RURAL INDUSTRIES RESEARCH
& DEVELOPMENT CORPORATION

Nutritional value of pearl millet as poultry feed

A report for the Rural Industries Research and Development Corporation

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October 1999

RIRDC Project No DAQ-243A

ISSN 1440-6845

"Nutritional value of pearl millet for poultry"
Project no. DAQ 243J

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Published in October 1999

FOREWORD

The change of mix in Australian grain production is likely to be of considerable value to the grains industry. However, the combined effects of changes in production and rising domestic feed demand over the medium term are likely to reduce Australia's ability to be a net exporter of feedgrains, particularly from eastern Australia. Consequently, in coming years, the probability that Australia will have to import significant quantities of feedgrains is higher than in the past. The strong demand for feedgrains and limited supplies are expected to support higher prices well into the near future. However the production of feedgrains in Australia is forecast to decline over the medium term. It is therefore essential that research be undertaken to find alternative feed sources for livestock, especially poultry, to reduce feed cost increases and maintain an internationally competitive poultry industry.

Varieties of pearl millet in the USA have been shown to be at least equivalent to maize and superior to sorghum in terms of yield and nutritive value. Such comparisons of the feeding value of the pearl millet grain have never been undertaken in Australia. Pearl millet has been identified as a suitable alternative to sorghum in low rainfall and sandy areas of Australia. The potential benefits from the application of existing knowledge and from further research in pearl millet are substantial for feed grain crops in Australia.

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ACKNOWLEDGEMENT

We would like to acknowledge the assistance and dedication of the scientific, technical and farm staff at QPRDC and the biochemistry staff at Animal Research Institute, Yeerongpilly. We thank Dr David Farrell (former Director QPRDC), Mr David Robinson and Mr Paul Mannion for their scientific support and to Mr Kerry Barram and the farm staff for their technical assistance. We also thank Mr Peter Martin and Mr Colin Palmer for their assistance in the chemical and amino acid analyses.

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Executive Summary

In the USA pearl millet was developed as a summer annual crop and now is grown on 1.5 million acres. Agronomic studies and breeding efforts supported by the US Agency for International Development have demonstrated that it is a promising grain crop for areas of the US in which drought, soil type, short season, or excessive heat diminishes yield potential of sorghum. Also, short -season pearl millet hybrids are a promising double-crop after wheat. In 1994, a new grain-type pearl millet was planted on more than 15,000 acres in Georgia and Florida for livestock feed. In general, varieties of pearl millet in the US have a higher protein level and higher lysine content than sorghum grown under similar conditions. It has a higher energy value because of greater oil content and lower proportion of less digestible material.

Pearl millet has been identified as a suitable alternative crop to sorghum in low rainfall and sandy areas in Queensland. The potential benefits from the application of existing knowledge and from further research in pearl millet are substantial for feed grain crops in warm-temperate agriculture. Current Australian millet varieties have never been evaluated as a feed grain for poultry.

The main objective of this project were to examine the potential of two millet varieties (Katherine pearl millet and Siberian millet) currently available in Australia, as a poultry feed ingredient. The millets were grown at Biloela Research Station, Biloela, Queensland and clean grain was transported to Queensland Poultry Research and Development Centre for evaluation. Chemical analyses were performed on these two grains to measure the protein, fat, fibre, starch, phosphorus, calcium, gross energy and amino acid content. Feeding experiments were conducted on broiler and layer birds to measure the metabolisable energy content and the digestibility of amino acids in the two millets. Finally an inclusion level experiment was conducted to determine the level of inclusion of the millets in the diets of layer birds for satisfactory performance.

Katherine pearl millet and Siberian millet had higher protein, fat and crude fibre compared to sorghum. Katherine pearl millet contained nearly 2% more protein than sorghum which had similar protein content to Siberian millet. The crude fibre content of Siberian millet was three times that of Katherine pearl millet which was more than twice as high as sorghum. The neutral-detergent fibre (NDF) content of the three grains are in similar proportion as for their crude fibre content. The fat content of the millet varieties were similar but were twice as high as the fat content of sorghum. The starch content in Katherine is 10% higher than Siberian (63 vs 53%), wheras the gross energy (GE) is the same.

