RESPONSE OF RABBITS TO CEREAL BY-PRODUCTS AS ENERGY SOURCES IN DIETS

RESPUESTA DE LOS CONEJOS A LA INCLUSIÓN EN LA DIETA DE SUBPRODUCTOS DE CEREALES COMO FUENTES DE ENERGÍA

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ADDITIONAL KEYWORDS

Cereal offals. Performance traits. Carcass yield. Maize. Millet. Sorghum.

PALABRAS CLAVE ADICIONALES

Rendimientos. Canal. Maíz. Mijo. Sorgo.

SUMMARY

The nutritive value of cereal offals as energy sources in diets for rabbits was assessed. Four diets containing equal levels of crude protein (170 g/kg) were formulated. Maize grain was used as control (diet 1) which was replaced by maize, millet and sorghum offals in diets 2, 3 and 4, respectively. Forty New Zealand White X Chinchilla growing rabbits of both sexes which weighed 915±6 g (mean±standard deviation) at start of the study were assigned to 4 diets (10 rabbits/diet).

Millet offal contained higher crude protein, crude fibre and ash concentrations than maize or sorghum offals; but maize offal was higher in fat than the two other offals. Gross energy content of sorghum offal was closer to that of maize grain and higher than values for maize or millet offals. The average daily feed, digestible energy (DE), crude protein and water intakes of rabbits on diets 2 or 3 were higher ($p<0.01$) and resulted in greater daily weight gains ($p<0.05$) than animals on diets 1 or 4. Feed and protein utilization efficiencies were similar among rabbits on the different diets except that rabbits on diet 4 utilized protein more efficiently ($p<0.05$) than those on diet 1. Digestibility of nutrients was significantly ($p<0.01$) higher with diet 1, similar between diets 2 and 3, and lower ($p<0.01$) with diet 4. The carcass yields and organ weights were not significantly ($p>0.05$) affected by the diets fed; however, caecal digesta from rabbits fed diets 1 or 4 were lighter ($p<0.05$) than the ones from rabbits on diets 2 or 3.

RESUMEN

Se determinó el valor nutritivo de los subproductos de cereales como fuentes de energía en las raciones para conejos. Se for-

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mularon cuatro raciones isoproteicas (170 g de proteína bruta/kg). El grano de maíz (dieta 1) se usó como control que fue reemplazado por subproductos de maíz, mijo y sorgo en las dietas 2, 3 y 4 respectivamente. Cada dieta se suministró a un lote de 10 conejos en crecimiento de ambos sexos de raza New Zealand White x Chinchilla que al comienzo del estudio pesaban 915±6 g.

El subproducuto de mijo, contenía mayor cantidad de proteína bruta y ceniza que los de maíz o sorgo, pero el subproducto de maíz contenía mayor cantidad de grasa que los otros dos. La concentración de energía bruta del subproducto de sorgo fue cercana a la del grano de maíz y superior a los subproductos de maíz y sorgo. Las ingestiones medias diarias de energía digestible (DE), proteína bruta y agua fueron más altas (p<0,01) y determinaron mayores ganancias diarias de peso (p<0,05) en las dietas 2 y 3 que en las dietas 1 y 4. La eficacia de utilización del alimento y de la proteína fueron similares en los conejos alimentados con todas las dietas, aunque en la 4, la que la proteína fue utilizada más eficazmente (p<0,05) que en la 1. La digestibilidad de los nutrientes fue significativamente (p<0,01) más alta en la dieta 1, similar en las dietas 2 y 3 y menor (p<0,01) en la dieta 4. Los rendimientos a la canal y peso de los órganos no fueron afectados por las raciones empleadas, sin embargo, los contenidos cecales fueron menores en las dietas 1 y 4 (p<0,05).

INTRODUCTION

Insufficient supplies of feedstuffs at economic prices have continued to limit the production and thus, availability of animal protein in the diets of humans in the developing countries. The situation has compelled animal nutritionists to intensify research into alternative feed sources to reduce cost of animal proteins. Perhaps the most researched area of monogastric animal nutrition is in grain replacement. Several studies have demonstrated the possibility of incorporating high levels (20-30 percent) of wheat straw (de Blas *et al.*, 1979; Masoero *et al.*, 1984), wheat bran (Villamide *et al.*, 1989) and rice by-products (Raharjo *et al.*, 1988 a, b; Kasa *et al.*, 1989) into balanced diets for rabbits with few deleterious effects on their growth performance.

