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Effects of oven-drying tubers of two high-protein sweet potato varieties at different temperatures on their feeding value in broilers

S. PANIGRAHI, E. B. OGUNTONA[1] AND B. R. ROBERTS

Natural Resources Institute, Central Avenue, Chatham Maritime, Kent ME4 4TB, England and [1]*University of Agriculture, PMB 2240, Abeokuta, Ogun State, Nigeria*

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Abstract 1. Unpeeled tubers from 2 high-protein varieties of sweet potato (white-fleshed Bosbok, and orange-fleshed Carmel) were chipped and oven-dried at 40, 60, or 80°C, to examine the effects on nutritive value. The dried ground chips were substituted for maize at 500 g/kg and the diets fed to day-old, Ross-1 broiler chicks for 3 weeks.

2. Compared with Carmel, Bosbok had a lower crude protein content (90 *v.* 138 g/kg DM) and trypsin inhibitor activity (TIA) (3 *v.* 5 mg of trypsin inhibited per g flour). Processing did not significantly affect TIA, but the lysine and cystine contents were lowered and the starch content raised as the drying temperature increased. However, whereas this was reflected in increased reducing sugars in Carmel, there was no trend in Bosbok.

3. The results of *in vitro* pancreatin digestibility and total dietary fibre assays showed variety and processing temperature to be significant factors influencing the nutritive value of sweet potato tubers, with a variety × temperature interaction also being indicated. The interaction was also observed for weight gain, dry matter intake, water : food intake ratios, excreta water content, presence of bile in excreta and liver weights. The best growth was obtained with Bosbok dried at 60°C, for which liveweights at 21 d were 11% lower than for the maize controls.

INTRODUCTION

Sweet potato *(Ipomoea batatas)* is a traditional food crop in many societies. However, the utilisation pattern during the last 30 years reveals a significant shift towards processing for animal feed (Scott and Suarez, 1994). Fresh sweet potato tubers have a low dry matter content, which can range from between 136 and 351 g/kg for different varieties (Tsou and Villareal, 1982). The water content needs to be reduced before the raw material can be converted into particles sufficiently small for consumption by chicks and before it can be readily mixed with other dietary ingredients. The cost of drying (and factors affecting this, e.g. initial dry matter content) and the nutritional value of the meal are the major criteria for the selection of sweet potato varieties and processing techniques for poultry feeding.

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Sweet potato tuber has frequently been compared with maize in terms of its value in poultry diets. There is, however, much disagreement on the extent to which this substitution can take place without losses in production, with Tillman and Davis (1943) reporting that sweet potato could replace only 10–20% of maize in chick diets, Job *et al.* (1979) reporting that a 60% replacement (i.e. 344 g/kg dietary sweet potato) was possible and, more recently, Tewe (1994) reporting that a 30% replacement of maize, equivalent to an inclusion rate of 180 g sweet potato/kg diet was optimal. Part of the reason for these conflicting reports lies in the considerable variation that has been reported in the nutritional composition of, and anti-nutritional factors in, different varieties of sweet potato tubers. Thus, the protein content may range from 13 (Li, 1982) to 131 g/kg dry matter (Collins and Walter, 1982) and starch digestibility may vary from 29·4 to 76·8% of that of maize starch (Zhang *et al.,* 1993). Similarly, anti-nutritional components may be present in variable concentrations, notably trypsin inhibitors which can vary from 0·3 to 36·3 trypsin inhibitor units per g of fresh tubers (Bradbury *et al.,* 1985) and furanoterpenoid compounds may be produced in certain stress conditions, such as during fungal attack and weevil damage (Woolfe, 1992).

These considerations are further complicated by the fact that processing conditions may affect the nutritive value of sweet potato. Thus roasting, a common traditional method of preparing sweet potato tubers for human consumption, imparts sweetness to the foodstuff by activating the amylases present such that some starch is hydrolysed to sugars. It is, therefore, not surprising that Furuya (1986) reported that the digestible energy of sweet potato for pigs depended on processing methods, the value increasing progressively for freeze-dried, sun-dried, oven-dried, and boiled tubers. Because Tewe (1994) confirmed that oven-drying was superior to sun-drying in terms of growth responses in chicks, it is tempting to speculate that the slower rates of drying achieved in oven-drying compared with sun-drying, enhances the digestible energy to a greater extent by converting more of the starch into sugars. Tewe (1994), however, also suggested that the unacceptability of dietary sweet potato may be attributed to the presence of high concentrations of sugars in the tubers.

These reports have led to the postulate that different conditions of chipping and drying could have different effects on the nutritive value of sweet potato varieties for broiler chicks, with the implication that some varieties might be more suitable for development as a dietary ingredient for poultry. It is especially important to identify any processing conditions that might produce adverse effects on the nutritional value of the tuber meal and to develop techniques that produce meals of a consistent nature and high quality. This is of particular importance in tropical developing countries where sun-drying is generally more cost-effective than oven-drying and where the effects of seasonal climatic conditions (e.g. temperature and humidity) also need to be considered.

Because the selection of sweet potato genotypes and appropriate tuber drying methods are the major factors affecting its utilisation by poultry, it is essential to determine whether these factors could interact to influence its nutritional value. The present study, therefore, investigated the responses of young broiler chicks to diets containing processed tubers of 2 varieties of sweet potato, oven-dried at different temperatures. In addition the experiment was designed to determine the replacement value of a high protein sweet potato for maize when included at 500 g/kg in broiler chick diets.