The total amino acid profile of Katherine pearl millet is much better than sorghum and Siberian millet. The lysine, threonine, tryptophane and leucine content in Katherine is much higher than in Siberian millet whereas, methionine was found to be slightly higher in Siberian millet. Katherine pearl millet contains twice as much lysine, methionine and tryptophan than sorghum.

The apparent metabolisable energy (AME) content of Katherine pearl millet was more than 1 mega joule(MJ) higher than Siberian millet and sorghum. The AME content of Katherine in broilers and layers was 14.8 MJ and for Siberian millet it was 13.6 MJ.

The amino acid digestibilities of the millets were similar to sorghum. The lysine digestibility in broilers for Katherine pearl millet was 10% higher than Siberian millet (0.73 vs 0.63). The amino acid digestibilities of Katherine pearl millet was 5-7% higher in broilers than in layers.

The layer feeding experiment showed that diets containing inclusion levels of 200, 400, and 600 g/kg of the Katherine millet and the 400 g/kg of the Siberian millet had no effect on egg production, feed conversion, egg weight, egg mass, specific gravity and bird final body weight. The only significant difference (P=0.009) found among treatments was for feed intake. Hens consuming the Siberian millet (400 g/kg) had significantly higher feed intake (P<0.05) than birds fed on Katherine (200 and 600 g/kg) and the control diets. This could be due to the higher content of crude fibre and neural-detergent fibre found in the Siberian millet when compared with Katherine pearl millet. High fibre content in the diet is usually correlated with dietary AME depression and birds need to increase intake in order to obtain enough protein and energy to maintain production. Differences (P<0.05) in feed intake were also found among the birds fed the Katherine pearl millet at 600 g/kg. These birds consumed significantly less food than birds fed Katherine pearl millet at 200 and 400 g/kg respectively.

It was possible to make recommendations on the value of pearl millet varieties available in Australia as poultry feed ingredient. Practical inclusion rates of 600g/kg for the Katherine pearl millet and 400g/kg for the Siberian millet is recommended for layer diets.

Further research on the upper inclusion levels of pearl millet in broiler diets and the interaction of enzymes on the utilisation of nutrients in the millet varieties is warranted.

1. INTRODUCTION

With the escalation of poultry feed prices and the real prospect of declining availability of grains for livestock, it is opportune that research efforts be directed to finding alternatives to wheat/sorghum based diets. The cost of traditional poultry feeds has maintained a sustained upward trend since the fossil fuel energy crisis of the early 1970's. This has stimulated research to develop alternative and cheaper sources of nutrients for poultry. Since one of the major causes of the increasing cost of feed is the man-animal competition for energy-intensive traditional food materials, alternative or non-traditional poultry feed materials must be those that are not eaten or relished by humans. It is well known that nearly 60% of the total poultry production costs are attributed to feed costs. For the poultry industries to be internationally competitive, this production cost needs to decrease or its increase slowed. A comparison of feed grain prices in the USA and Australia shows that the prices in US are 30% lower than in Australia ($A180 cf $A265/tonne). One of the methods of decreasing this cost is to replace the traditional feeding ingredients with cheaper, yet equally efficient, alternatives that are not consumed by humans.

In any intensive livestock production system, feed costs amount to a considerable proportion of production cost. In Australia 60-65% (PRDC 1991) of production is feed related. Poultry diets are generally based on cereal grains such as wheat etc. A dilemma facing the poultry industries is that the demand for cereal grains as stockfeed and for human consumption is steadily increasing. The eventual implementation of the GATT Agreement and the recent support of ASEAN Nations for trade liberalisation will have far reaching effects leading to a need to find alternatives to grains grown primarily for human consumption. Finding suitable grain, especially for Northern Australian producers, is difficult because of the climatic and environmental conditions that prevail in this region.

Pearl millet has been identified as a suitable alternative crop to sorghum in low rainfall and sandy areas in Queensland. The potential benefits from the application of existing knowledge and from further research in pearl millet are substantial for feed grain crops in warm-temperate agriculture (Andrews and Kumar, 1992). In the US pearl millet is considered to be the new feed grain crop in a number of States eg Indiana and Kansas.

