AGRICULTURAL WASTE- AND BY-PRODUCTS FOR NON RUMINANTS IN AUSTRALIA: SOME PRELIMINARY OBSERVATIONS

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SUMMARY

A survey of the waste by-products (WBP) available in Australia was carried out. Chemical analyses of many of the WBP showed high fibre levels and relatively low nutrient densities. Experiments were conducted with rats, pigs, chickens and laying hens to evaluate some of the major WBP as a feed source for non-ruminants. Production declined as fibre levels in the experimental diets increased. There was the possibility of endogenous, but undefined, factors in rice bran which caused a depression in egg production when fed at high levels to laying hens.

INTRODUCTION

The current price of wheat is close to $200/tonne, while both oats and maize are about $220/tonne. The immediate outlook is uncertain because of recent dry conditions and widespread crop failure and pig and poultry producers may soon have to pay close to $300/tonne for grower diets. What then are the alternative energy sources?

Triticale has been hailed as the new man-made grain and likely to replace much of the wheat in diets of livestock. It usually out-yields wheat in the same environment. Because of growth inhibitors (King 1980) in some samples it can safely replace no more than 50% of the grain in the diet of pigs (Farrell 1981). Hassab (pers. comm. 1982) on the basis of a field trial suggested that even at 50% of the diet triticale can depress *growth* of young pigs by 15% compared to a diet without triticale although this difference is reduced after pigs reach 55 kg. Triticale is subject to similar growing conditions to those of other cereal crops althouth it may be a little more drought-resistant and recovers more satisfactorily following dry conditions (Farrell 1981). Unfortunately there are now rusts which are specific to many varieties of triticale and the plant breeder has therefore to select for rust resistance in addition to many other characteristics (R. Jessop, pers. comm. 1982). Buckwheat is another grain that has been grown in Australia and its nutritive value has been examined by Farrell (1978). It does not yield very well, it has some agronomic disadvantages, and it may not be acceptable to livestock in large amounts.

There are other concentrated forms of energy such as broken rice and rice pollard (Farrell and Warren 1981) but these are selling at well over $200/tonne, and are often not available to the home mixer or the stockfeed manufacturer when grains are in scarce supply.

Alternative feed sources are mainly by-products of the feed and food industries. Those that can be easily and usefully incorporated into diets are already being used, although probably not to the best advantage because they are available in only a few locations and in limited supply.

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Waste by-products (WBP) are animal or vegetable by-products from cropping, processing *or* manufacturing that are usually not commercially available and have little or no market value. WBP are sometimes returned to the ground as organic fertilizer (animal wastes, vegetable harvesting waste, and straw), left in designated refuse areas to decompose (processing sludges and liquors), or fed to ruminants (vegetable and fruit processing wastes).

With a few exceptions WBP are high in cellulose and therefore low in digestible energy, and may contain toxic residues from insecticides, fertilizers, processing chemicals or fungal growth. Research is necessary to determine the nutritional value of WBP for pigs and poultry to be able to make recommendations in order to utilize fully the nutrients they contain. Since'many WBP are very high in fibre and information on their nutritional value is limited; they are more safely incorporated into the diets of ruminant animals than of non-ruminants. In small amounts they could be of value in non-ruminant diets, particularly of sows and boars where some fibre is a dietetic requirement to prevent constipation and can be fermented to some extent in the hind gut. Fibre is probably more effectively utilized by mature than by growing stock. WBP are less likely to be used effectively in poultry diets although some vegetable and fruit wastes were recently reviewed (El Moghazy and El Boushy 1982).

The use of WBP in animal diets depends on a number of interrelated economic and nutritional constraints. Any cost benefit over a grain-based conventional diet will depend largely on the costs associated with drying and handling the WBP. Nutritional constraints may include palatability and acceptability or toxic factors, and the need for additional minerals, vitamins and amino acids to overcome imbalances or deficiencies in the total diet.

Because of changes in local and world situations, grain supplies fluctuate, prices may fall, and the interest in WBP usually declines. Consequently until recently there has not been a concerted effort to examine alternative feed sources particularly for pigs but also for poultry. There is a large project at the University of New England on the potential of WBP for pig diets. This paper describes some research that has been undertaken on these products in Armidale with pigs, poultry and laboratory rats.