MATERIALS AND METHODS

Processing the tubers

Two varieties of sweet potato, commercially imported into the UK in 1993, were used. These were the South African 'Bosbok', which has a reddish-purple skin and white flesh, and the Israeli 'Carmel', which is smaller and rounder than Bosbok, and has an orange-yellow flesh. The tubers were rubbed clean to remove as much soil as possible, and chipped in a Crypto Peerless Dito Sama TRS Electric food processor to produce chips of 1 to 3 mm thickness. Chips were piled approx. 2 cm deep on aluminum foil-lined trays and placed in a force-draught Hedin drier. The temperatures were set at 40, 60 or 80°C for both varieties of sweet potato, each treatment being carried out in a separate single batch. For the 80°C treatment, it took about 10 h for the oven to reach the required temperature, whereas with the 60 and 40°C treatments the temperatures were reached in about 8 and 5 h, respectively. The chips were turned over periodically to facilitate drying, and were collected when they appeared sufficiently dry. The total time required for drying varied between 20 h at 80°C, 32 h at 60°C and 43 h at 40°C. Tuber processing was completed within 5 d of their procurement in order to minimise rotting and associated changes. Dried chips appeared to be darker brown, with no discernible difference being noted between the 2 varieties. From the weights of fresh and dried chips processed, the dry matter contents of the 2 varieties were estimated as 135 g/kg for Bosbok and 130 g/kg for Carmel. The chips were ground through a 4 mm screen for the broiler trial.

The proximate compositions of sweet potato samples were determined according to the methods recommended by the Ministry of Agriculture, Fisheries and Food (1986). Analyses of starch and sugars were carried out by ethanol extraction (stage one) followed by determination of reducing sugars using potassium ferricyanide. Total sugars were determined by hydrolysing an aliquot of the aqueous extract in 0·7M hydrochloric acid, followed by potassium ferricyanide detection. The starch content was analysed by hydrolysing the insoluble residue from stage one in 0·7M hydrocholoric acid and determining the reducing sugar content by reaction with potassium ferricyanide. The amino acid composition of hydrochloric acid-hydrolysed dried and defatted samples was determined using a Biotronik Amino Acid LC5000 Analyser. Trypsin inhibitor activity (TIA) was determined by a modification of the method of Smith *et al.* (1980). However, because this method gave slightly different results between batches and the values depended on the quantity of sample used in the assay, the small differences between samples as a result of different sweet potato tuber processing temperatures may not be reliable. Biochemical assays included dietary fibre (TDF), as described by Prosky *et al.* (1985), without adjusting for residual nitrogen and pancreatin digestibility using a modified method of Zhang *et al.* (1993).

Broiler trial

The dried sweet potato tuber meal samples were substituted for maize that was included at 500 g/kg in a broiler chick starter diet calculated to contain 240 g crude protein/kg and 12·65 MJ AME/kg. The compositions of the experimental diets are shown in Table 1.

Day-old, Ross-1 broiler pullets (weighing approximately 40 g) were housed in

Table 1. *Composition of the experimental diets (g/kg unless otherwise stated)*

Ingredients:	Inclusion rate
Maize or sweet potato	500·0
Wheatfeed	16·0
Fishmeal	104·4
Soyabean meal	223·0
Sunflower meal	111·5
Maize oil	32·0
Limestone	6·0
Sodium chloride	1·1
Methionine	1·0
Vitamin/mineral premix	5·0
Calculated analyses:	
Moisture	880·0
Crude protein	240·0
Crude fibre	48·8
Crude fat	67·1
Ash	65·7
Calcium	10·0
Phosphorus	7·5
Lysine	14·2
Methionine + cystine	9·5
Apparent metabolisable energy (MJ/kg)	12·80

The calculated crude protein contents of diets were (g/kg): Control diet 240; Bosbok at 40°C 232; Bosbok at 60°C 238; Bosbok at 80°C 237, Carmel at 40°C 253; Carmel at 60°C 256; Carmel at 80°C 257.

metabolism cages in an environmentally controlled room, maintained in accordance with Ross Poultry recommendations. The caging system comprised 2 blocks of 16 cages, with each block having 4 tiers. Dietary treatments were allocated at random to the 32 cages, with 4 of the treatments (Bosbok at 60°C, Bosbok at 80°C, Carmel at 40°C and Carmel at 80°C) being replicated 5 times (20 chicks) and the other 3 being replicated 4 times (16 chicks). The diets were fed *ad libitum* and food intakes and weight gains for each cage were recorded weekly. Water intake was also recorded during the first 8 d. A nutrient retention study was conducted between 11 and 14 d, using the total collection method; excreta were oven-dried at 60°C. Diets and excreta were analysed for gross energy contents using a Gallenkamp adiabatic oxygen bomb calorimeter and for nitrogen contents using a Kjeltic 1030 analyser. From the balance studies, dry matter retention, apparent metabolisable energy (AME) values and nitrogen retention of diets were calculated. The AME values were corrected for nitrogen equilibrium (zero retention) using a factor of 34·4 kJ/g nitrogen retained in the body.

After 14 d birds were transferred to larger cages and feeding was continued for a further week, in duplicates of 8 chicks per cage. Live weights of the birds were recorded per cage at the beginning and end of this period. Chicks were starved for 20 h before slaughter and post mortem examination, where the weights of liver and pancreas were recorded.