Dryland summer cropping in Queensland is currently based on sorghum. According to Queensland Department of Primary Industries (QDPI) agronomist and millet breeder, Dr P. Lawrence, (*pers com*) the viability of this sorghum-dominated farming system is being questioned by farmers. They are looking for alternative crops to spread the risk in these highly variable dryland croping environments. Growers are reporting uneconomic yields from sorghum crops, especially from later plantings, in the North Burnett, Callide, Central Highlands and Warrego regions because of:

- lower commodity prices resulting from domestic requirements already being filled by earlier crops produced in southern regions by the time CQ and SWQ producers have harvested,
- a high risk reliance on stored soil moisture as the probability of late summer-season rainfall greatly diminishes,
- poor “standability” of current sorghum varieties resulting in significant harvest losses,

- increases in sorghum ergot disease (as evidenced in the 1996/97 crop) is an emerging constraint to productivity of late-planted crops that flower into the cooler months.

Furthermore, the need for sorghum varieties to avoid excessive heat during head emergence dictates late planting as the only planting time option for many producers in the Central Highlands and Warrego regions. This negates any opportunity to spread planting times over the whole summer season as a risk management option for the above-mentioned problems.

Current pearl millet varieties are dual forage-grain types; pearl millet grain hybrids and varieties are currently not available in Australia. Plant breeding research over the past 20 years in Africa, India, and USA for pearl millet grain types using Iniadi germplasm from Togo has resulted in the development of early maturing, high-yielding breeding lines with good general adaptation. In 1996, three breeding programs in the USA released parental inbreds (both A & R lines) plus germplasm bulks that have been derived from Iniadi germplasm and are suitable for mechanised farming.

An excellent opportunity exists to provide a new risk-management crop option for grain growers in the form of a successful pearl millet grain industry. Pearl millet has been extensively studied overseas and is particularly suited to complement sorghum in dryland farming systems across CQ and SWQ because:

- it has a shorter crop-growth duration and better heat tolerance than sorghum, which would allow for spring planting of pearl millet. This would provide more options for risk management,
- it is adapted to semi-arid environments with low fertility, is more drought tolerant than sorghum, and will out-yield sorghum in sandy well-drained environments with low rainfall,
- it will provide a new market for growers, which they are actively seeking,
- overseas breeding programs have produced both hybrids and open-pollinated varieties (which mean much lower seed costs than hybrids) that are highly adapted to similar soils and environments to CQ and SWQ.

Pearl millet is widely grown as a food crop in subsistence agriculture in Africa and in the Indian Subcontinent on a total of 26 million ha where grain yields average 500-600 kg/ha. In the US pearl millet was developed as a summer annual crop and now is grown on 1.5 million acres. Agronomic studies and breeding efforts supported by the US Agency for International Development have demonstrated that it is a promising grain crop for areas of the US in which drought, soil type, short season, or excessive heat diminishes yield potential of sorghum. Also, short -season pearl millet hybrids are a promising double-crop after wheat. In 1994, a new grain-type pearl millet was planted on more than 15,000 acres in Georgia and Florida for livestock feed.

Results from poultry feeding experiments in the USA using pearl millet with maize or sorghum indicate that pearl millet is at least equivalent to maize and generally superior to sorghum in protein content and quality, protein efficiency ratio (PER) values, and metabolizable energy (ME) levels, (Hoseney *et al*. (1987), Rooney and McDonough (1987), Sullivan et al. (1990), and Bramel-Cox *et al*. (1992)). Pearl millet does not contain any condensed polyphenols such as the tannins in sorghum that can interfere with or slow down digestibility. Chicken feeding experiments by Sullivan et al. (1990) showed that weight gains and feed/gain ratios obtained in pearl millet based diets are equal to that of maize and some sorghum. Smith et al. (1989) similarly reports that pearl millet can replace maize in chicken diets without affecting weight gain or feed efficiency. Both the gross energy and ME values of pearl millet tend to be higher then those of maize and many have been previously underestimated by 20% (Fancher et al. 1987).