Presently, tropical agricultural extraction industry turns out large quantity of by-products annually which may have nutritive potential as animal feedstuffs. Cheeke (1986) recommended that further research into the nutritional content and digestibility of tropical feeds and by-products was needed to develop efficient feeding systems for rabbits in the tropics and sub-tropics. In Nigeria, there has been a steady increase in grain production since the restriction of importation of grains and other livestock feedstuffs in 1986. A large proportion of cereals (maize, millet and sorghum grains) are processed by breweries and flour industries with a resultant increase in the output of their by-products (offals). These by-products are not directly utilizable by humans; therefore, the possibility of converting them into cheap and wholesome animal products for human consumption could be exploited. However, while there is documentary evidence for the utilization or possibility of utilizing millet and sorghum grains as feedstuffs for monogastric animals (Luis *et al.*, 1981; Okoh *et al.*, 1982), similar reports on their by-products are not known to the authors. The objective of this study was to assess the grain replacement value of the cereal offals in diets for rabbits using maize grain as control.

MATERIALS AND METHODS

CEREAL OFFALS

The maize, millet and sorghum offals were obtained from a local milling factory in Sokoto as by-products of the respective grains. They consist essentially of the aleurone layer (bran) of the grains which was removed before grinding. However some broken particles of the endosperm are usually included, depending on the efficiency of the milling machine. All the offals were assayed for residual moisture, crude protein, fat (ether extract), ash and crude fibre using standard procedures (AOAC, 1990). Gross energy values (using Gallenkamp oxygen ballistic bomb calorimeter) of the offals were also determined. Samples of sorghum offal were analysed for tannin content. Tannins were extracted with methanol and estimated by the vanillin hydrochloric acid method of Burns (1971).

DIETS

Four isonitrogenous diets were formulated to provide 170 g crude protein/kg diet and similar levels of crude fibre by adjusting the levels of groundnut meal, and rice hull, respectively, in each of the dietary treatments **(table I)**. The control diet (diet 1) contained maize as the major energy

Table I. *Composition of experimental diets.* (Composición de las dietas experimentales).

Ingredients (g/kg dry matter)	Diets 1 Maize grain	2 Maize offal	3 Millet offal	4 Sorghum offal
Ground maize	504	-	-	-
Maize offal	-	559	-	-
Mllet offal	-	-	568	-
Sorghum offal	-	-	-	519
Groundnut meal	163	148	139	168
Soya bean meal	100	100	100	100
Rice hull	200	160	160	180
Sodium chloride	5	5	5	5
Bone meal	10	10	10	10
Ground limestone	15	15	15	15
Vitamin and mineral premix*	3	3	3	3
Total	1000	1000	1000	1000

*Zoodry (Roche) vitamin and minerals premix, supplying the following per kg diet: Vitamin A, 5000 i.u; D_3,1140 i.u.; E, 6.0 i.u; K, 0.8 mg; B_1, 0.6 mg; B_2, 2.4 mg; B_6, 1.4 mg; nicotinic acid, 14.0 mg; calcium pantothenate, 4.0 mg; biotin, 0.02 mg; B_{12}, 8.0 mg; folic acid, 0.04 mg; Vitamin C, 10.0 mg; choline chloride, 120.0 mg; bacitracin, 8.0 mg; methionine, 80.0 mg; manganese, 40.0 mg; iron, 20.0 mg; zinc, 18.0 mg; copper, 0.8 mg; iodine, 0.62 mg; cobalt, 90.0 mg; selenium, 40.0 mg.

source while in three others maize grain was totally replaced by maize offal (diet 2), millet offal (diet 3) or sorghum offal (diet 4). Methionine supplementation in each diet was very low (80 mg/kg diet; provided in the premix).

ANIMALS AND FEEDING TRIALS

In order to determine the feeding value of the offals, 40 New Zealand White X Chincilla growing rabbits of both sexes from the same farm were used. Prophylactic medication a week prior to commencement of the study included wormer (Ivermectin, by MSD, U.S.A., 20 ug/kg body weight) and coccidiostat (Amprolium, by Alved Pharma, India, 0.04 percent in drinking water). The animals weighed 915±6 g (mean ± standard deviation) at the start of the feeding trial. The rabbits were randomly distributed into 4 dietary treatments of 10 rabbits each on weight basis. The animals were individually housed in metal cages where feed and water were provided *ad libitum* throughout the 70-day experimental period. Rearing of the animals was done under natural lighting of 12 h/day (06.00-18.00 h). Data on feed consumption and weight gains were recorded weekly but those of water intakes were recorded daily.

