The Utilization of Acid Ensiled Fish Waste and Sugar Refinery By-Product in Diets for Growing-Finishing Pigs

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Summary

Twenty females (Landrace x Large White) with a mean (± SD) initial BW of 35.2 (± 0.6) kg and an average age of 13 weeks were used in the study. Based on results of a preliminary experiment, diets were formulated to contain 200 g acid ensiled fish waste (AFW) kg^{-1}.DM. Both Jett and sugarcane final molasses (SFM) were used in combination as an energy source in the diets. Dietary inclusion levels of Jett/SFM g.kg^{-1} DM for treatments were: 100/100, 200/0, 259/259, and 517/0 labeled, T1, T2, T3 and T4, respectively. A commercial pig grower feed was used as the control (labeled T0) representing the standard cereal based diet fed. The five treatments were replicated four times. These treatments were randomly allocated to the twenty pens in a complete randomized design.

There were significant differences (P< 0.046) among treatments for final bodyweight, dry matter intake (DMI), average daily gain (ADG) and feed conversion ratio (FCR). Average daily gain for pigs on treatments T1, T2, T3 and T4 where Jett and SFM supplied the major proportion of the dietary energy ranged from 472 to 526 g.d^{-1}. These values represented 78.5 and 87.5%, respectively of the ADG (601 g.d^{-1}) achieved by the animals maintained on the control (T0). Treatment T3 with a combination of 260 g SFM and 260 g Jett. kg^{-1} DM had the lowest (P< 0.05) faecal DM and ADG performance. Ration with the highest dietary Jett inclusion level treatment, T4 had the best FCR (2.6) giving a 25.7% improvement over the control (3.5). There was no significant difference in P_2 back fat (P> 0.858), hot carcass weight (P> 0.065), dressing % (P> 0.118) and loin eye area (P> 0.883) among treatments. No significant differences (P> 0.454) was observed among treatments for haemoglobin, MCHC, and white blood cell count. Glucose (P< 0.023), ALT (P< 0.028), total protein (P< 0.049) and blood urea (P< 0.048) showed significant treatments effects. The values obtained for ALT, AST and Alkaline phosphate indicated that there was normal functioning of the spleen, kidney, and liver for all treatments. It was concluded that AFW with SFM and Jett when fed to pigs can give acceptable animal performance in the tropics, and thereby reducing the level of imported soybean meal and corn in the ration.

Résumé

L'utilisation de déchets de poisson ensilés dans l'acide et du sous produit du sucre de raffinage dans les régimes des cochons en croissance, en voie de finition

Vingt femelles (Landrace x Large White) avec une moyenne (± SD) poids du corps initial de 35,2 (± 0,6) kg et une moyenne d'âge de 13 semaines ont été utilisées dans cet essai. Dès les résultats de cet essai préliminaire, les rations ont été définies avec une contenance de 200 g de déchets de poisson ensilés dans l'acide (DPA).kg^{-1} de matière sèche. Tous les deux, «Jett» et la mélasse finale de la canne à sucre (MFS) étaient utilisés en combinaison avec une source d'énergie dans les régimes. L'inclusion dans les régimes des différents niveaux de « Jett »/MFS g.kg^{-1} de matière sèche pour les différents niveaux d'essai étaient: 100/100, 200/0, 260/260 et 517/0 étiqueté, T_1, T_2, T_3 et T_4 respectivement.