In general, feeding test results support data from biochemical analyses, which indicate that pearl millet, is similar to maize and superior to sorghum as a feed grain. A number of factors are thought to be responsible. Pearl millet grain generally has a higher crude protein level by 1 to 2 percentage points relative to sorghum grown with similar cultural practices. Pearl millet is still deficient in essential amino acids, but averages 35% more lysine than sorghum (Rooney and McDonough 1987). Pearl millet grain has 5 to 6% oil and a lower proportion of the less digestible cross-linked prolamines (Jambunathan and Subramanian 1988). These differences can be partly attributed to the different structure of the kernel. The proportion of germ in pearl millet grain (17%) is about double that of sorghum, while the endosperm accounts for 75% of pearl millet grain as against 82% of sorghum grain

Pearl millet will outyield sorghum and maize in low rainfall (200-500mm), sandy, well drained environments, conservatively estimated at 100,000ha in Australia. The gross margins for dryland millet, sorghum and maize are $240, $56 and $4 respectively and under irrigation the margins are $426, $182 and $379, (Harris and Collins pers comm). In general, varieties of pearl millet in the US have a higher protein level and higher lysine content than sorghum grown under similar conditions. It has a higher energy value because of greater oil content and lower proportion of less digestible cross-linked prolamines

2. OBJECTIVES

The objectives of this project were:

- To determine the gross chemical composition of varieties of millet
- To determine the metabolisable energy content of the selected millet varieties when fed to layers and broilers.
- To establish the digestible amino acid values of the millet varieties when fed to broilers and layers
- To determine the upper inclusion level of pearl millet in layer diets.

2. METHODOLOGY

Two millet varieties, Katherine pearl millet and Siberian millet were grown at Biloela Research Station, Biloela, Queensland. After harvesting and cleaning, the millets were transported to Queensland Poultry Research and Development Centre (QPRDC) for nutritional analysis and testing of their suitability as poultry feed ingredient.

1. Chemical Analyses

The determination of dry matter, protein, ash, crude fibre, calcium and phosphorus content of the two millet varieties were undertaken according to the methods of the AOAC (1992).

The amino acid analyses were undertaken by ion-exchange chromatography (Walter HPLC) after hydrolysis with 6 M HCL at 110° C for 18 h under reflux conditions.

2. Metabolisable energy

AME Bio-assay.

Apparent metabolisable energy (AME) was determined using the classical method where total collection of excreta and measurement of food intake was measured. Birds were fed on the experimental diets for 7 days.

The procedure was carried out as follows:

Diets were offered to the birds on Friday March 19.

Monday March 22 (7:00 am) all feeders were removed from cages.

Monday March 22 (9:30 pm) collection trays were placed under cages and birds were fed the experimental diets. Initial weight of feeders with feed was determined

All excreta on each tray was collected on days 23, 24, 25, and placed in aluminium trays and stored at –5 °C frozen.

Friday March 26 all feed were removed at 7: 00 am and feed consumed was recorded.

Excreta was collected at 1:00 pm (final collection). Aluminium trays were left to thaw out.

Excreta collected was oven dried for 3-4 days at 70 °C.

After all excreta was oven dried, trays were removed from ovens and allowed to equilibrate with ambient temperature for 3-4 h. Dried excreta was ground and gross energy of the feed and excreta samples were determined using an AC-350 LECO adiabatic bomb calorimeter.

The above procedure was conducted on 23 day old commercial broiler birds that were housed in individual cages. For determination of AME in layers, adult White Leghorn hens aged 33 weeks were used.

AME values were calculated using the following formula after correcting for moisture content to an as fed basis.

$$AME(MJ/kg) = \frac{(\text{Feed Intake} * GE) - (\text{Excreta Output} * GE\ \text{excreta})}{\text{Feed Intake}}$$

3. Amino acid digestiblity

Layer experiment:

Two groups of six adult White Leghorn hens (33 weeks old) were used for this experiment. Birds were housed in individual cages. Diets were fed *ad libitum* with removable feeders. Water was constantly available to each hen through the use of individual nipple drinkers. Experimental feed diets were prepared by mixing the millet to be assayed with a highly digestible protein (casein), minerals and vitamins. Celite (20 g) was used as a marker and added to each experimental diet. The birds were fasted 6 hours before being fed the experimental feed.

On the seventh day birds were humanely killed by cervical dislocation and immediately opened to remove digesta from the vitelline diverticulum (formerly Meckel’s diverticulum) to 40-mm back from ileo-caecal junction. Ileal digesta of birds within a pen was pooled, frozen immediately after collection and subsequently freeze-dried. Dried ileal digesta samples were ground/crushed using a mortar/pestle and stored in airtight containers at –20 °C for chemical analysis. A proportion of each sample was used for an acid insoluble ash analysis.