SURVEY

In order to determine what waste- and by-products were available, the amount and seasonal variation, a postal survey of food processors was carried out.

We surveyed over 150 organisations and received information on 61 by-products, The material ranged from unbaked dough to macademia nut waste. The by-products that are available in the greatest quantity are molasses and cheese whey. The annual production of molasses probably exceeds 200,000 tonnes and of whey 50 million litres. Molasses is an excellent source of energy and it is used in pig diets extensively in countries such as Cuba. It is currently priced at $50/tonne and has a digestible energy value similar to wheat. A major problem with molasses is that it contains no protein. It is therefore necessary to include in such a diet high quality proteins such as soyabean meal and fish meal in relatively large amounts. Consequently the diet becomes expensive.

Many of the products reported in the survey were in wet form and could not be stored for any length of time. For example one company reported that they produced about 20,000 tonnes/year of mixed vegetable waste on a seasonal basis. Included in this was 1,000 tonnes of asparagus waste, 800 tonnes of beetroot waste and 10,000 tonnes of sweetcorn trash. In Western Australia one company produces 11 million litres of cheddar cheese whey annually. This whey contains only 5% dry matter and about 1% protein and is used as a pig feed. In Canada some of the water is removed and the whey contains about 20% solids (Modler 1979). Despite its low protein whey also contains about 0.5 g of calcium and phosphorus per litre. Thus a grower-finishing pig on a diet of grain supplemented with 5 litres of whey daily would receive adequate protein and other nutrients but would need additions of vitamins A and D. The difficulty with such a system is to maintain a high standard of hygiene particularly of equipment handling the whey. If this is not observed then health problems will occur. In Victoria there are about 8,500 tonnes of yeast residue produced each year by one company. The residue contains about 15% solid material and is probably suitable for feeding to pigs..

Biscuit waste is a valuable by-product and there is also unbaked dough from some bread and biscuit manufacturers. Production could exceed 5,000 tonnes per year throughout the country. Although some of this waste is used by the pig industry there is not much information to guide producers as to how biscuit waste should be used. Furthermore there is wide variation in the chemical composition of 'waste between manufacturers and some variation within a manufacturer from batch to batch.

Two other interesting waste-products are from the fruit and winery industries. Citrus pulp is available in large quantities and although it is high in fibre, it also contains reasonable amounts of crude protein (840%) depending on the starting material. Grape or winery pomace is the residue after distillation of grape marc and has the reputation of being a very poor quality material largely because of its high tannin content (Morgan and Trinder 1980). Tannins appear to markedly reduce the digestibility of some nutrients particularly amino acids. Both of these materials may be dried at little cost in Australia because the potential fuel (rice hulls.) used to fire the furnace is also a waste-product of little commercial value.

During certain times of the year and depending on the economic climate soft fruits and vegetables may be dumped. These could be of value and represent an opportunity to obtain irregular supplies of very cheap feed-stuffs, but most livestock producers are not sufficiently flexible to be able to incorporate such material into their diets. Banana production however frequently has a regular supply of low-grade banana and-banana skins during the season. For about 8 months of the year these could provide a useful source of wet-waste-product but the producer would need to design his feeding system to incorporate these materials.

The Survey uncovered a wide range of potential ingredients and their location. It also highlighted the difficulties of including the material into pig rations under commercial conditions. Part of the difficulty lies in that only seasonally small quantities are available, they usually cannot be stored, and removal of moisture under most circumstances is costly.

CHEMICAL ANALYSES

Having identified waste- and by-products that may be useful as feedstuffs, the next step is to carry out chemical analysis as a rough guide to their nutritive value. There already exist tables showing the chemical composition of some of these products but the product is often highly variable in composition. It is therefore necessary to analyse local products to obtain meaningful values. The chemical composition of several waste- and by-products is shown in Table 1. The main characteristics of these products are their generally high fibre content and medium to low protein contents. This limits the amount that can be included in pig diets, particularly of growing pigs. In addition, citrus pulp and winery pomace contain tannins but these do not appear to be unusually high; tannin content for a sample of grain sorghum was 0.09%.