Une ration commerciale pour la croissance des cochons était utilisée comme le témoin T_0 représentant le régime standard basé sur la céréale. Les 5 niveaux d'essai ont été répliqués quatre fois. Ces niveaux d'essai ont été alloués au hasard au 20 box dans un design complètement au hasard. Il y avait des différences significatives (P< 0,046) entre les niveaux d'essai pour le poids corporel final, la consommation de matière sèche (CMS), le gain moyen quotidien (GMQ) et, le ratio de conversion de l'aliment (RCA). Le gain moyen quotidien pour les cochons mis sur les niveaux d'essai T_1, T_2, T_3 et T_4, où «Jett» et MFS ont fournit la proportion majeure d'énergie diététique, ont eu une gamme de 472 à 526 g.d^{-1}. Ces valeurs ont représenté 78,5 et 87,5% respectivement de GMQ (601 g.d^{-1}) achevé par les animaux sur le régime de témoin (T_0). Niveau d'essai T_3 avec une combinaison de 260 g MFS et 260 g de «Jett».kg^{-1} a eu la plus basse (P< 0,05) performance au niveau de matière sèche fécale et de GMQ. La ration avec la plus haute inclusion de niveau de «Jett» pour un niveau d'essai, T_4 a eu le meilleur RCA (2,6) donnant une augmentation sur le témoin (3,5) de 25,7%. La régression de GMQ sur le niveau d'inclusion de «Jett» a montré une relation cubique (P 0,001) significative (R^2= 90,8%). Une réponse similaire

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a été observée quand le GMQ était régressé sur la relation (R^2= 98,4%). Il n'y avait pas une différence significative dans le P_2 graisse de dos (P< 0,858), le poids de carcasse chaude (P< 0,065), le pourcentage de carcasse transformé (P> 0,118) et l'area de «l'œil» du gigot (P> 0,883) entre les niveaux d'essai. Aucune différence significative (P> 0,454) était observée entre les niveaux d'essai pour l'hémoglobine, Moyenne Cellule Concentration d'Hémoglobine (MCCH) et le compte de globules blancs. Le glucose (P< 0,023), l' Aminotranferase d'Alanine (TAl) (P< 0,028), la protéine complète (P< 0,049) et l'urée sanguine (P< 0,048) ont montré les effets significatifs de niveau d'essai. Aucune différence significative n'a été observée pour l' Aminotranferase d'Asparatate (Tas) (P> 0,346) et le phosphate alcalin (P> 0,679). Les valeurs obtenues pour le TAl et le phosphate alcalin ont indiqué qu'il y avait un fonctionnement normal de la rate, les reins et le foie pour tous les niveaux d'essai. On conclut que DPA avec MFS et «Jett» donnés aux cochons rendent une performance acceptable de l'animal dans les tropiques.

1. Introduction

The advent of WTO, escalating grain prices and increasing demand for grain on the world market, makes it imperative to seek local feed sources for more sustainable pig production feeding systems in many tropical areas. One resource is fish waste (by-catch scrap fish, heads and offals) which is regularly discarded from processing plants, fish wholesale and retail markets. Worldwide discarded fish waste averaged 27 million tonnes per year which is about 30% of the total world catch (1). Spoilt fish harbours pathogenic bacteria, viruses, fungi, yeast and toxins which pose a potential risk to humans and the environment if not properly disposed of Machin (12). Summer (23) compared fish meal production and the process of making fish silage, and concluded that the latter is more suited for tropical conditions. The technique for making fish silage is cheap and simple (29). It can be made from by-catch or fish waste, preferably chopped or ground prior to the addition of acids (12) or carbohydrates (19). Of the mineral acids used in acid ensilage, sulphuric or hydrochloric were indicated as the best (7, 28).

Sugarcane plant (*Sacchrum officinarum*) and its by-products can be used as a major energy source for most livestock (21). Glucose, fructose and sucrose are carbohydrates of simple structure, which are found in variable proportions in sugarcane-derived feeds (10). Sugarcane final molasses (3), sugar cane juice (13), and Jett (4, 20) can be used as a source of energy for feeding pigs.

The objective of this study was to evaluate the performance of growing-finishing pigs fed diets composed primarily of acid ensiled fish waste (as a major protein source), sugarcane final molasses and Jett (combined as a source of energy) when compared to a typical commercial corn and soybean meal pig grower used by local farmers.

2. Material and methods

2.1. Animal and management

Twenty females (Landrace x Large White) with initial mean BW of 35.2 (± 0.6) kg and an average age of 13 weeks were used in the study. All pigs were treated with Ivermectin (obtained from ECO Animal Health, Southern Africa [Pty] Ltd) that effected control against gastrointestinal and external parasites. Pigs were tagged and housed in individual pens on solid concrete floors with dimensions of 1.6 × 0.75 meters. Throughout the trial water was provided *ad-libitum*, but feed was offered at the rate of 350 g DM.kg^{-1} BW. Body weights were taken and recorded weekly until the termination of the trial at 83 days. Animals were fed at approximately 9:00 am each day except on the day of weighing where it varied between 10 to 10:30 am. On the day of weighing fresh stool samples were collected from each animal for dry matter determination. Animals were observed daily at feeding for any abnormal behaviour.