Table 2. *Composition of the dried sweet potato tuber meals (g/kg DM unless otherwise stated*

Sweet potato variety	Bosbok			Carmel		
Drying temperature (°C)	40	60	80	40	60	80
Dry matter (g/kg)	909·5	916·2	921·2	903·6	919·1	935·3
Crude protein	87·2	99·1	97·7	134·0	139·3	138·6
Crude fibre	44·5	—	—	60·8	—	—
Crude fat	6·7	4·8	5·2	13·5	12·2	10·9
Ash	53·9	60·7	58·5	89·6	91·9	92·5
Calcium	2·9	—	—	3·3	—	—
Phosphorus	3·0	—	—	3·4	—	—
Reducing sugars	166·9	141·1	169·0	169·0	111·7	80·3
Total sugars	359·3	307·7	354·0	373·6	349·6	283·8
Total starch	350·3	395·3	407·6	226·2	298·1	351·9
Trypsin inhibitor activity (mg trypsin inhibited per g sample)	2·2	3·2	3·5	5·4	5·2	5·2

Statistical analyses

Experimental data were treated to factorial analysis of variance using a general linear model (Statgraphics for Personal Computer) that adjusted for the unbalanced design. The relationships between performance indices and other symptoms in birds, and the chemical composition of the tubers were examined by simple linear regression.

RESULTS

Chemical composition of dried sweet potato tuber chips

The proximate compositions, trypsin inhibitor activity and starch and sugar contents the 6 sweet potato samples are shown in Table 2. The Bosbok variety has a lower crude protein than the Carmel variety (9 g/kg DM *v.* 13 g/kg DM); these concentrations are at the higher end of the range commonly reported for sweet potato tubers. The crude protein contents of the dried samples were found to be lower after processing at 40°C compared with heating at 60 or 80°C, particularly for Bosbok. The reason for this is not clear.

The amino acid compositions of the samples are shown in Table 3. For both varieties of sweet potato the lysine content decreased as the temperature of drying increased, the reduction was almost double in Bosbok compared to that in Carmel. There was also a smaller decrease in the cystine content of similar magnitude for both varieties. Changes in other amino acids were variable.

The processing temperature had major effects on the carbohydrate composition of the sweet potato tuber meal. The total starch content decreased at lower drying temperatures for both varieties; however, whereas in Carmel there was a corresponding increase in total sugars and reducing sugar concentrations, for Bosbok sugar concentrations were lowest after processing at a temperature of 60°C.

TIA was significantly lower in Bosbok (3 mg of trypsin inhibited per 100 g meal) than in Carmel (5·2 mg of trypsin inhibited per g meal). No significant effects of drying temperature on TIA were detected for either of the two varieties.

Table 3. *Amino acid composition of dried sweet potato tuber meals (g/16 g N)*

Sweet potato variety	Bosbok			Carmel		
Drying temperature (°C)	40	60	80	40	60	80
Aspartic acid	19·19	15·58	16·80	22·51	22·13	22·28
Threonine	3·04	2·71	2·70	3·64	3·17	3·60
Serine	4·47	3·35	3·31	3·95	3·46	3·92
Glutamic acid	10·49	12·36	11·22	10·89	10·86	10·90
Glycine	3·25	2·68	2·77	2·92	2·51	2·81
Alanine	5·65	4·95	5·17	4·64	4·54	5·06
Valine	5·06	4·63	4·85	4·63	4·26	4·69
Isoleucine	3·38	3·04	3·13	2·87	2·65	2·99
Leucine	5·01	4·46	4·58	4·16	3·98	4·25
Tyrosine	3·13	3·08	2·97	2·78	2·72	2·66
Phenylalanine	3·47	3·38	3·07	2·90	2·77	3·20
Histidine	1·84	2·30	1·87	2·17	2·53	2·08
Arginine	4·95	3·37	3·72	4·69	4·12	4·39
Proline	2·57	1·90	2·19	2·66	2·75	2·56
Lysine	3·88	3·20	2·61	3·83	3·30	3·22
Cystine	3·10	2·58	2·52	2·93	2·46	2·40
Methionine	2·61	2·08	2·30	2·28	2·30	2·18
Recovery (%)	85·79	75·65	75·88	84·45	80·51	83·19

In vitro digestibility assays

The results from pancreatin and TDF assays are summarised in Table 4. In the pancreatin assay there was a significant effect of temperature and a variety × temperature interaction. However, organic matter digestibility indicated a significant effect of variety (with Carmel having the higher digestibility), temperature, and a variety × temperature interaction. This indicated that, for both varieties, digestibility was lowest after drying at 40°C; for Bosbok there was a continuing increase in digestibility with temperature, while with Carmel there was an increase at 60°C but a slight reduction at 80°C. Results of the TDF assay gave different results, with Bosbok having a higher digestibility than Carmel.