Broiler experiment:

Fifty commercial chicks were purchased on 2nd March 1999 and were fed on a commercial starter diet until they reached 16 days of age. Three groups of 5 selected broiler chickens (21 days of age) were used for each millet grain in this experiment.

Birds were placed in metabolism cages. Diets were offered *ad libitum* to three pens (5 birds/pen) with removable feeders. Water was constantly available to the birds.

Both the millet varieties, Katherine pearl and Siberian were ground to pass through a 2mm screen. Each millet was mixed in a diet containing vitamins, minerals and an internal marker (Celite). An amount of 22.5 kg per diet containing 96% of either Katherine or Siberian millet was prepared. The proportion of each ingredient was mixed as follow:

	%	Kg
Pearl Millet	96.5	21.710
Vitamin supplement 1	0.15	0.034
Vitamin supplement 2	0.20	0.050
Minerals	0.15	0.034
Dicalcium phosphate	1.00	0.230
Celite	2.00	0.450
	-----	-------
Total	100	22.508

Moisture content of each ingredient was determined.

On Friday 26th May, birds were killed by cervical dislocation and immediately opened to remove digesta from the vitelline diverticulum (formerly Meckel's diverticulum) to 40-mm back from ileo-caecal junction. Ileal digesta of birds within a pen was pooled, frozen immediately after collection and subsequently freeze-dried. Dried ileal digesta samples were ground/crushed using a mortar/pestle and stored in airtight containers at –20 °C for chemical analysis. A proportion of each sample was used for an acid insoluble ash determination.

The amino acid analysis of the digesta and diet was analysed as per the method described for the analysis of the grain samples.

Ileal amino acid digestibilities were calculated using acid-insoluble ash (AIA) as the marker. Celite was added to diets to improve the precision of the measurements as suggested by Ravindran *et al* (1999).

$$\text{Amino acid digestibility (\%)} = \frac{(AA/AIA)\text{diet} - (AA/AIA)\text{ileal}}{(AA/AIA)\text{diet}} * 100$$

where (AA/AIA) is the ratio of amino acid to acid-insoluble ash in diet and in ileal digesta.

4. Layer feeding experiment

The diets (see Table 1) were formulated to contain similar energy and protein levels and to satisfy the minimum nutrient requirement for maximum egg production. The variety Katherine was fed at three levels (200, 400 and 600 g/kg) whilst the variety Siberian was fed at 400 (g/kg). A commercial layer diet based on sorghum, wheat and soybean meal was used as the control diet.

Table 1. Ingredient and chemical composition (g/kg) of the experimental diets

Ingredient	Control	K200	K400	K600	S400
Sorghum	400	207.99	160	70	145.3
Wheat	289.2	310.0	172.6	75.2	160.0
Sunflower meal	80	80	80	80	37
Soybean	96.1	63.5	51.7	39.1	107.8
Katherine millet	-	200	400	600	-
Siberian millet	-	-	-	-	400
Sunflower oil	1.62	1.52	1.51	1.56	9.36
Meat & bone meal	39.3	39.4	38.6	37.7	47.5
Limestone powder	43.0	44.5	43.3	43.5	42.0
Salt	1.56	1.74	1.75	1.8	1.46
Sodium bicarbonate	0.39	0.44	0.44	0.45	0.36
DL Methionine	1.54	1.17	0.99	0.72	2.79
Lysine	1.79	2.81	3.35	3.87	2.08
Vitamin/mineral premix[1]	2.0	2.0	2.0	2.0	2.0
Choline	0.45	0.45	0.45	0.45	0.45
Yolk pigment	0.04	0.04	0.04	0.04	0.04
Analysis*					
Crude protein	169	163	159	155	171
Lysine	7.8	7.8	7.8	7.8	7.8
Methionine	4.0	4.0	4.1	4.2	4.6
TSAA	6.7	6.7	6.7	6.7	6.7
Calcium	36	37	36	36	36
Total phosphorus	6	6	6	6	6
AME (MJ/Kg)	11.4	11.3	11.3	11.2	11.0

*calculated values

[1]The vitamin and mineral premixes added per kg of diet: 2.5 mg retinol, 75 ug D_3, 5 mg a-tocopherol acetate, 2 mg menadione sodium bisulfite, 1 mg thiamine, 4 mg riboflavin, 2 mg pyridoxine, 10 ug B_{12}, 1 mg folic acid, 10 mg niacin, 10 mg Ca pantothenate, 30 ug biotin, 225 mg choline, 50 mg Mn, 50 mg Zn, 50 mg Fe, 600 ug Mo, 500 ug Co, 600 ug 1, 4 mg Cu, 70 ug Se, 80 mg Banox.