2.2. Feeds and feeding

2.2.1. Preparation of acid silage

Fish waste and offals were collected from a local processing plant; the material was completely macerated into very small pieces and placed in plastic vats. The macerated material was mixed with

Table 1
Chemical analysis of Acid ensiled Fish Waste (AFW), Jett, and Sugarcane Final Molasses (SFM), Soya Bean Meal (SBM), Wheat Middlings (WMID) and Pig grower

Ingredients	DM ($g.kg^{-1}$)	CP ($g. kg^{-1}$ DM)	Ash	EE	Brix0	pH	Reducing sugars	Total sugars
AFW	297	545	124	71	-	1.5	-	-
Jett	575	-	-	-	38.5	4.1	187.2	484
SFM	801	37.2	102.3	-	75	5.2	270.3	376.0
SBM	824	470	57.3	14.9	-	-	-	-
WMID	849	195	48.3	23.4	-	-	-	-
Pig grower	899	171	49.8	31.3	-	-	-	-

diluted sulphuric acid (50%) at the rate of 60 $ml.kg^{-1}$. The mixture was then transferred to metallic vats where it was heated on an open flame for 45 minutes, cooled and then stored in 22.5 l plastic containers, and covered with hermetically sealed covers. The chemical composition of ensiled fish waste is given in table 1.

2.2.2. Jett and Sugarcane Final Molasses (SFM)
Both Jett (the liquid residue remaining after the refining of brown sugar to white sugar) and SFM were obtained from the local sugar refinery. The composition of both Jett and SFM is given in table 1

2.2.3. Diet formulation
The diets were formulated using the NRC (18) feeding standards as a guideline.
Based on results of a preliminary experiment, diets were formulated to contain 200 g $AFW.kg^{-1}$ DM allowing for the reduction of soybean meal (SBM) in the diet table 2.

Both Jett and SFM were used as an energy source in the diets, allowing for the reduction of up to 86.4% of the corn in the diet by weight. A commercial pig grower feed based on SBM and corn which is typical of that used by farmers was used as the control in this experiment.

2.3. Carcass evaluation

At the termination of the trial (83 days), pigs were slaughtered and the following parameters were measured: live weight prior to slaughter after a 24-h fast, weight of hot dressed carcass, loin eye area between the 12^{th} and 13^{th} rib, back fat thickness over the 12^{th} and 13^{th} rib both at the midline and P_2 site approximately 6.5 cm off the midline.

2.4. Chemical, blood and bio-chemical analysis

2.4.1. Proximate analysis
Proximate analysis was done on soybean meal, wheat

Table 2
Composition ($g.kg^{-1}$ DM) of the experimental diets and pig grower (Control)

		Levels of Jett/SFM (g kg^{-1} DM)			
	Control	100/100	200/0	259/259	517/0
Ingredients	T0	T1	T2	T3	T4
1. Wheat Middlings	0	70	70	70	70
2. Ground Corn	660.9	507	507	90	90
3. Soyabean Meal (SBM)	272.6	0	0	100	100
4. Acid ensiled Fish Waste	0	200	200	200	200
5. Jett	0	100	200	258.5	517
6. C-Molasses	25.6	100	0	258.5	0
7. Vit./Min Premix	9.6	10	10	10	10
8. Di-calcium phosphate	9.6	10	10	10	10
9. Limestone	18.4	0	0	0	0
10. Salt (Nacl)	3.3	3.0	3.0	3.0	3.0
Total	1000	1000	1000	1000	1000
Chemical analysis ($g.kg^{-1}$DM)					
Crude protein (N x 6.25)	171	164	165	166	166
DE $MJ.kg^{-1}$	13.6	14.7	14.7	13.6	13.6
Ca	11.0	10.9	10.9	11.1	11.1
P	5.4	6.3	6.3	5.8	5.8
Lysine	10.8	12.0	12.0	13.8	13.8

Middlings, acid ensiled fish waste and sugarcane final molasses according to the procedures outlined by the AOAC (2).