Broiler trial

Performance during 0–14 d

Data on the performance of chicks are summarised in Table 5. The weight gain and dry matter intake were significantly influenced by variety, with Bosbok producing better overall results than Carmel. There were significant variety × temperature interactions for weight gain and dry matter intake. Performance with Bosbok was optimal at 60°C drying, whereas with Carmel there was a declining trend with increased drying temperature from 40 through 60 and 80°C. Compared with Carmel, Bosbok had a significantly higher efficiency of dry matter utilisation (EDMU), dry matter retention and AME. These parameters were not significantly influenced by the temperature at which the tubers were processed. Furthermore, much of the varietal effects could be attributed to the different ash contents of the samples, as revealed from retention data calculated on the basis of the organic matter content of diets:

Table 4. In vitro *digestibility of dried sweet potato tuber meals*

	Sweet potato variety									
	Bosbok			Carmel				Significance ($P<$)		
Drying temperature (°C)	40	60	80	40	60	80	Pooled SEM[1]	Variety	Temperature	Var. × Temp.
Pancreatin digestibility (%)	62·8[a]	67·3[b]	68·0[b]	62·2[a]	69·5[c]	67·2[b]	0·15	NS	0·001	0·01
Pancreatin organic matter digestibility (%)	68·1[a]	71·6[b]	72·5[b]	70·0[a]	78·1[c]	74·4[b]	0·15	0·001	0·001	0·01
Total dietary fibre[2] (%):										
Unashed	17·4	19·3	19·0	22·6	23·8	22·4	—	—	—	—
Ashed	16·8	17·5	16·6	20·1	20·8	20·1	—	—	—	—

[1] SEM = pooled standard error of means.
[2] Final residue from assay ashed or unashed; analyses carried out in duplicates.
Values in the same horizontal line with different superscripts are significantly different ($P<0·05$).

Table 5. *Performance of chicks during 0–14 days (Least Squares Means)*

Drying temperature (%)	Maize control	Sweet potato variety: Bosbok 40	Bosbok 60	Bosbok 80	Carmel 40	Carmel 60	Carmel 80	Pooled SEM[1]	Significance (P<): Diet	Var.	Temp.	Var. × Temp.
Growth parameters:												
Weight gain (g)	381^{a}	307^{c}	332^{bd}	322^{bc}	302^{d}	293de	281^{e}	2·32	0·001	0·001	NS	0·05
Dry matter (DM) intake (g)	418^{a}	371^{cd}	402^{ab}	388^{bc}	378^{cd}	365de	352^{e}	2·44	0·001	0·001	NS	0·01
Organic matter intake (g)	387^{a}	345^{cd}	372^{ab}	361^{bc}	347^{cd}	335de	321^{e}	2·24	0·001	0·001	NS	0·01
EDMU[2]	0·911^{a}	0·828^{b}	0·827^{b}	0·832^{b}	0·798^{b}	0·802^{b}	0·798^{b}	0·005	0·001	0·05	NS	NS
Efficiency of organic matter utilisation	0·985^{a}	0·891^{b}	0·894^{b}	0·893^{b}	0·870^{b}	0·874^{b}	0·875^{b}	0·005	0·001	NS	NS	NS
Nutrient retention:												
Dry matter retention (%)	0·599^{ab}	0·606^{b}	0·610^{b}	0·608^{b}	0·592^{ab}	0·591^{ab}	0·587^{a}	0·002	NS	0.01	NS	NS
Organic matter retention (%)	0·635^{a}	0·642^{a}	0·648^{a}	0·648^{a}	0·642^{a}	0·643^{a}	0·636^{a}	0·002	NS	NS	NS	NS
N[3] retention (%)	0·545^{a}	0·552^{a}	0·623^{bc}	0·571^{a}	0·631^{bc}	0·669^{c}	0·647^{c}	0·008	0·01	0·01	0·05	NS
AME[4] of DM (MJ/kg DM)	12·79^{c}	12·12^{b}	12·02^{b}	11·97^{b}	11·87^{ab}	11·64^{a}	11·61^{a}	0·04	0·001	0·01	NS	NS
AME of organic matter (MJ/kg DM)	13·83^{a}	13·03^{b}	13·00^{b}	12·86^{b}	12·94^{b}	12·68^{b}	12·72^{b}	0·05	0·001	NS	NS	NS
AMEn of DM (MJ/kg DM)	11·90^{a}	11·31^{c}	11·11^{bc}	11·11^{bc}	10·87^{ab}	10·62^{a}	10·60^{a}	0·039	0·001	0.001	NS	NS
N retained: GE metabolised (g/MJ)	2·02^{ab}	1·93^{a}	2·20^{b}	2·11^{ab}	2·43^{c}	2·56^{c}	2·53^{c}	0·024	0·001	0·001	0·05	NS
Other symptoms:												
Water:food intake (ml/g)	3·04^{a}	3·59^{b}	3·73^{bc}	3·77^{c}	4·36^{d}	4·49^{d}	4·82^{e}	0·021	0·001	0·001	0·001	0.05
Water: DM intake (ml/g)	3·42^{a}	4·02^{b}	4·16^{b}	4·20^{b}	4·88^{c}	4·98^{c}	5·31^{d}	0·023	0·001	0·001	0·01	NS
Excreta water content (%)	67·0^{a}	75·2^{b}	78·7^{c}	77·6^{bc}	83·7^{d}	84·1^{d}	84·6^{d}	0·36	0·001	0·001	0·01	0·05
Pasty vents-day 6 (%)[5]	19^{a}	19^{a}	56^{bc}	63^{cd}	30^{ab}	87^{d}	74^{cd}	3·7	0·01	NS	0·001	NS
Pasty vents-day 6 (score)[6]	0·55^{a}	0·55^{a}	1·41^{ab}	1·18^{ab}	0·81^{a}	2·90^{c}	1·92^{bc}	0·139	0·01	0·05	0·01	NS
Bile in excreta-day (score) 10[6]	0·95^{ac}	0·70^{abc}	0·09^{a}	0·39^{ab}	3·19^{e}	1·85^{d}	1·33^{cd}	0·088	0·001	0·001	0·001	0·01