Shown in Table 1 are digestible energy (DE) values of dried citrus pulp waste and dried winery pomace for pigs. The citrus pulp waste has a DE similar to that of oats, The DE of winery pomace is much lower than that of citrus pulp since the fibre content is higher. Similar measurements with pigs indicate that the DE value of 4.1 MJ/kg for winery pomace is probably an underestimate.

ANIMAL EXPERIMENTS

Experiments with Rats

Studies with growing rats may serve as an indicator of performance that may be expected when the same diets are offered to pigs (Ivan and Farrell 1975). Rat experiments are inexpensive and results are obtained in about 2 to 3 weeks. Procedures followed were those described by Ivan and Farrell (1975).

Shown in Table 2 are the results of an experiment in which various waste- and by-productswere incorporated into a basal diet at levels of from 10 to 30%. The growth rate of rats on most of the diets was equal to or superior to that on the basal diet. Biscuit waste and winery pomace showed promise as ingredients suitable for inclusion in pig diets. Winery pomace has been investigated in a subsequent experiment.

Shown in Table 3 are the results of a rat growth trial designed mainly to study the value of winery pomace. It would seem that a safe level for its inclusion in the diet is 15%, while a small depression was observed in growth rate and FCR when levels were 20 to 25%. Citrus pulp also showed a lower growth and FCR than the basal diet. Apple pomace and macademia nut waste both at 20% of the diet gave performance equal to that of rats on the basal diet (Table 2). Macademia nut waste contains 37% fat but it is also high in fibre (see Table 1).

Experiments with Pigs

Least-cost feeds were formulated for growing pigs according to the recommendations of the ARC (1981). Winery pomace (estimated DE value of 6.0 MJ/kg DM) was substituted for rice hulls and sorghum in a grain-based basal diet at levels of 5, 10, 15 and 20%. Restricted amounts of feed were offered once daily so that pigs received similar calculated amounts of digestible energy and other nutrients relative to their metabolic weights. Pigs weighing approximately 20 kg at the start of the trial were individually penned and feed intakes were adjusted weekly according

TABLE 1 Dry matter (DM), crude protein (CP), acid detergent fibre (ADF), ash and digestible energy (DE) of some by-products compared to wheat, barley and oats.

By-products	Dry Matter (%)	Ash (%)	ADF (%)	CP (%)	Fat (%)	DE ($MJkg^{-1}$)	Tannin (%)
Barley offal	92.5	3.9	26.7	9.4	-	-	
Biscuit dust	95.0	3.1	8.4	14.9	-	-	
Dried citrus pulp	90.0	5.4	19.8	7.5	-	10.6**	0.70
Macademia nut waste	97.9	1.0	41.4	10.12	37.0	-	
Peanut waste (hulls)	90.9	5.2	64.9	7.6	-	-	
Dried potato offal	94.0	4.0	24.8	11.7	-	-	
Dried tomato pomace	98.2	9.8	51.9	12.7	-	-	
Dried winery pomace	93.5	5.5	50.3	11.2	-	4.1**	0.40
Dried apple pomace	29.9	-	-	6.1	-	-	
Wheat grain*	88.8	3.6	9.5	15.6	4.1	14.4	
Barley grain*	89.4	2.2	6.6	10.6	1.8	12.7	
Oat grain*	90.2	3.2	15.2	9.4	6.5	12.1	

* Australian samples: Australian Feeds Information Centre (1978) and Australian Pig Manual (1979).
**This study.

TABLE 2 Acid detergent fibre (ADF), crude protein (CP) and ash contents (dry matter basis) of the experimental diets and growth rate and feed conversion (FCR) of rats.

No.	Diet	ADF (%)	CP (%)	Ash (%)	Gain (g/d)	FCR
1	30% biscuit waste*	6.4	19.7	4.3	5.1^{b}	2.32^{a}
2	10% winery pomace	8.8	21.4	5.1	5.1^{b}	2.49^{a}
3	20% rice bran	5.1	21.1	5.5	4.9^{b}	2.48^{a}
4	20% tomato pomace	12.8	20.5	5.5	4.6^{ab}	2.69^{b}
5	20% citrus pulp	7.9	19.4	5.2	4.3^{a}	2.81^{b}
6	20% barley offal	8.4	19.9	4.7	4.1^{a}	2.86^{b}
7	Basal diet	4.3	22.9	4.9	4.6^{ab}	2.49^{a}

* % By-product in basal diet 'as fed'.
Values in the same column with different superscripts (a-b) are significantly different ($P \leq 0.05$).

to bodyweight. 'Feed consumption was recorded and the trial finished when the pigs weighed 45.0 kg. Results are shown in Table 4.