2.4.2. Water- soluble and reducing sugars
The water-soluble carbohydrates were determined as a brix^0 value using a refractometer, and reducing sugars and sucrose were determined by the method outlined by Miller (16).

2.4.3 Determination of pH
pH values were determined by means of an Expandable Ion Analyser EA 920 (Orion Research) and pH meter (Microprocessor Based pocket Size ATC pH tester model 59000-20) by Cole and Parmer.

2.4.4 Health of animals
Animals were observed daily at feeding for any abnormal behaviour or conditions that may have developed from being fed the experimental diets.

2.4.4.1 Blood and bio-chemical analysis
At the termination of the trial after a 24 hr fast with access to water only, animals were bled via the anterior vena cava. The blood samples taken were placed in vacutainers containing an anti-coagulant (potassium EDTA) for complete blood count and vacutainers without anti-coagulant for serum chemistry. Samples taken were immediately placed into a cooler with ice and transported within an hour to the laboratory for analysis. Complete blood count was done using an automated haematology analyzer model K-4500 manufactured by Sysmex Cooperation, Kobe, Japan.
Serum biochemistry was done using an automatic biochemical analyzer A Menarini Diagnostics (Classic model OM24452 Rev0-031980, manufacturer A. Menanini Diagnostics- via Sette, 3-Florence (Italy). STANBIO Laboratory Texas U.S.A supplied Kits for analysis of Alanine Aminotransferase (ALT), Aspertate Aminotransferase (AST), Alkaline Phosphate (AP), glucose, total protein, and blood urea.

2.5 Statistical design and analysis
There were five treatments, T0 (control, commercial pig grower) T1, T2, T3, and T4 with varying levels of Jett/SFM (Table 2). Each treatment had four replicates. These treatments were randomly allocated to the twenty pens resulting in a completely randomized design. Analysis of variance and Fisher's pair-wise comparison for mean separation were used for treatment comparison. In addition regression analysis of BW gain on level of Jett inclusion, and on dry matter intake was done to examine the response. In all cases, MINITAB statistical software (17) was used for analysis.

3. Results and discussions

3.1. Feeding varying levels of Jett and Sugarcane Final Molasses with Acid Ensiled Fish Waste

SFM is generally used to improve the palatability of dry feed where it is often incorporated at levels between 2 to 10% in the final mix. Some researchers have experimented with the inclusion of SFM and Jett in the ration of pigs as energy sources; these ingredients were generally fed separately in the ration (3, 4, 20). SFM at the dietary inclusion level of 200 g.kg-1 was found to be adequate and up to 300 g.kg^{-1} DM produced loose faeces and recommended not to be exceeded. Levels of Jett in the diet up to 680 g.kg^{-1} DM have been fed without any negative impact on performance.
In the current study these ingredients were fed in combination; SFM dietary inclusion level ranged from 100 to 259 g.kg^{-1} DM where as Jett ranged from 100 to 517 g.kg^{-1} DM. The regression of faecal dry matter on the dietary inclusion level of Jett showed a significant ($P< 0.024$) inverse relationship but the R^2 value was low (R^2= 25.2%). A similar response was observed when faecal dry matter was regressed on dietary level of SFM (R^2= 22%). JETT/SFM in the diets explained a 25% influence on faecal DM. Treatment T3 with a combination of 259 g SFM and 259 g Jett. kg^{-1} DM had the highest water intake (6.2 l.d^{-1}) and the lowest ($P< 0.05$) faecal DM (214 g.kg^{-1}), and ADG (468 g.d^{-1}) performance (Table 3).