Each of the five experimental diets was fed to 30 Isabrown birds during 20 weeks. These birds were 33 weeks of age at the beginning of the experiment and were housed in an individual wire cage with feed and water available *ad libitum*. Egg production was recorded for five consecutive days/week with weekly measurements for feed intake and egg weight whilst specific gravity was recorded monthly. All birds were weighed at the end of the experimental period. A completely randomised experimental design was used in this experiment; data were analysed using an ANOVA and treatment means compared using a protected Least Significant Difference (LSD) test.

4. DISCUSSION OF RESULTS

Chemical composition

Results of the chemical composition of Katherine pearl millet and Siberian millet are given in the table below. Measurements for sorghum are given for comparison.

Table 2 Chemical composition of Katherine and Siberian millet

Percentage	**Katherine**	**Siberian**	**Sorghum**
DM	88.9	90	86.7
Ash	2.3	4.3	1.2
Protein	13.7	11.8	11.2
Fat	6.5	5.4	2.8
Ca	0.03	0.03	0.04
P	0.45	0.32	0.31
CF	5.1	15.4	2.2
NDF	10.0	24.8	6.1
Starch	63.4	53.0	
GE (MJ/kg)	19.2	19.1	18.06
Amino acids (g/kg DM)			
Arginine	5.06	3.25	3.8
Cystine	2.35	2.21	1.8
Glycine	3.49	2.79	3.1
Histidine	2.64	1.58	2.4
Iso Leucine	4.81	3.95	4.4
Leucine	11.53	9.58	15.1
Lysine	3.41	1.5	2.3
Methionine	2.66	3.44	1.5
Phenylalanine	5.52	5.9	5.9
Serine	5.46	4.72	4.8
Threonine	4.44	3.33	3.5
Tryptophan	3.15	1.58	1.2
Tyrosine	3.32	3.62	4.2
Valine	5.97	4.85	5.5

Both Katherine and Siberian millet had higher protein, fat and crude fibre compared to sorghum. Katherine pearl millet contained nearly 2% more protein than sorghum which had similar protein content to Siberian millet. The crude fibre content of Siberian millet was three times that of Katherine pearl millet which was more than twice as high as that of sorghum. The neutral-detergent fibre (NDF) content of the three grains are in similar proportion as for their crude fibre content. The fat content of the millet varieties were similar (6.5 and 5.4% respectively for Katherine and Siberian) but were twice as high as the fat content of sorghum (2.8%). The starch content in Katherine is 10% higher than Siberian (63 vs 53%), whereas the gross energy (GE) content is the same.

The total amino acid profile of Katherine pearl millet is much better than sorghum and Siberian millet. The lysine, threonine, tryptophane and leucine content in Katherine is much higher than in Siberian millet whereas, methionine was found to be slightly higher in Siberian millet. Katherine pearl millet contains twice as much lysine, methionine and tryptophan than sorghum.

Ileal amino acid digestibility and AME

Results of the ileal digestibility coefficients and AME are presented in Table 3. Measurments for sorghum is given for comparison. Ileal amino acid digestibilities of the millets were similar to sorghum. In broilers, the digestibility of lysine for Katherine millet was 10% higher than for Siberian millet (0.73 vs 0.63) and this was lower than sorghum (range 0.75-0.79). The amino acid digestibilities of Katherine appeared to be 5 to 7% higher in broilers than in layers. This difference between broilers and layers was also observed by Ravindran (*pers.com*) working on sorghum.

