Evaluation of the nutritive value of yellow rice in rats and broiler chicks

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Yellow discoloration often develops in rice kernels during post-harvest storage, due possibly to fungal activity. The present study examined the changes in nutrient composition taking place during yellowing of rice, and the effects of feeding rats and broiler chicks on a moderately yellow rice at 600 g/kg diet. Nitrogen content was found to be higher in rice grains that had become more yellow, only part of the increase being in non-protein-N; however, relative to crude protein (N × 6·25) the concentrations of lysine, methionine, cystine and arginine were lower. There were no significant differences between white and yellow rice in the food intake, weight gain and efficiency of food utilization (EFU) of rats and chicks when diets were formulated to contain similar nutrient concentrations, or the same basal ingredient composition. Diet pelleting increased food intake and weight gain in both animal species, but reduced dry matter and energy digestibility in rats; effects on nutrient retention in chicks were largely non-significant. Liver weights of rats and chicks and pancreas weights of chicks were unaffected by yellow rice; however, chicks fed on mash had a larger pancreas on average than those fed on pellets. Thus, whilst the nutrient composition of rice is altered during yellowing, a moderately yellow rice is unlikely to produce major adverse effects when fed to rats and broiler chicks.

Yellow rice: Toxicity: Nutritive value: Rats: Broiler chicks

Yellow discoloration of rice grains during post-harvest drying and storage (sometimes termed stack-burnt rice) is a common problem in tropical countries which reduces the acceptability of the rice and results in its down-grading for human consumption, with consequent economic losses to the farmer. Rice yellowing has been associated with the growth of specific fungi (Van der Wolk, 1913), and may be caused by an increase in the temperature of the rice stack resulting from the heat of metabolism of fungi (International Rice Research Institute, 1983). Several fungi belonging to the genera *Aspergillus* and *Penicillium*, and others including *Humicola lanuginosa* and *Corynascus sepedonium*, have been isolated from yellow rice (Phillips *et al.* 1988, 1989). Gras *et al.* (1989) reported that yellowing can also occur in rice that is stored under optimum conditions. It is now believed that the discoloration is due to a non-enzymic browning reaction between the reducing groups of sugars and free amino groups of proteins, with fungal infection of the grain increasing the concentrations of these groups by amylolytic and proteolytic activities, thereby accelerating the browning of the kernels (D. R. Twiddy and S. I. Phillips, personal communication).

There is limited information in the literature concerning the effects of feeding yellow rice to animals, and it is not clear whether yellowing is associated with a loss in nutritive value or in the production of toxins. There are some reports of a correlation between liver lesions (Kinosita & Shikata, 1965; Moreau, 1979), including cirrhosis (Saito, 1959), and the consumption of a yellow rice that had become mouldy with *Penicillium islandicum*. Yellow rice is reported to contain a lower concentration of lysine than white rice (Eggum *et al.*

1984), and may, therefore, be regarded as having a lower nutritive value. However, Noland *et al.* (1969) reported that yellow rice could replace half the maize in the diets of growing and finishing pigs without any adverse effects on growth or on meat quality.

The present study was undertaken to examine the effects of yellowing on the nutrient composition and the nutritional and toxicological characteristics of rice. Feeding trials were carried out with (*a*) rats as a model for humans, in view of the importance of rice as a staple human food, and (*b*) broiler chicks to determine the potential for use of such down-graded rice in non-ruminant diets. As there was some uncertainty about the ability of rats and young chicks to consume mash feeds containing whole rice, and the possibility that pelleting could affect normal and yellow rice differently, experiments were based on a 2×2 factorial design that also studied the effects of diet pelleting.

EXPERIMENTAL METHODS

Composition of the rice

Samples (70 kg) of milled white and yellow rice were obtained from the International Rice Research Institute in the Philippines. The yellow rice sample was separated into four grades of yellow to determine whether any systematic change in nutrient composition had occurred during the yellowing process. The sample, graded visually, comprised (g/kg): 149 white (normal), 502 slightly yellow, 278 moderately yellow or light brown, 71 very yellow (almost brown) rice. The white rice sample comprised (g/kg): 992 normal, 8 slightly-to-moderately yellow rice.