Notes: Least squares means adjusted for Block and Tier effects only. Var. = variety; temp. = temperature. [1] SEM = Pooled standard error of means. [2] EDMU = efficiency of dry matter utilisation (gain : food); [3] N = nitrogen; [4] AME = apparent metabolisable energy; AMEn = nitrogen corrected AME; [5] % of chicks affected; [6] scored on a 1–3 scoring system. Diet effects: values in the same horizontal line with different superscripts are significantly different ($P < 0·05$).

whereas for dry matter retention and AME of dry matter there were significant effects of variety, these were not significant for organic matter retention and AME of organic matter. Nitrogen retention was significantly influenced by variety and temperature of processing, but there was no interaction. The ratio of nitrogen retained: gross energy metabolised was also significantly affected by the variety and temperature of processing.

The water: food intake ratio was significantly higher in the Carmel groups than in the Bosbok groups. Increased drying temperature also increased this ratio, with a significant interaction of temperature and variety, indicating a higher water: food ratio at 80°C for Carmel than for Bosbok. The higher water intake was reflected in the water content of excreta. It was noted that, during oven-drying, the excreta from the Carmel variety darkened significantly, and became much more lumpy and hard in comparison with the excreta from other groups.

Chicks fed on diets containing sweet potato excreted more biliary material than the controls, a response that was dependent on variety and drying temperature. There was also a significant interaction indicating that, with Carmel, bile excretion decreased steadily with the increase in drying temperatures. In Bosbok, the condition was most severe in the 60°C treatment group. During the first week, there was also a significantly higher incidence and degree of pasty vents in chicks fed on diets with sweet potato than in chicks fed on the maize-containing diet. Carmel produced more severely pasty vents than Bosbok, and there was also a significant effect of drying temperature, with 40°C producing the least, 60°C the highest and 80°C an intermediate degree of pastiness for each variety.

The maize diet produced significantly better growth than the sweet potato-based diets. Compared with the Bosbok 60°C treatment, (the best of the sweet potato groups in terms of performance), the control group produced a 12·9% higher weight gain, 3·8% higher dry matter intake, and a 9·2% better EDMU. Although the dry matter retentions were not significantly different, the AME value was 6·0% higher in the control. However, nitrogen retention was significantly better in the Bosbok 60°C treatment. Compared with the groups fed on the sweet potato-based diets, the controls had a significantly lower ratio of water: food intake, which resulted in a lower water content of excreta, a lower degree of pasty vents and lower bile concentrations in excreta.

Performance during 14–21 d

These results are summarised in Table 6. Because the cages were changed and the replications reduced on day 14, the weight gain for 14 to 21 d was analysed with the 14 d liveweights as a covariate. Comparisons of the 14 to 21 d liveweights indicated that improvements in weight gain took place during the third week in some of the sweet potato groups relative to the maize controls. However, it was also apparent that in the Carmel 40°C treatment, performance deteriorated significantly during this period, particularly in terms of the EDMU. Bile secretion was still highest in this group, with the variety × temperature interaction persisting at day 21.

Table 6. *Performance of chicks during 14–21 days*

		Sweet potato variety											
		Bosbok			Carmel						Significance ($P<$)		
Drying temperature (°C)	Maize control	40	60	80	40	60	80	RMSE[1]	Covariate	Diet	Var.	Temp.	Var. × Temp.
Actual liveweight—day 21 (g)	724 ± 42	611 ± 46	645 ± 32	640 ± 11	545 ± 7	578 ± 14	536 ± 5	—	—	—	—	—	
Least Squares Means:													
Weight gain (g)	262	268	255	268	208	265	247	38·5	NS	NS	NS	NS	NS
Dry matter intake (g)	481	431	451	455	400	422	399	41·2	NS	NS	NS	NS	NS
Efficiency of dry matter utilisation (EDMU)[2]	0·55^{ab}	0·62^{b}	0·57^{ab}	0·59^{ab}	0·52^{a}	0·62^{ab}	0·60^{ab}	0·039	NS	NS	NS	NS	NS
Bile in excreta-day 21[3]	0·90^{abc}	0·94^{abc}	0·37^{ab}	0·56^{ab}	2·04^{c}	1·33^{bc}	0·36^{a}	0·22	NS	0·01	NS	0·001	0·01

Notes: Least squares means adjust for 14 day body weight as the covariate. Var. = variety; temp. = temperature. [1] RMSE = root mean square error; [2] gain : food. [3] scored on a 1–3 system.