Table 3
The Live performance of growing-finishing pigs fed, Jett and Sugarcane Final Molasses, with Acid ensiled Fish Waste

	Treatments levels of Jett/SFM (g.kg^{-1} DM)						
Parameters	T0 Control	T1 100/100	T2 200/0	T3 259/259	T4 517/0	±SEM	P-value
Initial BW (kg)	35.9	35.1	35.0	34.4	35.4	1.14	P> 0.953
Final BW (kg)	85.8	74.4	76.0	73.0	79.0	2.24	P< 0.046
Feed Intake (g DM.d^{-1})	2076	1526	1545	1458	1339	0.09	P< 0.001
Feed Intake (g DM.100 g^{-1}BW)	3.4	2.8	2.8	2.7	2.3	0.1	P< 0.001
Water Intake (l.d^{-1})	5.6	5.7	4.4	6.2	3.9	0.46	P> 0.059
ADG (g.d^{-1})	601	473	494	468	526	23	P< 0.031
FCR	3.5	3.3	3.1	3.1	2.6	0.13	P< 0.017
Faeacal DM g.kg^{-1}	378.5	333.9	313.2	214.1	264.6	2.67	P< 0.029

Ly and Mollineda (11) reported that liquid diets based on molasses do not contribute to having the stomach function as a digesta reservoir. Further, there is an increase in the diameter and area of the centrifugal colon which negatively affects anti-peristalsis, and would contribute to the incapacity of large intestine to absorb water. This may partially explain the excessive water content of the faeces and lower ADG performance.

3.1.1. Live performance of growing-finishing pigs.

The summary of the performance of pigs is given in table 3. There were significant differences ($P< 0.046$) among treatments for final bodyweight, dry matter intake (DMI), average daily gain (ADG) and, feed conversion ratio (FCR). DMI (g DM.100 g^{-1} BW) for treatment T1, T2, T3 and T4 ranged from 67.6 to 82.4% of the control T0. Where as average daily gain for pigs on treatment T1, T2, T3 and T4 where Jett and SFM supplied the major proportion of the dietary energy ranged from 468 to 526 $g.d^{-1}$. These values represented 78.5 and 87.5% of the ADG (601 $g.d^{-1}$) achieved by the animals fed the control diet, respectively. These values were also lower than pigs fed Jett by Diaz (14) and those fed conventional cereal diets under a tropical environment (6). Current technology have allowed for greater extraction of sugars during the refining process. Comparative composition between the Jett and SFM used in this study and the literature indicated that Jett had lower sucrose content (20) but SFM used was similar (27).

The regression of ADG on dietary inclusion level of Jett was explored. ADG on dietary inclusion level of Jett showed a significant ($P< 0.001$) cubic relationship (R^2= 90.8%) (Figure 1).

The carcasses were lean with low level of back fat at the P_2 site, thus, response observed would be indicative of the lean growth rate of these pigs (18). Ration with the highest dietary Jett inclusion level treatment T4 had the best FCR (2.6) giving a 25.7% improvement over the control (3.5). The protein contribution to the conventional pig diet by maize is not insignificant but has a poorly balanced amino acid profile (22), whereas Jett contains virtually no protein. When the diet is supplemented with equal amounts of protein from soybean meal and fishmeal or AFW, the Jett diet is likely to have a better amino acid composition. Even if the lysine component is correctly balanced, other amino acids may be in greater deficit on a maize-based diet (22).

3.1.2. Carcass analysis.

Summary of the carcass analysis is represented in table 4.

There were significant differences ($P< 0.047$) among treatments for bodyweight at slaughter and back fat at the midline. However, there was no significant difference in P_2 back fat ($P> 0.858$), hot carcass weight ($P> 0.065$), dressing % ($P> 0.118$) and loin eye area ($P> 0.883$). DP% was not so different from Tibbetts *et al*. (24), Speedy *et al*. (22) and Kjos *et al*. (8), but values were higher than those of Figueroa *et al*. (6) and Lallo *et al*. (9). Back fat (P_2 values) were well within acceptable limits for animals slaughtered within the