DIGESTIBILITY AND CARCASS YIELD

On day 61 of the trial all rabbits were transferred to metabolism cages where the first 3 days of feeding were used as adjustment period. Faecal collection for measurement of nutrient digestibility was done during the last 7 days (64-70) of the trial. The daily faecal output was stored in deep freezer (-18°C) until day 70 before they were dried for 48 h at 60°C to constant weight. Chemical composition and gross energy of the diets and faecal samples were determined as describes for the cereal offals (AOAC, 1990). On day 70, rabbits were deprived of food for 12 h, weighed and anaesthesized (using diethyl ether), exsanguinated and eviscerated. Body organs were removed from each rabbit, weighed fresh and later expressed as

Table II. *Determined chemical contents of the diets and cereal offals.* (Componentes quimicos determinados en las raciones y residuos de cereales).

Nutrients (g/kg dry matter)	Diets 1	2	3	4	Offals Maize	Millet	Sorghum
Dry matter	882	891	887	889	903	894	886
Crude protein	173	174	174	172	115	121	78
Ether extract	63	77	65	61	46	38	28
Crude fibre	196	195	208	197	90	116	76
Ash	77	84	111	98	36	72	45
Carbohydrate (NFE)	521	470	442	492	713	653	773
Gross energy (MJ/kg)	18.05	16.18	16.10	17.09	15.18	14.89	16.70
Digestible energy (MJ/kg)	12.8	10.9	10.8	10.0	-	-	-

percentages of final body weight at slaughter. The eviscerated carcasses were roasted to remove fur for the determination of carcass yield. Analysis of variance was used to statistically examine data generated from the study and differences among the means were tested by Duncan's multiple range test (Steel and Torrie, 1980).

RESULTS

CHEMICAL COMPOSITION OF CEREAL OFFALS (TABLE II)

Millet offal contained more crude protein, crude fibre and ash than the maize or sorghum offals. On the other hand, maize offal was slightly higher in fat than millet and much higher than sorghum offals. Similarly, sorghum offal had higher carbohydrate (NFE) and gross energy concentrations than maize or millet offal; but maize offal was superior to millet offal in concentration of the two nutrients. Tannin content of sorghum offal was 4.13 g/kg dry master.

PERFORMANCE OF ANIMALS (TABLE III)

Voluntary feed intake of rabbits on diets 2 and 3, respectively, were similar (p>0.05) but these were significantly (p<0.01) higher than those of animals on diets 1 or 4. Consequently, the two diets supported similar daily weight gains of rabbits better (p<0.05) than diets 1 or 4. In addition there were significant (p<0.01) effects of diets on protein, digestible energy (DE), and water intake; the patterns of which paralleled changes in feed intake of

Table III. *Performance traits of rabbits fed reference and test diets.* (Rendimiento de los conejos alimentados con las diferentes raciones).

Performance traits (Mean)	Diets 1 Maize grain	2 Maize offal	3 Millet offal	4 Sorghum offal	SEM	p<
Initial body wt (g)	905.8	920.8	916.5	916.7	-	-
Final body wt (g)	1780.6^{b}	2019.8^{a}	2098.9^{a}	1826.8^{b}	5.51	0.05
Weight gain (g/day)	12.6^{b}	15.7^{a}	16.9^{a}	13.0^{b}	1.31	0.05
Feed intake (g/day)	43.2^{b}	54.5^{a}	57.7^{a}	48.1^{b}	4.12	0.01
Digestible energy intake (MJ/day)	0.56^{b}	0.60^{a}	0.62^{a}	0.54^{c}	0.01	0.05
Crude protein intake (g/day)	5.9^{b}	6.l^{ab}	6.4^{a}	4.6^{c}	0.64	0.01
Water intake (ml/day)	159.4^{b}	207.3^{a}	211.4^{a}	129.1^{c}	5.86	0.01
Feed/gain	3.5	3.5	3.4	3.7	0.13	ns
Digestible energy/gain	44.1^{a}	38.1^{b}	36.9^{b}	41.3^{ab}	1.31	0.05
Gain/protein	2.4^{b}	2.6^{ab}	2.6^{ab}	2.8^{a}	0.41	0.05
Water/gain	12.8^{a}	13.2^{a}	12.5^{a}	9.9^{b}	1.87	0.05