The proximate compositions of rice were determined according to the methods recommended by the Ministry of Agriculture, Fisheries and Food (1986), the amino acid composition of hydrochloric acid-hydrolysed dried and defatted samples was determined using a Biotronik Amino acid LC5000 analyser, and gross energy values using a Gallenkamp adiabatic bomb calorimeter (Tables 1 and 2). Non-protein-nitrogen determinations were carried out according to Backhoff (1976), using 20 ml trichloroacetic acid and centrifuging the homogenized material before filtration to prevent the rice starch clogging up the filter paper.

Feeding trials

Two approaches were adopted in studying the effects of including yellow rice in the diets of rats and chicks: the first examined whether the feeding of yellow rice produced any short-term toxic effects (Expts 1 and 2) using diets balanced for nutrients, and the second compared the nutritive value of yellow rice with that of the control white rice by substitution in a basal diet (Expt 3).

Expt 1

White and yellow rice were incorporated at 600 g/kg in rat diets of similar proximate, lysine, and methionine plus cystine contents, based on the analysis of each rice. To facilitate the detection of any differences existing in the feeding value of the two rice types, dietary crude protein, lysine and methionine plus cystine were kept at concentrations submaximal to the requirements of rats. Pelleting was carried out with the addition of 50 g water/kg in a Lister pelleter equipped with a 3·5 mm die head. The experimental diets were: white-rice mash, yellow-rice mash, white-rice pellets, yellow-rice pellets and commercial pellets (8 mm diameter, Beekay Rat and Mouse autoclavable diet obtained from Bantin and Kingman, UK, Ltd) (CON). The composition and proximate analyses of diets are shown in Table 3.

Sixty male Wistar rats (Sprague–Dawley), weighing 60–80 g, were obtained from Bantin and Kingman UK Ltd. They were housed in groups of three in plastic cages arranged in five

Table 1. *Composition of the white (normal) and yellow milled rice samples (g/kg unless otherwise stated)*

	White rice	Yellow rice
Moisture	119·7	110·9
Crude protein (nitrogen × 6·25):		
Mean	82·9	87·0
SE	0·65	0·89
Crude fat	7·1	3·7
Crude fibre	4·6	4·8
Ash	5·3	4·9
Calcium	0·05	0·07
Phosphorus	1·1	1·0
Starch*	743·0	736·0
Available starch and sugars†	763·0	744·0
Sugars‡	10·5	11·6
Sugars§	< 15	< 15
Gross energy:		
(MJ/kg)	15·83	15·86
(MJ/kg DM)	17·69	17·62
Nitrogen (dried and defatted)	13·7	14·5
Amino acids (g/16 g N)		
Aspartic acid	9·83	10·56
Threonine	3·79	3·86
Serine	5·29	5·34
Glutamic acid	19·07	19·95
Proline	4·69	4·83
Glycine	4·83	5·05
Alanine	6·19	6·60
Cystine	2·29	2·25
Valine	6·42	6·60
Methionine	2·95	2·87
Isoleucine	4·51	4·82
Leucine	8·34	8·71
Tyrosine	4·95	5·21
Phenylalanine	5·62	5·99
Histidine	2·73	2·85
Lysine (total)	3·91	3·54
Lysine (reactive)	99 %	98 %
Arginine	8·53	8·72

* Polarimetric method.
† Modified method of Clegg (1956).
‡ Luff–Schoorl method.
§ Lane and Eynon method (Ministry of Agriculture, Fisheries and Food, 1982).

tiers, each cage equipped with a feeder and a water bottle drinker. The experimental room was maintained at 22°, ambient humidity and with a 12 h light–dark cycle. Four groups of rats were fed on each diet in an incomplete randomized block design, with cages being allocated such that none of the diets was represented in the same tier more than once. The food intake, growth rate and efficiency of food utilization (EFU) of rats were recorded during 6 weeks of feeding. After 4 weeks, a nutrient digestibility study was carried out in which faeces were collected over a 7 d period and dried in a forced-draught oven at 60° for 48 h. Dry matter (DM) digestibility of diets was determined according to DM digestibility = (DM intake − faecal DM)/DM intake. Gross energy values of diets and faeces were determined using a Parr adiabatic bomb calorimeter and N contents using a Tecator

Table 2. *Composition of the various grades of yellow rice*

Grades of yellow colour (x)...	Normal white rice (1)	Slightly yellow rice (2)	Moderately yellow rice (3)	Very yellow (brownish) rice (4)
Amount of rice (g/kg total rice)	149	502·0	278	71
Moisture (g/kg)	109·7	106·1	109·9	110·0
Crude protein (nitrogen × 6·25)* (y):				
Mean	81·4	85·8	90·8	91·9
SE	0·49	0·24	0·42	0·36
Total N (g/kg DM)†	14·62	15·36	16·32	16·52
Non-protein N (g/kg DM)†	0·16	0·19	0·22	0·45
Gross energy (MJ/kg DM)	17·80	17·85	17·80	17·73