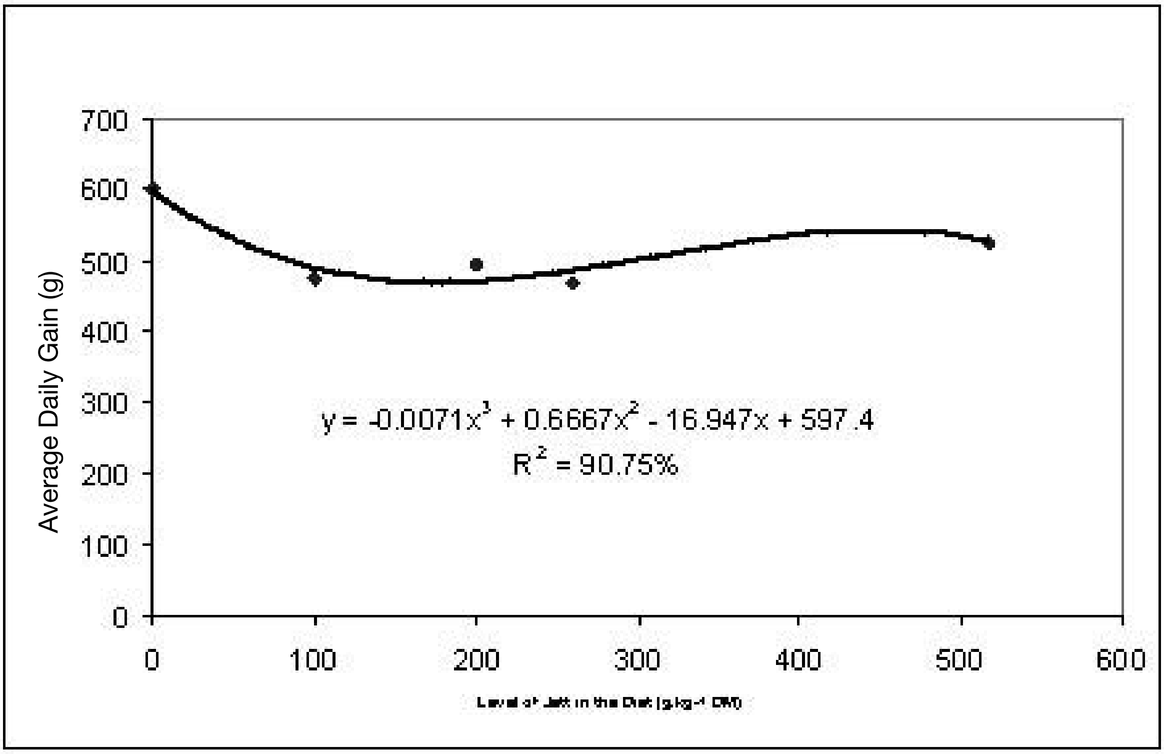

Figure 1: The response Average Daily of Gain ($g.d^{-1}$) to dietary Jett inclusion level, ($g.kg^{-1}$ DM).

Table 4
The Carcass Analysis for pigs fed Acid ensiled Fish Waste and varying levels of Jett and Sugarcane Final Molasses in the diet

	Treatments Levels of Jett /SFM (g kg^{-1} DM)						
Parameters	T0 (Control)	T1 100/100	T2 200/0	T3 259/259	T4 517/0	± SEM	P-Value
BW at Slaughter (kg)	83	70.8	72.5	70	76.3	2.5	P< 0.047
Hot Carcass Wt (kg)	61.6	57.8	53.1	51.9	51.7	2.33	P> 0.065
Dressing %	74.1	73.0	73.3	74.2	75.7	0.6	P> 0.118
Loin Eye Area (cm^2)	52.34	50.29	46.20	46.33	50.67	4.5	P> 0.883
BackFat midline (mm)	13.438	18.44	18.44	10.94	16.25	1.21	P< 0.010
P_2 (mm)	10.31	10.31	10.63	8.13	10.31	1.57	P> 0.858

weight range, and the values reflected the leanness of the carcasses. Back fat values were lower than that obtained by Speedy *et al*. (22) who investigated the comparison of sugar cane juice and maize as energy sources in diets of growing pigs. Similarly, the values for back fat were much lower than that of Velazquez and Preston (25), Tibbetts *et al*. (24), but not so different to that of Figueroa *et al*. (6) and Kjos *et al*. (8). These factors are, however, affected by breed, age, weight, feeding and health (26). Postmortem examination of the carcasses did not reveal any signs of ill health.