^{abc}Means in a row with different superscript differ (p<0.01 or p<0.05)
ns: No significant difference among means in a row.

rabbits on diets 1, 2 and 3. However, intakes of the three nutrients in diet 4 were lowest. On the contrary, diet 1 significantly ($p<0.01$) induced higher water intake than diet 4, although the latter diet was consumed more than diet 1. No significant differences were found in feed utilization efficiencies among the animals except that gain/ protein ratio of rabbits fed diet 4 was higher ($p<0.05$) than that of animals on diet 1.Water was also more efficiently ($p<0.05$) utilized by rabbits on diet 4 than rabbits on the three other diets. Similarly, diet 1 was less efficient in DE utilization of animals in comparison with diets 2 and 3.

NUTRIENT DIGESTIBILITY COEFFICIENTS (TABLE IV)

The nutrients in diet 1 were consistently and significantly ($p<0.01$) better digested than the ones in test diets. Exception to this trend was the depressed ($p<0.05$) digestibility of crude fibre in the reference diet in relation to values obtained from the test diets. Digestibility coeffiicients of all the nutrients in diets 2 and 3 were similar. On the other hand, digestibility of dry matter, crude protein, ash and carbohydrate fractions in diet 4 decreased thus reducing their availability to animals significantly ($p<0.01$). Overall, fat was best digested followed by carbohydrate whereas digestibility of crude fibre and ash appeared relatively poor.

CARCASS YIELD AND ORGAN WEIGHTS (TABLE V)

The mean carcass dressing-out percentages did not differ appreciably among animals on the reference and test diets. Also, the relative weights of organs were remarkably similar. In contrast, the caecal digesta, expressed as percentages of live body weight, from animals fed diets 1 or 4 were lighter ($p<0.05$) than the digesta from

Table IV. *Apparent digestibility (percent) of nutrients in reference and test diets.* (Digestibilidad aparente, p.100, en las raciones empleadas).

Nutrients	Diets 1 Maize grain	2 Maize offal	3 Millet offal	4 Sorghum offal	SEM	p<
Dry matter	74.8[a]	70.4[b]	69.2[b]	64.3[c]	1.9	0.01
Crude protein	78.6[a]	68.2[b]	67.5[b]	60.4[c]	2.0	0.01
Fat (ether extract)	93.8[a]	83.8[b]	86.0[b]	83.9[b]	1.4	0.05
Crude fibre	23.1[b]	29.0[a]	27.7[a]	25.4[ab]	1.0	0.05
Ash	35.6[a]	26.7[b]	26.9[b]	11.7[c]	1.8	0.01
Carbohydrate	81.0[a]	78.4[b]	77.7[b]	70.6[c]	1.8	0.01
Gross energy	71.3[a]	67.7[b]	67.1[b]	64.1[b]	1.1	0.05

[abc]Means in a row with different superscripts differ ($p<0.01$ or $p<0.05$).

rabbits offered diets 2 or 3.

DISCUSSION

The cereal offals were used primarily to supply energy at the expense of maize grains despite their lower gross energy values. For instance, gross energy content of maize grain was reported to be 18.47 or 18.17 MJ/kg (Luis *et al.*, 1981; Onifade and Tewe, 1993, respectively) compared with 15.18 and 14.89 MJ/kg of maize and millet offals, respectively. The low crude protein, crude fibre and ash components of sorghum offal accounted for its relatively high carbohydrate fraction. This explained its high gross energy value which was close to that of maize grains. The higher fat content of maize offal was reflected in diet 2 and could boost DE content of the diet. Although millet offal had high ash value, the calcium and phosphorus contents of millet grains are similar to those of sorghum or maize grains (Luis *et al.*, 1981). Therefore, the higher ash content of millet offal may have been due in part to the presence of silica.

The observed significantly high intake of diets 2 and 3 was due to the lower energy contents of both diets. In an attempt to compensate for the low caloric content of the diets, rabbits consumed more feed and consequently more DE which manifestad in higher weight gains by the animals. The average daily weight gains recorded in the present study were similar to the 15.6

Table V. *Carcass yield and organ weights (percent of final body weight) of rabbits fed diets of different cereal offals*. (Rendimiento a la canal y pesos de los órganos, p.100 del peso corporal final, de conejos alimentados con raciones a base de diferentes residuos de cereales).