Regression equation	r^2	Statistical significance (*P*) of terms: x^2	x	Constant
Linear: $y = 3{\cdot}641x + 78{\cdot}408$	0·91	—	0·0001	0·0001
Quadratic: $y = -0{\cdot}820x^2 + 7{\cdot}741x + 74{\cdot}308$	0·95	0·0011	0·0001	0·0001

* Six replicates.

† Total and non-protein N contents of control white rice were 15·07 and 0·16 g/kg DM respectively.

Kjeltec 1002 distilling unit and 1007 digester. The digestible energy (DE) and N contents of diets were calculated. At the end of the trial a general post-mortem examination was carried out and liver weights were recorded.

Expt 2

The four rice-based rat diets in Expt 1 contained less apparent metabolizable energy and lysine plus sulphur-containing amino acids than those recommended for broiler chicks (Bolton & Blair, 1982); however, since use of nutrient concentrations that result in a submaximal growth rate generally enhances the detection of differences between entities being compared, the diets were fed to chicks.

Forty-eight 1-d-old, Ross-1 broiler cockerels, obtained from Ross Poultry UK Ltd, were housed in groups of three in cages that were arranged in four tiers. The room was provided with a 23 h light–1 h dark cycle, and kept at ambient humidity. Room temperature was initially set at 32° and then reduced by 0·5°/d. Four groups of chicks were fed on each diet in a randomized block design that took into account the possible effects of tiers. Food intakes, body-weights and EFU of chicks were recorded during a 16 d feeding period. After 10 d, a nutrient retention study was carried out in which excreta were collected over a 3 d period and analysed as in Expt 1. At the end of the feeding trial a general post-mortem examination was carried out and the weights of livers and pancreas were recorded.

Expt 3

White and yellow rice were included at 600 g/kg in broiler chick diets of the same basal raw material composition (Table 4), thus allowing a direct comparison of the nutritive value of the two rice types. Sixty-four 1-d-old Ross-1 broiler cockerels were housed in groups of four, as in Expt 2, and fed on white and yellow rice-based diets in the mash form or as pellets. All methods were similar to those used in Expt 2.

Table 3. *Composition of the experimental diets (g/kg unless otherwise stated)*

	Expts 1 and 2		Expt 3
	White rice (WR)	Yellow rice (YR)	Basal
Constituents			
Rice	600·00	600·00	600·00
Fish meal	19·18	17·88	50·00
Meat-and-bone meal	—	—	19·85
Soya-bean meal	246·29	223·90	233·33
Maize	—	6·18	73·78
Sunflower meal	92·11	98·73	—
Dicalcium phosphate	25·07	25·48	16·39
Limestone	10·17	10·06	—
Salt	3·43	3·44	2·27
Lysine	0·75	1·33	1·58
Vitamin–mineral–choline premixes*	3·00	3·00	3·00

Proximate analyses of diets	White-rice mash	Yellow-rice mash	White-rice pellets	Yellow-rice pellets	Commercial pellets	Basal
Moisture	109	105	116	120	105	104†
Crude protein (nitrogen × 6·25)	193	216	199	187	222	WR-203; YR-206
Crude fibre	36	37	32	31	39	17·9†
Crude fat	12	12	12	8	42	17·6†
Ash	54	65	79	58	57	55·1†
Calcium†	12·5	12·5	12·5	12·5	12·5	10·0
Phosphorus†	7·5	7·5	7·5	7·5	7·5	6·9
Lysine†	11·6	11·6	11·6	11·6	11·6	13·0
Methionine + cystine†	7·3	7·3	7·3	7·3	7·3	7·54
Gross energy (MJ/kg DM)	17·12	17·12	17·12	17·12	18·6	18·1
DE rats (MJ/kg)†	13·5	13·5	13·5	13·5	13·5	—
ME chicks (MJ/kg)†	11·5	11·5	11·5	11·5	11·5	13·1

DM, dry matter; DE, digestible energy; ME, metabolizable energy.
* The vitamin premix provided the following nutrients (mg/kg diet): retinol 3·44, cholecalciferol 62·5, α-tocopherol 10, menadione 2·0, thiamin 0·50, riboflavin 6·00, nicotinic acid 2·0 g, pyridoxine 0·1 g, pantothenic acid 1·0 g, biotin 8, folic acid 0·1 g, cyanocobalamin 0·5. Choline chloride was added at 1 g/kg. The mineral premix provided the following nutrients (mg/kg diet): manganese 80·01, zinc 60·00, copper 0·5 g, selenium 10, iodine 0·1 g.
† Calculated.