3.2. Blood chemistry and haematology for pigs

Blood chemistry and haematology values are summarized in table 5.

There were no significant differences (P> 0.454) among treatments for haemoglobin, MCHC, and white blood cell count. There were however significant differences (P< 0.017) in fibrinogen. Haemoglobin levels were within the reference values (14) for all treatments, which suggested that adequate iron was supplied by all the diets. MCHC of pigs on treatments T0, T1, T3 and T4 were all within the normal range. However, animal on treatment T2 had values 30% below the reference value but this was not significant (P> 0.454). Numbers of the various circulating blood cells vary with normal physiological as well as pathological conditions. It is also recognized that the variations that normally exist among individuals within a given population can be attributed to sex, age, nutrition, physical exertion, ambient temperature, and diurnal and sexual cycle.

Glucose (P< 0.023), ALT (P< 0.028), total protein (P< 0.049) and blood urea (P< 0.048) all showed significant differences among treatments. No significant differences were observed for AST (P> 0.346) and alkaline phosphate (P> 0.679). The alkaline phosphate levels were within the normal range (110-340 UL). The values obtained for ALT, AST and Alkaline phosphate indicated that there was normal spleen, kidney, and liver function (15). The glucose levels of pigs in the trial were within the normal range (3.8 to 5.38 mmol.l^{-1}), the higher levels observed for treatments T1, T2, T3, and T4 compared to the control (T0) would be reflec-

Table 5
Haematology and Bio-Chemistry Parameters for Pigs fed Varying Levels of Jett and Sugarcane Final Molasses in the diet

	Treatments Levels of Jett/SFM (g. kg^{-1} DM)						
Parameters	T0 (control)	T1 100/100	T2 200/0	T3 259/259	T4 517/0	± SEM	P-value
Blood urea (mmol.l^{-1})	3.8	2.65	1.85	3.275	4.175	0.43	P< 0.048
T. Protein (g.l^{-1})	75.75	69.25	63	67.75	73.75	2.21	P< 0.049
Alk. phoshate (µL)	134	89.4	145.75	133.25	141	22.3	P> 0.679
AST (UL)	46.25	88.25	51.75	68.5	57.75	8.9	P> 0.346
ALT (UL)	80.75	97	74.5	102	87	4.79	P< 0.028
Glucose (mmol.l^{-1})	3.83	4.925	5.38	4.65	5.33	0.28	P< 0.023
Hgb (g.l^{-1})	125	131.25	128.75	130	138.75	4.95	P> 0.598
Hct (l. l^{-1})	0.3925	0.415	0.4075	0.4075	0.4425	0.013	P> 0.325
MCHC (g.l^{-1})	318.75	316.25	238.54	318.5	313.5	3.72	P> 0.454
WBC 10^9.l^{-1}	22.98	21.63	20.45	24	21.95	4.3	P> 0.991
Lymphs 10^9.l^{-1}	16.28	12.26	9.695	14.985	12.74	2.3	P> 0.527
Total Solids (g.l^{-1})	77.75	71.5	67.25	69.25	74.75	1.73	P< 0.014
Fibrinogen (g.l^{-1})	3.5	2.5	2.0	1.5	2.25	0.3	P< 0.07

tive of the high levels of sugars in these diets. Blood urea levels were within the reference values (3.0-8.5 mmol.l^{-1}) for pigs on treatment T3, T4 and T0 but it was 11.6 and 38.3% below the normal range for T1 and T2. Blood urea is derived from the metabolism of protein and the amount of dietary protein consumed and digested often will alter blood urea (5). Treatment T1 and T2 had no soybean meal the major source of protein outside of AFW came from corn.

Conclusions

It was concluded that AFW with SFM and Jett when combined in a balanced ration and fed to pigs can give acceptable performance under tropical conditions. AFW with SFM and Jett when combined lead to a reduction in the level of imported soybean meal and corn in the ration.

However, there is a need for further work to be done in order to further improve performance.

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