while the ADF fraction includes cellulose and lignin as the primary components (Mirzaei-Aghsaghali and Maheri-Sis, 2011). NDF is more highly correlated with feed volume and chewing activity than ADF or CF (Coppock, 1987; Varga et al., 1998). The NDF concentration could be affected by several factors such as temperature, light intensity, water availability, latitude, maturity, and harvesting and storage methods (Van Soest, 1994). On the other hand, concentrations of ADF and lignin are correlated more with digestibility (Mirzaei-Aghsaghali and Maheri-Sis, 2008). Many factors influence the relationship between ADF and digestibility, including forage variety, maturity at harvest, and storage conditions (Van Soest, 1965; Varga et al., 1998). Non-cell wall components are not influenced by lignin, but they can often be highly correlated. Therefore, lignin concentration affects mainly the availability of cell wall polysaccharides (Van Soest, 1994). According to Nagadi et al. (2000), degradability of cell wall carbohydrates is mainly limited by lignin content, accentuating its influence on feed utilization (Ahmad and Wilman, 2001). Bosch and Bruining (1995) confirmed that grass silages, with high lignin content, have a lower digestibility compared to silages that contained low levels of lignin. A possibility therefore exists of BDG-carried PW having higher digestibility values as a result of their significantly lower ($P<0.05$) ADL concentrations than WO:PW.

Ash and Norton (1987) demonstrated the dependence of maintenance and weight gain by goats on the protein and energy contents of feeds. The National Research Council (NRC), Animal Nutrition Sub-Committee on Feed Composition (Ash and Norton, 1987), classified feedstuffs containing averagely less than 18% CF and less than 20% CP on a dry matter basis as energy concentrates while those containing at least 20% crude protein were classified as protein sources. Based on these criteria, the selected blends of WO and BDG with PW of 2.0 parts could be regarded as an energy source and a protein source, respectively. Even though the selected wheat offal-carried pineapple waste (1WO:2PW) could be regarded as an energy source, its crude protein level was higher than the recommended level by ARC (1980) and NRC (1985) for optimum microbial gut activities. It was also higher than the minimum 7% dietary level that is needed to meet the maintenance protein requirements of a mature cow (Hersom, 2012), and probably the requirements of cattle at various production stages at appropriate inclusion levels (Asaolu, 2013). Hence, in addition to being an energy source, 1WO:2PW could possibly meet ruminants' crude protein requirements. Gatenby (2002) however indicated that the ARC (1980) and NRC (1985) levels are too low, with a suggestion that 10 to 12% crude protein in the diet is necessary for better production in ruminants. The crude protein content of the selected BDG-carried pineapple waste (1BDG:2PW) not only met all the minimum requirements for ruminants, but was higher than the suggested level of 10 to 12% by Gatenby (2002) for better production by ruminants and also exceeded the range of 11.00 to 13.00% known to be capable of supplying adequate protein for maintenance and moderate growth in goats (NRC, 1981).

Acceptability and preference ranking of wheat offal- and brewers' dried grains-carried pineapple wastes by Red Sokoto goats

Cafeteria techniques, one of which was adopted for this study, have been used over time (Bamikole et al., 2004; Babayemi, 2007; Babayemi et al., 2009; Olorunnisomo and Fayomi, 2012; Ososanya and Olorunnisomo, 2015; Akinwande et al., 2015) to assess the acceptability of various feeds by ruminants. In this study, it can be inferred from Table 9 that Red Sokoto goats would accept CCON, 1WO:2PW and {50(1WO:2PW):50CCON} as the CoP of each of these supplements was greater than one (Ososanya and Olorunnisomo, 2015). Using the same criterion, the animals would be expected to reject the other two supplements, that is, the BDG-carried pineapple waste [1BDG:2PW] and its equal mixture with the formulated conventional concentrate [{50(1BDG:2PW):50CCON}]. However, it had been noted in some previous studies (Olorunnisomo and Fayomi, 2012; Ososanya and Olorunnisomo, 2015) that CoP may not be a realistic measure of acceptability of diets by ruminants since it does not take into consideration the previous experience of the animals or the importance of changing dietary preference of animals. On the other hand, percentage preference (PP) appears to be a more realistic index of acceptability since it does not foreclose the possibility of changing dietary preference among livestock (Ososanya and Olorunnisomo, 2015). With the range of PP values observed in this study as indices, the experimental supplements could be said to be preferred in the following order; CCON> {50(1WO:2PW):50CCON}> 1WO:2PW> {50(1BDG:2PW):50CCON}> 1BDG:2PW. In other words, the animals would opt for the conventional

Table 9. Acceptability and preference of Red Sokoto goats fed ratio one to two blends of wheat offal- and brewers' dried grains-carried pineapple waste (1WO:2PW and 1BDG:2PW), a sole conventional concentrate (CCON), and equal mixtures of each blend with the conventional concentrate{50(1WO:2PW):50CCON} and {50(1BDG:2PW):50CCON}.