Statistical analysis

Rat and chick performance data were analysed by factorial analysis of variance, using SPSS (1988). Probabilities higher than $P = 0{\cdot}05$ were regarded as non-significant.

RESULTS

Composition of the rice samples

The crude protein content of the yellow rice was slightly higher than that of the white rice. Within the yellow-rice sample, N content of grains increased curvilinearly with degree of yellowing (quadratic relationship), the white fraction containing 81·4 g crude protein/kg compared with 82·9 g/kg for the control white-rice sample (Table 2); both samples had similar non-protein-N contents. Within the yellow-rice sample, non-protein-N increased

Table 4. *Expt 1. Performance of rats fed on rice-based diets of the same nutrient composition and a commercial control diet (6 weeks)**

Diets...	White-rice mash	Yellow-rice mash	White-rice pellets	Yellow-rice pellets	Commercial rat pellets	SE of treatment means	Statistical significance ($P=$) of main effects: Diet form†	Statistical significance ($P=$) of main effects: Rice type†
Growth performance								
Initial body-wt (g)	66·4	68·2	69·6	67·5	66·0	1·52	—	—
Wt gain (g)	256	252	296	283	282	10·1	0·007	NS
Food intake (g)	829	819	965	957	952	26·9	0·0001	NS
Efficiency of food utilization	0·31	0·31	0·31	0·29	0·30	0·006	NS	NS
Nutrient digestibility								
Dry matter (DM) digestibility	0·87	0·87	0·84	0·84	0·78	0·005	0·0001	NS
N digestibility	0·83	0·83	0·82	0·82	0·78	0·005	0·106	NS
Digestible energy (MJ/kg DM)	15·26	14·99	14·62	14·50	14·67	0·08	0·0001	0·030
Excreta water content (g/kg)	217	202	188	206	345	18·2	NS	NS
Organ wts‡								
Body-wt (g)§	295	294	335	320	319	7·5	—	—
Liver wt (g)§	9·01	9·61	10·46	9·91	12·09	0·456	NS	NS

NS, not significant.

* For details of diets, see Table 3.

† The diet form by rice type interaction term was not significant in any variable.

‡ Residual df for organ weights 43, for other variables 12.

§ Liver weights were analysed with body-weight as covariate (statistical significance $P < 0.0001$, diet $P < 0.0001$).

with the yellowing of grains but this could only account for a fraction of the total increase in N, indicating perhaps that the amino acids were higher in the yellow rice. The recovery of amino acids from rice, however, decreased as yellowing increased.

There were no major differences in starch, available starch, sugar, crude fibre, ash, calcium and phosphorus contents of the two rice types. The crude fat content of yellow rice was approximately half that of white rice, but since the values were less than 10 g/kg its significance is unclear. Gross energy values of white and yellow rice were similar.

Lysine content, expressed relative to the crude protein, was 9·5% lower in yellow than in the white rice sample (6·2% lower when expressed relative to the amount of rice). As yellowing increased, methionine, cystine, total and 'reactive' lysine, and arginine concentrations declined relative to the crude protein content (values not shown), but histidine content appeared to increase; however, relative to the amount of rice the only trends apparent were minor increases in the aspartic acid and arginine contents.

Expt 1

The results are summarized in Table 4. No significant differences were apparent between the white- and yellow-rice-based diets in food intake, weight gain and EFU of rats, when the diet was presented in mash form or as pellets. However, pelleted diets produced a significantly higher food intake than mash diets, and rats consequently attained a higher

Table 5. *Expt 2. Performance of chicks fed on rice-based diets balanced for nutrients (16 days)**