Table 3 Means and SEM of Ileal amino acid digestibility coefficients and AME in Katherine and Siberian millet for layers and broilers

	Katherine Broiler		Siberian Broiler		Katherine Layer		Siberian Layer		Sorghum* Range (%)
Amino acid	MEAN	SEM	MEAN	SEM	MEAN	SEM	MEAN	SEM	
Alanine	0.841	0.018	0.854	0.019	0.808	0.037	0.871	0.021	83-89
Arginine	0.852	0.022	0.846	0.018	0.802	0.030	0.801	0.058	78-86
Asp.acid	0.764	0.033	0.720	0.024	0.705	0.029	0.706	0.063	78-84
Cystine	0.664	0.040	0.671	0.096	0.657	0.055	0.633	0.029	
Glut. Acid	0.862	0.015	0.856	0.019	0.838	0.030	0.865	0.024	84-90
Glycine	0.677	0.040	0.705	0.036	0.621	0.029	0.674	0.082	66-75
Histidine	0.797	0.026	0.803	0.043	0.774	0.002	0.800	0.038	72-80
isoleucine	0.801	0.032	0.801	0.022	0.770	0.028	0.789	0.057	78-84
Leucine	0.838	0.020	0.843	0.019	0.820	0.032	0.845	0.036	83-89
Lysine	0.735	0.045	0.631	0.029	0.678	0.064	0.669	0.006	75-79
Methionine	0.879	0.044	0.870	0.046	0.843	0.032	0.878	0.004	80-87
Phenylala	0.813	0.022	0.833	0.022	0.795	0.028	0.829	0.040	80-85
Proline	0.819	0.018	0.795	0.022	0.780	0.013	0.789	0.048	
Serine	0.739	0.029	0.772	0.030	0.621	0.042	0.736	0.076	74-80
Threonine	0.672	0.040	0.699	0.030	0.551	0.029	0.687	0.056	64-72
Tryptophan	0.865	0.027	0.828	0.015	0.806	0.070	0.809	0.040	72-84
Tyrosine	0.767	0.026	0.828	0.031	0.725	0.061	0.826	0.033	73-80
Valine	0.789	0.057	0.798	0.025	0.746	0.031	0.787	0.056	76-83
AME (MJ/kg)	15		13.5		14.6		13.7		13.8

* Ravindran *et al* (1998)

The AME content of Katherine was more than 1 MJ higher than that of sorghum, whereas the energy content of Siberian millet was the same as for sorghum. The AME content of Katherine was the same in broilers and layers (15.0 vs 14.6 MJ/kg).Similarly with Siberian millet (13.5 vs 13.7 MJ/kg).

These results suggest that Katherine and Siberian millet can be substituted for sorghum in layer and broiler diets.

Layer feeding experiment

Diets containing inclusion levels of 200, 400 and 600 g/kg of the Katherine millet and the 400 g/kg of the Siberian millet had no effect on egg production, feed conversion, egg weight, egg mass, specific gravity and bird final body weight (Table 4). Similar results were obtained by Kumar *et al*, (1991) and Collins *et al*, (1997) when comparing pearl millet with corn based diets. However, the numerical reduction in egg output by birds consuming Katherine millet at 600g/kg may be of commercial significance. The only significant difference (P=0.009) found among treatments was for feed intake. Hens consuming the Siberian millet (400 g/kg) had significantly higher feed intake (P<0.05) than birds fed on Katherine pearl millet (200 and 600 g/kg) and control diets. This could be due to the higher content of crude fibre and NDF (154 and 248 g/kg, respectively) found in Siberian millet when compared with the Katherine pearl millet (75 and 151g/kg of crude fibre and NDF respectively). High fibre content in the diet is usually correlated with dietary AME depression and birds need to increase intake in order to obtain enough protein and energy to maintain production. The AME results indicated that Siberian millet contained at least 1.5 MJ/Kg DM less than the Katherine millet.

Differences (P<0.05) in feed intake were also found among the birds fed the Katherine variety at 600 g/kg. These birds consumed significantly less food than birds fed Katherine millet at 200 and 400 g/kg respectively. During the course of the experiment some regurgitated food was noticed in some birds consuming the Katherine pearl millet at 600 g/kg. Although this depression of feed intake did not have adverse effect on feed conversion, the reduction in feed intake is difficult to explain.