Table 7. *Organ weights of chicks*

Drying temperature (°C)	Maize control	Sweet potato variety: Bosbok 40	Bosbok 60	Bosbok 80	Carmel 40	Carmel 60	Carmel 80	Pooled SEM	Covariate	Significance (*P*<): Variety	Temp.	Var. × temp.
Actual weights:												
Body weight (g)	661	539	574	565	472	499	463	5·3				
Liver weight (g)	14·4	12·9	13·6	13·3	11·5	11·8	12·1	0·16	0·001	NS	NS	0·05
Pancreas weight (g)	2·12	2·56	2·36	2·37	2·84	2·84	2·84	0·034	0·001	0·001	NS	NS
Least Square Means:[2]								RMSE[1]	Covariate	Diet		
Liver weight (g)	11·62[a]	12·86[b]	12·74[b]	12·66[b]	12·94[b]	12·63[b]	13·76[c]	1·02	0·001	0·01		
Pancreas weight (g)	1·77[a]	2·55[b]	2·26[b]	2·29[c]	3·03[d]	2·98[d]	3·04[d]	0·32	0·001	0·001		
Least Square Means:[3]												
Liver weight (g)	—	12·38[a]	12·20[a]	12·14[a]	12·58[a]	12·22[a]	13·42[b]	1·035	0·001	0·05		
Pancreas weight (g)	—	2·49[a]	2·18[b]	2·21[b]	2·99[c]	2·93[c]	3·01[c]	0·32	0·001	0·001		

Notes: Var. = variety; temp. = temperature. [1] RMSE = root mean square error, [2] adjusted for bodyweights including control data: 101 degrees of freedom; [3] adjusted for bodyweights excluding control data: 87 degrees of freedom. Values in the same horizontal line without common superscripts are significantly different ($P<0{\cdot}05$).

Organ weights.

Although it has previously been argued that organ weights *(Y)* should be analysed in relation to body weights *(X)* according to the model $Y = aX^b$ (Panigrahi *et al.*, 1992), in this experiment there were no major advantages in that model over the linear model $Y = a + bX$ for either pancreas or liver weights (correlation coefficients (r^2) for liver weights being 0·68 and 0·64, respectively, for the 2 models). It was, therefore, considered appropriate to analyse the data using the body weight as a covariate (Table 7). This analysis revealed that chicks fed on sweet potato-based diets had enlarged livers in comparison with the maize controls, with a significant interaction between variety and drying temperature. This indicated that Carmel resulted in larger livers at 80°C drying. Carmel also produced significantly larger pancreases than Bosbok, with no consistent effect of temperature being apparent.

DISCUSSION

The study has shown that the two different varieties of sweet potato tubers studied have different nutritive values and that their utilisation can be affected by the processing methods used to convert fresh tubers into a form suitable for feeding to chicks. Whereas chick weight gain over 0–14 d of age was higher with Bosbok than with Carmel, an interaction between variety and tuber-drying temperatures showed gain to be optimal at 60°C for Bosbok, but for Carmel, it decreased linearly as drying temperature increased from 40 through 60 and 80°C.

There does not appear to be a clear-cut explanation for the different responses of chicks fed on the different sweet potato tuber meal diets, and it is only possible to speculate on avenues for future study. Because some of the effects of variety on dry matter retention, EDMU, and AME were accounted for by the different ash contents of the 2 varieties, with temperature having no significant effect on these parameters, the utilisation of the tubers appears to have been primarily affected by different degrees of depression of food intake. It was therefore, of interest that weight gain was negatively correlated with the water:food intake ratio, with an r^2 of $-0{\cdot}57$ (significance of slope, $P < 0{\cdot}001$) when the control diet data were excluded from the regression analysis (Figure 1). This might suggest that food intakes were restricted by the high and variable water-absorbing nature of the tuber carbohydrates, with the high viscosity of the resulting chyme, perhaps, reducing the rate of passage in the gastro-intestinal tract, as has been described for chicks fed diets containing soluble carbohydrate carboxymethlcellulose (van Klis *et al.*, 1993). The observation that the excreta in the Carmel groups became hard and lumpy during oven-drying lends further support to the view that the texture of the diets was different for the 2 varieties. However, weight gain was also negatively correlated with protein:AME ratio (r^2 $-0{\cdot}63$; significance of slope, $P < 0{\cdot}05$), indicating that chick performance could also have been affected by the different protein:AME ratios of diets.

Further, the presence of bile in the excreta raised concerns on whether anti-nutritional or toxic factors were involved in depressing chick performance. The bile in excreta was negatively correlated with the sweet potato starch content of tubers (with an r^2 of $-0{\cdot}81$; significance of slope $P < 0{\cdot}001$) when the control data are excluded

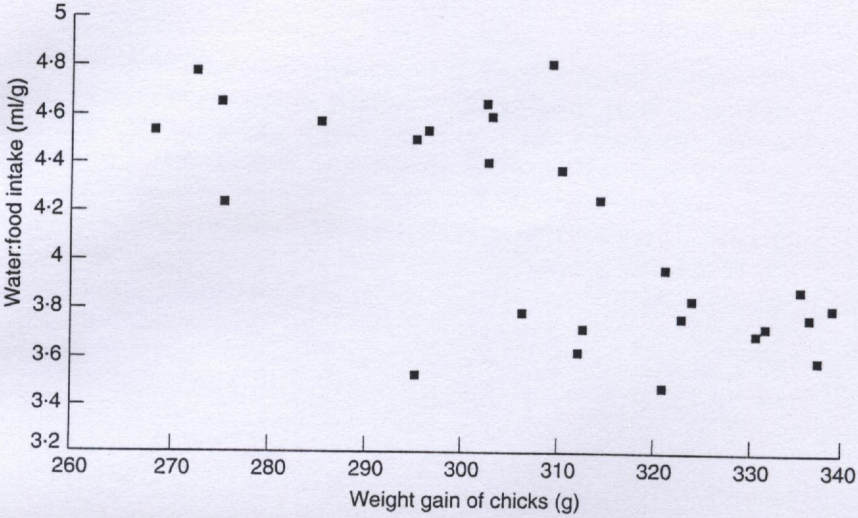

Figure 1. *Relationship between weight gain and water:food intake of chicks fed the sweet potato based diets (weight gain = 459·2 − 36·9 × water:food ratio;* r^2, 0·57, *r.s.d.*, 15·7).