Organs (p.100 body weight)	Diets 1 Maize grain	2 Maize offal	3 Millet offal	4 Sorghum offal	SEM	p<
Carcass yield (p. cent)	67.7	68.4	67.6	67.8	0.95	ns
Liver	2.8	3.0	2.6	2.6	0.22	ns
Heart	0.2	0.2	0.3	0.2	-	ns
Lungs	0.4	0.4	0.4	0.3	-	ns
Kidneys	0.6	0.7	0.7	0.6	-	ns
Testes	0.2	0.2	0.3	0.4	-	ns
Spleen (g)*	0.5	0.5	0.6	0.4	-	ns
Stomach	1.0	1.1	1.2	1.0	-	ns
Caecum	1.2	1.4	1.4	1.3	-	ns
Gastric content (p.100 body weight)	3.8	3.6	3.8	3.8	0.43	ns
Caecal content (p.100 body weight)	4.8[b]	5.4[a]	5.9[a]	4.8[b]	0.65	0.05

[ab]means in the same row with different superscript differ (p<0.05). ns, no significant difference (p>0.05).
*spleen was not expressed as p. cent body wteight because it was very light, negligible.

g reported for rabbits fed cassava root meal fortified with fish meal and palm oil (Omole and Onwudike, 1982), 12 g for rabbits on broiler mash (Ekpenyong, 1984) and 13.4 g for rabbits on maize diet (Onifade and Tewe, 1993). Moreover, average daily gains of 15-20 g have been reported to be the common range in the tropics (Aduku and Olukosi, 1990). Feed conversion and protein utilization efficiencies in this study seemed to be superior to the 4.6 and 1.2, respectively, reported by Onifade and Tewe (1993) when rabbits were fed maize grain diet. However, the feed conversions by rabbits in this study were similar to that of 3.01 and 3.02 for rabbits on starch and digestible fibre diets, respectively (Gidenne and Jehl, 1996). The poorer DE utilization in diets 2 and 3 is difficult to explain. lt seemed that the lower the digestibility of nutrients the higher were the efficiencies of their utilization.

Digestibilities of dry matter, protein, ash and carbohydrate in diet 4 were poorer than in the rest of the diets due to high tannin content of sorghum offal. Tannin is refuted for depressing nutrient digestibility and utilization (Vohra *et al.,* 1966; Nelson *et al.*, 1975). Nutrient digestibilities in this study were higher than values reported by de Blas *et al.* (1989) for rabbits fed wheat straw diets. Similarly, values obtained with wheat bran, and dried distillers grains and solubles (Villamide *et al.*, 1989) were lower than the values recorded in this work. The differences might be related to the nature of fibres in terms of their digestibilities. Fibres from the cereal offals are supposedly *soft* whose undigestible fractions were relatively lower than the ones used by the other authors. For instance, Fekete and Gippert (1986) have also reported a higher fibre digestibility for corn than for wheat grains.

The generalised polydipsia among the experimental rabbits was accentuated by the more intake of diets 2 and 3 which was necessary for adequate digestion of the diets. In general, there is close positive relationship between feed and water intake in most domestic animal species (Kasa *et al.,* 1989). However, result of water intake of animals on diet 4 was at variance with the known feed-water relationship. A plausible explanation for the variation was the high tannin content of sorghum offal which probably depressed thirst of the animals.

The similar results for carcass yield from animals on the reference and test diets showed that none of the diets adversely affected the edible portion or body organs of rabbits. In computing the carcass yield, the head and feet were left on the carcass in addition to intact skin. This probably explained the higher yield recorded in our study compared to the 60-62 percent in Europe where rabbits are flayed; or the 50 percent in United States of America where head and feet are removed (Aduku and Olukosi, 1990). The higher weights of fresh caecal digesta from rabbits on diets 2 or 3 resulted from the higher intake of the diets and/or increased water holding capacity of digestible fibre (Cherbut *et al*., 1988) of the digesta.

CONCLUSION

The study has shown that maize

and millet offals possess good feeding values as energy sources in diets for rabbits and supported faster rates of gains than maize grains. The use of the offals in commercial quantity when compounding diets for rabbits could, therefore, reduce cost of feeds and make rabbit products available at cheaper prices in the developing countries where the offals are readily available.

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