Diets ...	White-rice mash	Yellow-rice mash	White-rice pellets	Yellow-rice pellets	SE of treatment means	Statistical significance ($P =$) of main effects and interactions		
						Diet form	Rice type	Diet form × rice type
Growth performance								
Initial body-wt (g)	38·5	38·6	38·4	38·9	0·03	—	—	—
Wt gain (g)	319	324	415	411	15·3	0·0001	NS	NS
Food intake (g)	481	481	597	590	17·1	0·0001	NS	NS
Efficiency of food utilization	0·66	0·67	0·69	0·70	0·016	0·110	NS	NS
Nutrient digestibility								
Dry matter (DM) retention	0·71	0·76	0·72	0·72	0·012	NS	0·058	0·111
Nitrogen retention	0·60	0·64	0·61	0·61	0·016	NS	NS	NS
Apparent metabolizable energy (MJ/kg DM)	12·94	13·26	13·69	12·77	0·195	0·083	NS	NS
Excreta water content (g/kg)	267	220	327	305	20·0	0·04	0·113	NS
Organ wts†‡								
Body-wt (g)	331	329	416	407	13·7	—	—	—
Liver wt (g)	10·14	9·56	11·65	11·60	0·463	NS	NS	NS
Pancreas wt (g)	1·09	1·24	1·15	1·19	0·006	0·031	0·058	NS

NS, not significant.

* For details of diets, see Table 3.

† Residual df for organ weights 40, for other variables 12.

‡ Organ weights were analysed with body-weight as covariate (statistical significance: $P < 0·0001$ for liver weights and $P = 0·027$ for pancreas weights).

growth rate; this was due to difficulty experienced by rats in holding and consuming the mash feed. EFU was unaffected by the diet form, and there were no significant interactions between rice type and diet form in any of these variables.

There were no significant differences between the white- and yellow-rice-based diets in DM and N digestibilities, but the DE of the yellow-rice-based diet was lower than that of the white-rice-based diet. Diet pelleting reduced DM and energy digestibility of both diets to about the same degree. The water contents of faeces were similar in all the rice-based diet groups.

The commercial diet produced a similar food intake, weight gain and EFU to those obtained with the pelleted rice-based diets; however, whilst it had the same DE as those for the rice-based diets, DM and N digestibilities were significantly lower ($P < 0·05$). The water content of faeces from the commercial-diet group was significantly higher than those from all other groups.

No mortality was recorded. Liver weights were unaffected by the type of rice or form of diet.

Expt 2

These results are summarized in Table 5. The food intake, weight gain and EFU of chicks fed on yellow-rice-based diets were not significantly different from those of chicks fed on the white-rice-based diets, and there were no significant interactions between rice type and

Table 6. *Expt 3. Performance of chicks fed on rice-based diets of the same basal raw material composition (15 d)**

Diets…	White-rice mash	Yellow-rice mash	White-rice pellets	Yellow-rice pellets	SE of treatment means	Statistical significance ($P =$) of main effects and interactions: Diet form	Rice type	Diet form × rice type
Growth performance								
Initial body wt (g)	38·7	38·9	38·6	38·9	0·27	—	—	—
Wt gain (g)	397	363	420	413	19·9	0·091	NS	NS
Food intake (g)	520	483	545	531	24·1	0·159	NS	NS
Efficiency of food utilization	0·76	0·75	0·77	0·78	0·010	0·082	NS	NS
Nutrient digestibility								
Dry matter (DM) retention	0·80	0·81	0·81	0·80	0·006	NS	NS	NS
Nitrogen retention	0·66	0·68	0·67	0·66	0·010	NS	NS	NS
Apparent metabolizable energy (MJ/kg DM)	14·91	15·25	15·09	14·97	0·099	NS	NS	0·038
Excreta water content (g/kg)	305	267	362	364	30·6	0·028	NS	NS
Organ wts†‡								
Body wt (g)	430	400	448	441	12·8	—	—	—
Liver wt (g)	14·23	13·09	15·12	14·41	0·627	NS	NS	NS
Pancreas wt (g)	1·41	1·38	1·39	1·29	0·053	0·023	NS	NS

NS, not significant.

* For details of diets, see Table 3.

† Residual df for organ weights 56, and for other variables 12.

‡ Organ weights were analysed with body-wt as covariate (statistical significance: $P < 0·0001$ for liver weights and $P = 0·027$ for pancreas weights).

diet form in these variables. However, chicks fed on pelleted diets consumed significantly more food and attained a higher growth rate than those fed on mash diets. Over the 16 d experimental period EFU was slightly higher for the pellet than for mash diets; however, a closer examination of the data showed similar EFU for both forms of diets between 8 and 16 d, indicating than an improvement in EFU of mash diets had taken place after the first week of age.