Table 4. Egg output (%), Intake (g/d), egg weight (g), egg mass (g/d), feed conversion ratio (FCR), specific gravity (SG) and final body weight (kg) for laying hens fed pearl millet experimental diets during 20 weeks

Treatment	Inclusion g/kg	Output	Intake	Egg Wt.	Egg mass	FCR	SG	Body Wt.
Control	0	93.3	121.3 ^{bc}	65.0	60.6	2.0	1.09	2.1
Katherine	200	92.7	120.1 ^{bc}	65.0	60.2	2.0	1.111	2.1
Katherine	400	93.7	125.5 ^{ab}	65.1	61.4	2.06	1.09	2.2
Katherine	600	90.4	118.3 ^{c}	65.8	59.3	1.99	1.088	2.1
Siberian	400	94.2	130.1 ^{a}	65.9	61.9	2.10	1.091	2.1
P[1]		0.16	0.009	0.81	0.23	0.13	0.410	0.81
LSD		2.93	7.06	1.98	2.39	0.098	0.026	0.13

1= Probability. LSD= least significant difference at 5%

The results suggest that Katherine and Siberian millet are suitable as a feed ingredient for layers. This finding is in agreement with those of Abd-Elrazig and Elzubeir (1998), Collins et al. (1997) and Mohan et al. (1991) who reported that pearl millet can be incorporated in layer diets at up to 60% of the diet without any adverse effect on layer performance.

5. IMPLICATIONS

There is little doubt that the demand for cereal grains for poultry feed will increase substantially especially with the problem of ergot in sorghum crops. It is essential that detailed knowledge of any alternative feed ingredient be established to allow them to be used effectively and efficiently. The experiments conducted have highlighted the nutritive value of the millets which is important when formulating least cost diets.

The layer experiment showed that Katherine pearl millet could be incorporated in the diets without any adverse effect on layer performance. Since the millets contain high levels of fibre this could be a limiting factor, however the utilisation of fibre could be improved with the use of specific food enzymes.

As the ileal amino acid digestibilities of millets are different in broilers and layers, this differences implies that different sets of coefficients need to be used when formulating diets based on amino acid digestibilities. The results from ileal amino acid digestibility and from the AME studies suggests that the millets, especially Katherine could be used as feed ingredients in broiler diets.

6. RECOMMENDATIONS

One of the objectives of this research was to provide industry with guidelines as to the use and inclusion levels of pearl millet in layer diets. These recommendations relate only to the varieties tested in these experiments which are available commercially. For layers, an inclusion level of 600 g/kg is recommended for Katherine pearl millet and 400g/kg recommended for Siberian millet. When formulating diets based on digestible amino acids different sets of digestibility coefficients are to be used depending on whether the diets are for broilers or layers.

Since GRDC is funding research on the development of a pearl millet feed grain industry for Australia, it is recommended that poultry nutritionists be involved in the screening of suitable cultivars. The interaction of plant breeders with poultry nutritionists will assist in selecting lines that have high nutritive values.

Many authors (eg Andrews and Kumar, 1992, Amto and Forrester, 1995) believe that the greatest advances in the next decade or so will come from the development of pearl millet as a feed grain crop, adapted to warmer climatic regions. Though the good nutritional status of the grain is already established, opportunities for further improvement in feed value are known to exist.

7. COMMUNICATION STRATEGY

Much of the information from this research has already been published in conference proceedings and publication. To date these are:

Singh,D.N., Perez-Maldonado,R., Mannion,P.,Martin,P., Palmer,C. and Lawrence,P. (1999). Pearl millet *(Pennisetium americanum)* – an alternative feed grain for poultry. *Queensland Poultry Science Symposium*, Gatton,Qld., **8**: 21.1 – 21.7.

Singh, D.N., Perez-Maldonado, R., Mannion, P.F. and Robinson, D. (2000). Pearl millet (*Pennistum americanum*) – an alternative feed grain for layers. *Proceedings Australian Poultry Science Symposium 12* (in press)

Singh, D.N., Perez-Maldonado, R., Mannion, P.F., Martin,P., and Palmer,C. (2000) Nutritive value of Pearl millet varieties in Australia. *Proceedings Australian Poultry Science Symposium 12* (in press)

The research outcomes of the project was requested by GRDC when they were considering a new project proposed by P Lawrence of QDPI on "Development of the Pearl millet feed grain industry for Australia". This new five year project is currently being supported by GRDC.

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