from the regression analysis (Figure 2). This may suggest bile secretion was increased when more of the starch was hydrolysed during processing. Changes in the carbohydrate and amino acid contents of sweet potato were generally indicative of the formation of Maillard reaction products that result from the condensation of amino acids with reducing sugars, as was also evident from the brown colour of the tuber chips of both varieties after drying. It is also noteworthy that the birds receiving the diets supplemented with the Carmel variety had larger pancreases than those receiving the Bosbok-supplemented diet. This may be related to the higher TIA in the former, with the concentrations being approximately 6 times the safe values suggested by Huisman (1992) for chickens (0·4–0·5 mg trypsin inhibited per g of diet). However, Ravindran and Sivakanesan (1995) reported that organ weights (including pancreas weights) and weight gain of broiler chicks were not affected by the inclusion of a sweet potato tuber of 19 TIA/g at up to 600 g/kg diet, or approximately 3–4 times the concentration of TIA in the Carmel treatments.

Thus, how far differences in dietary texture, protein:AME ratio, starch, sugar and non-starch polysaccharide composition, or TIA content of diets depressed food intake and weight gain, is unclear. In this respect, it may also be relevant that, whilst the 14 to 21 d performance data indicated that chicks receiving the Carmel strain dried at 60°C appeared to be adapting to the diet to improve their food intakes, in those receiving Carmel dried at 40°C, performance appeared to worsen in terms of EDMU. Further research is required to explain these findings.

The practical implications of the results of this experiment in developing countries relate to overall effect of the different processing temperatures on the performance of chicks. The study confirms the findings of Yeh (1982) that increasing the temperature at which sweet potato chips are dried reduces their lysine content. However, the reduction in lysine at 80°C drying, compared with 40°C drying, was

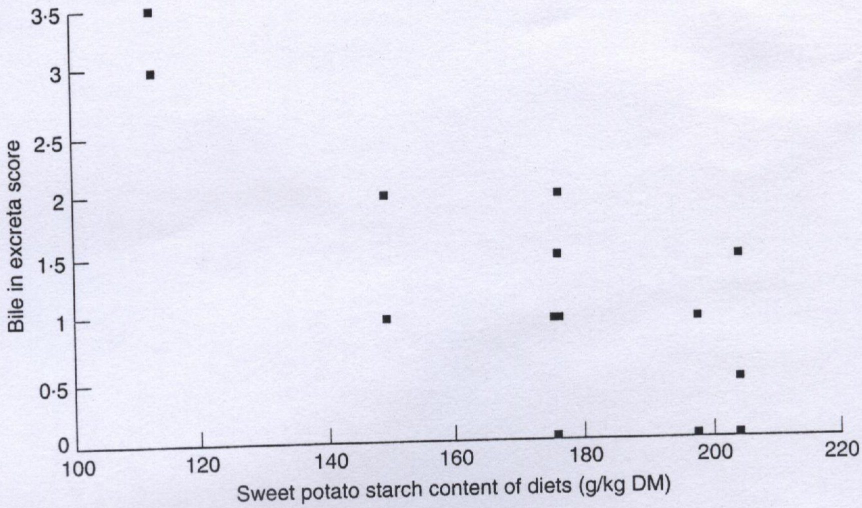

Figure 2. *Relationship between the starch constant of sweet potato and the presence of bile in the excreta of chicks in the feeding trial (bile in excreta* = *6·54* − *0·031* × *starch content;* r^2 0·81, *r.s.d.*, 0·49).

32% for Bosbok but only 15% for Carmel. Cystine concentrations in both varieties tended to decrease. These changes together with nitrogen retention and 21-d liveweight data suggest that 60°C temperature drying was optimal for both varieties of sweet potato tubers. In terms of application of the technology in those tropical developing countries where sun-drying is generally a more economic proposition, studies need to be undertaken to determine the effects on nutritive value of varying the sun-drying rate by altering the chip-loading density (checking the temperature on the surface of the chips), and processing tubers in different seasons (if this is feasible) to determine the effects of environmental temperature and humidity. Results of the present study suggests that major reductions in TIA cannot be expected under the drying conditions that are practical and economical in developing countries.