There were no significant effects of rice type or diet form on DM and N retentions, nor were there any significant interactions between rice type and diet form. Pelleting appeared to reduce the apparent metabolizable energy value of both rice-based diets. The water content of excreta from chicks fed on pelleted diets was significantly greater than those from chicks fed on mash diets.

No treatment-related mortality nor any effects on liver weight were recorded. Pancreas weights were significantly greater in mash diets than in pellet groups. There was a small effect ($P = 0·058$) of the rice type on pancreas weight, which was greater in the yellow-rice group.

Expt 3

These results are summarized in Table 6. There were no significant effects of the rice type or diet form on the food intake, weight gain and EFU of chicks, although the values tended to be poorer for the mash diets.

DM and N retentions were unaffected by the rice type or diet form. The apparent metabolizable energy values of yellow- and white-rice-based diets were similar, but there was an interaction between rice type and diet form indicating a greater detrimental effect of diet pelleting on yellow rice than on white rice. The water content of excreta was significantly higher in the pelleted groups than in the mash groups.

There was no treatment-related mortality. The type of rice fed had no significant effects on liver and pancreas weights; pancreas weights were, however, larger in mash than in the pellet groups.

DISCUSSION

The results of the present study indicate that yellowing of rice is associated with changes in nutrient composition, but a rice that is only moderately yellow will not produce any detrimental effects on growth when fed to rats and broiler chicks. The results further demonstrate that yellow rice can be included in broiler chick diets at 600 g/kg without depressing the growth rate.

The main alteration in the nutrient composition of rice during yellowing was an increase in N content, only a small proportion of which was as non-protein-N. The increase in crude protein could be associated with fungal activity on rough rice (Phillips *et al.* 1989). However, since much of the mycelium is likely to have been removed with the husk and bran layers during milling, and the milled rice was not examined for the presence of micro-organisms, any suggestion of a relationship between protein content and the presence of fungi would be speculative.

The lowering in the concentration of lysine compared with a white-rice control as colour of grains within the yellow-rice sample became more yellow is in agreement with the findings of Eggum *et al.* (1984) who suggested that lysine decomposition is dependent on the temperature and duration of stack burning. In the present study, there were also decreases in the concentrations of 'reactive' lysine, methionine, cystine and arginine, relative to the crude protein content, as rice grains became more yellow, which could perhaps be indications of Maillard browning (Hurrell & Carpenter, 1974). The small apparent increase in histidine observed may be associated with products of Maillard reaction that elute at the same time as histidine from the ion-exchange column (Plumb, 1989).

The feeding trials showed no significant differences between the white- and yellow-rice-based diets in their effects on rats and chicks; nor were there any consistent interactions to suggest that yellow rice was more prone than white rice to a lowering in nutritive value by the moist heat treatment of diet pelleting. Rat performances on the pelleted white- and yellow-rice-based diets were similar to that resulting from a commercial diet, and formulation of chick diets to contain the required apparent metabolizable energy (Expt 3) produced growth rates comparable with those obtained in other studies carried out under similar experimental conditions with a commercial-type diet of optimal nutrient specification (values not shown here). However, whilst the overall growth performance was unaffected, the DE of yellow rice in rats was slightly lower than that of the white rice, indicating a possible lowering in feeding value. This is in contrast to the findings of Eggum *et al.* (1984) that 'stack burning' of rice did not affect energy digestibility but decreased true protein digestibility and net protein utilization, which were lowered further in yellow rice than in white rice by heat treatment.

Since surplus rice and broken rice are used in non-ruminant livestock diets, it was of particular interest to study the utilization of the rice-based diets by young chicks. During the first week of Expt 2 EFU was lower in mash groups than in the pellet groups (not shown in Table 5) but EFU and DM retention between 10 and 13 d were similar, suggesting that

1-d-old chicks can utilize mash diets containing whole rice grains after a few days of adaptation, which appears to involve pancreatic hypertrophy. However, the lower overall weight gain of chicks fed on mash was primarily due to their low food intake caused by poor feed texture, a problem that was overcome by diet pelleting. The smaller difference in food intake between mash and pelleted feed in Expt 3 may also be due to an improvement in feed texture by the additional fat in these diets compared with the diets of Expt 2. The higher water content of excreta from chicks fed on pellets, compared with mash, is consistent with the suggestion of Marks (1981) that broiler chicks adjust their water intake to regulate food intake and EFU.

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