Test supplement	Intake (kg, DM)	Coefficient of preference (CoP)	Percent preference (PP)	Preference ranking
1WO:2PW	0.82^{bc}	1.10^{bc}	20.85^{bc}	3rd
1BDG:2PW	0.23^{d}	0.30^{d}	6.03^{d}	5th
CCON	1.20^{a}	1.52^{a}	28.83^{a}	1st
{50(1WO:2PW):50CCON}	1.06^{ab}	1.35^{ab}	26.61^{ab}	2nd
{50(1BDG:2PW):50CCON}	0.57^{c}	0.73^{c}	16.73^{c}	4th
SEM	0.11	0.13	2.89	-

[abc]Mean values in each column for the same parameter at different mixing ratios with different superscripts are significantly different at $P<0.05$.

concentrate in preference to any of the two vegetable-carried pineapple wastes. This is quite understandable and corroborates an earlier finding (Ikhimioya and Imasuen, 2007) that small ruminants would readily accept diets with which they have had previous experience. However, the levels of interaction between the values of PP for CCON, {50(1WO:2PW):50CCON} and 1WO:2PW (28.83^{a}, 26.61^{ab} and 20.85^{bc} %, respectively) indicate that the wheat offal-carried pineapple wastes would be more readily accepted by the animals as alternatives to CCON if and when necessary, with PP values of 16.73^{c} and 6.03^{d} %. The supplement 1BDG:2PW could even be regarded as a no-option for RS goats with such a very low (6.03%) percentage preference. Although palatable and readily consumed when in good condition (Heuzé et al., 2015), it is necessary to dry BDG so that they do not contain more than 10% moisture when they are intended for long storage (Boessinger et al., 2005). The moisture content of 1BDG:2PW was however greater than the 10% threshold level. Feed mixtures containing BDG spoil quite rapidly (Gohl, 1982), and the palatability decreases with storage time (Heuzé et al., 2015), particularly when stored at higher than 10% moisture levels (Boessinger et al., 2005) for more than 2 to 5 days in warm temperatures (Amaral-Phillips and Hemken, 2002; Thomas et al., 2010). The palatability and hence the acceptability, of the BDG-carried PW that were assessed in this study could have been negatively affected by the rather longer storage period under the prevailing ambient temperature at the experimental site.

CONCLUSION AND RECOMMENDATIONS

The nutritional potentials of pineapple waste as a source of energy, fibre and antioxidants in ruminant nutrition were highlighted by the results of this study. The major limitation to its utilization; high moisture content, was also highlighted. However, the blend ratio with pineapple waste of 2.0 parts was optimum for both wheat offals and brewers' dried grains to effectively dry pineapple waste for possible incorporation into a feed, with an edge in favour of wheat offals. The proximate compositions of the selected blends of wheat offal and brewers' dried grains with pineapple waste of 2.0 parts suggest their potentials as an energy source and a protein source respectively in ruminant nutrition. This would go a long way in achieving the twin-objective of addressing the waste disposal problem associated with pineapple waste and the nutritional stress commonly experienced by ruminants in developing countries, particularly during the long periods of dry season when protein and energy deficits in feed supply are most pronounced. Fortunately, acceptability results indicated that Red Sokoto goats would readily accept wheat offal-carried pineapple wastes as alternatives to conventional concentrates that are commonly used in supplementing ruminant diets but acceptability problems were recorded with brewers' dried grains-carried pineapple wastes. These problems arose most likely from the length and conditions of storage. Further studies to address the observed problems with brewers' dried grains-carried pineapple wastes are recommended while investigations into the incorporation of wheat offal-carried pineapple wastes into practical production diets for all classes of ruminants could commence.

Conflict of Interests

The authors have not declared any conflict of interests.

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Abbreviations

WO, Wheat offal; **PW,** fresh pineapple waste; **BDG,** brewers' dried grains; **BDG:PW,** brewers' dried grains-carried pineapple waste; **WO:PO,** wheat offal-carried pineapple waste; **CCON,** conventional concentrate; **RS,** Red Sokoto; **WAD,** West African Dwarf; **NRC,** National Research Council; **PP,** percentage preference; **CoP,** coefficient of preference.

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