The *in vitro* assays also showed the sweet potato samples to differ in digestibility, with a variety × temperature interaction also being indicated. However, the 2 *in vitro* methods gave very different results. Chick weight gain over 0–14 d or over 0–21 d and dry matter retention did not correlate with pancreatin digestibility (r^2 0·01 and 0·16, respectively) nor with pancreatin organic matter digestibility (r^2 0·26 and −0·16, respectively). Similarly, the assay figures did not correlate with dry matter retention data from the feeding trial. However, the results of TDF-ashed assay gave a better but not statistically significant correlation with weight gain over 0–14 d (r^2 0·58; significance of slope, $P = 0{\cdot}0767$), and a stronger correlation with 21-d liveweights (LWT): LWT = 984·9 − 21·1 × TDF-ashed; (r^2 0·71; significance of slope $P < 0{\cdot}05$). TDF-ashed values were also correlated with dry matter retention (DMRetn) data from the feeding trial (DMRetn = 0·692 − 0·005 × TDF; r^2 0·87; significance of slope $P < 0{\cdot}01$). It would appear that the lack of a strong correlation with 0–14 d weight gain resulted from the fact that *in vitro* assays cannot account for the effects of dietary texture on food intake. The results highlight the pitfalls of placing excessive reliance on *in vitro* digestibility assays for screening large numbers of new varieties for high nutritive value in sweet potato breeding. This may particularly apply to the use of the pancreatin assay which has been recommended (Zhang *et al.*, 1993) because it is a simple assay to conduct, and is certainly far simpler than the TDF assay.

This study was also designed to determine the replacement value of sweet potato for maize at the 500 g/kg inclusion rate in broiler diets. The finding that, even in the best treatment, weight gain did not reach that of the maize is not surprising in view of similar reports. The better performance of chicks fed on the maize diet was caused by their higher food intakes, EDMU and AME. It was, however, of interest to note that nitrogen retention from Bosbok 60°C was higher than that from the maize control, suggesting that the digestibility of amino acids in sweet potato may be higher than in maize. Overall, Carmel had higher nitrogen retentions than Bosbok. Comparison of the metabolisable energy value of maize, with that of sweet potato is complicated by the effects of variety and temperature and by whether one examines AME, AMEn, or AME of organic matter values. From the data obtained in this study, the AME AMEn values of the Bosbok 40°C treatment (that with the highest metabolisable energy) were estimated to be 15·28 and 14·24 MJ/kg DM, respectively (compared with an AME value of 16·13 MJ/kg DM for maize, the value used in formulating the basal diet).

In conclusion, this study has shown that there is potential for developing sweet potato as an ingredient for poultry diets. In the best sweet potato group (Bosbok dried at 60°C), weight gain of chicks by day 21 of feeding was only 11% lower than that resulting from a maize-based diet. Furthermore, there were indications that chicks were adapting to the dietary texture and improving food intakes as the duration of feeding increased. Balancing the diets for protein to energy ratio is likely to lead to much better performance, even at the 50% dietary inclusion rate of sweet potato tuber meal. This will be particularly useful in developing countries where sweet potato cultivation fits well within the farming system, but where the market for the commodity is limited and declining as it is increasingly regarded as a poor man's food (in Bamenda region of Cameroon, sweet potato is commonly known as dog's food). Genotype selection for high food intakes (by conducting short feeding trials), high digestibility, high protein content, high dry matter content, and appropriateness for processing under the socio-economic and climatic circumstances of the small farmer are the major factors that need attention in promoting the utilisation of this commodity. It is, however, acknowledged that there are likely to be significant trade-offs between these desirable characteristics. In this respect, the low dry matter contents of the tubers in the varieties used in this study may reduce the prospects of their commercial exploitation as an ingredient in poultry diets.

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Protective effect of ubiquinone (coenzyme Q_9) on ascites in broiler chickens

K. NAKAMURA, K. NOGUCHI[1], T. AOYAMA[1], T. NAKAJIMA[1] AND N. TANIMURA

Third Research Division, National Institute of Animal Health, Kannondai, Tsukuba, Ibaraki 305, Japan and [1]R&D Center, Idemitsu Materials, Kami-izumi, Sodegaura, Chiba 299-02, Japan

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Abstract 1. The effect of ubiquinone (CoQ_9) on ascites in broiler chickens was investigated.

2. The commercial broilers were divided into 2 groups of 100 birds each; CoQ_9-treated group and non-treated group.

3. The chickens were grown in a positive-pressured house with double high efficiency particulate air filtered intakes and exhaust, and thus were strictly isolated from infectious agents.

4. The chickens (15 to 21 d old) were exposed to cold stress in order to induce ascites.

5. The number of birds with ascites in the CoQ_9-treated group was significantly lower than in the non-treated group.

6. Survival and production rates were better in the CoQ_9-treated group than in the non-treated group.

INTRODUCTION

Sporadic occurrences of ascites caused by high altitude hypoxia (above 3500 m) and toxicosis have been described by Julian (1993). In many countries over the last 10 years there have been large increases in the number of broiler chickens affected with ascites at low altitudes (Julian, 1993). Therefore, ascites is becoming a major health concern in the poultry industry worldwide. Odum (1993) estimated that economic losses in the United States exceed 100,000,000 dollars annually from deaths occurring during live grow-out, and transportation to and condemnations at the processing plant. In Israel, ascites takes a high toll in the industry during winter (Shlosberg *et al.*, 1991). In Canada ascites is one of the major causes of condemnation during processing (Herenda and Jakel, 1994). In South Africa, ascites in broilers has produced ever-increasing losses since its first appearance in the 1970s (Huchzermeyer and De Ruyck, 1986). A recent report of poultry meat inspection in Japan shows that ascites is one of the most frequent diseases in broiler chickens (Harushima, 1993). Generally this disease is associated with marked dilation of the right ventricles and atria, indicating heart failure (Cueva *et al.*, 1974; Huchzermeyer and De Ruyck, 1986; Julian, 1993).