TABLE 3 Acid detergent fibre (ADF) and crude protein (CP) contents of experimental diets, weight gain and feed conversion (FCR) of rats on diets for 14 days.

No.	Diet	ADF (%)	CP (%)	Gain (g/d)	FCR
1	Control	3.8	18.0	4.6^{b}	2.29^{b}
2	10% winery pomace	8.5	18.8	4.4^{ab}	2.46^{b}
3	15% winery pomace	11.0	18.7	4.3^{ab}	2.52^{b}
4	20% winery pomace	13.5	18.0	4.0^{ab}	2.72^{a}
5	25% winery pomace	14.9	17.4	4.0^{ab}	2.80^{a}
6	20% citrus pulp	8.3	18.2	3.7^{a}	2.86^{a}
7	20% apple pomace	9.5	16.2	4.5^{b}	2.45^{b}
8	20% macademia nut waste	12.5	16.1	4.6^{b}	2.28^{b}

Values with different superscripts (a,b) significantly different ($P \leq 0.05$)

TABLE 4 Growth rate and feed conversion of pigs from 20 kg to 45 kg bodyweight fed various levels of winery pomace.

	Basal Diet	Winery pomace 5%	10%	15%	20%
Growth rate (g/d)	545^{a}	555^{a}	530^{ab}	532^{ab}	503^{b}
Feed conversion ratio	2.44^{a}	2.40^{a}	2.61^{ab}	2.68^{b}	2.94^{c}

Means with different superscripts (a-c) in the same row are significantly different ($P \leq 0.05$)

Although growth rates are generally low for all pigs because of the restricted energy intake, the inclusion of 20% winery pomace significantly reduced growth rates. Feed conversion ratios were significantly higher in diets containing 15% and 20% winery pomace and this was probably due to reduced nutrient digestibility.

Another product which may be available in the future in relatively large amounts is defatted rice bran. Rice bran contains about 19% oil, largely polyunsaturated and of high quality. The extracted bran contains about 20% crude protein and we have compared it with wheat bran in the diets of rats and pigs. In the rat experiment animals were fed ad libitum while the pigs were full fed, i.e. about 90% of appetite. The results are shown in Table 5. The rats showed small differences in intake on the different diets due possibly to spillage. It would seem that defatted rice bran can be included in amounts of up to 30% without a decline in pig performance and with an acceptable FCR. Defatted rice bran appears to be as good as wheat bran in nutritive value.

TABLE 5 Diet composition (%), determined analysis and production parameters of rats and pigs fed on diets based on defatted rice bran.

Group		1	2	3	4	5
Basal		100	89.7	79.4	69.1	79.4
Defatted rice bran			10.0	20.0	30.0	
Wheat bran						20.0
Vitamin and mineral mix			0.3	0.6	0.9	0.6
Digestible energy (MJ/kg DM)		14.5	14.1	13.8	13.5	13.8
Crude protein (%)		20.0	19.9	19.5	19.3	19.4
Acid detergent fibre (%)		7.3^a	7.5^a	8.2^b	8.3^b	8.9^c
Pigs:	Days to 45 kg W	48	47	43	44	46
	Liveweigh gain (g/d)	534	544	587	571	547
	FCR	2.3	2.3	2.2	2.2	2.3
Rats:	Liveweigh gain (g/d)	3.4	3.7	3.7	3.3	3.2
	Feed intake (g/d)	12.3^a	13.8^a	13.5^a	13.0^a	11.6^b
	FCR	3.6	3.8	3.7	4.0	3.7

Values within a row with different superscripts (a-c) are significantly different ($P \leqslant 0.05$)

Experiments with Poultry

Chickens

Four groups of eight 5-day-old male broiler chicks were placed on each of seven dietary treatments. Birds were placed in mesh wire cages in a room at 32°C and grown to 17 days of age. Least-cost diets were formulated to the specifications of the ARC (1975) and contained 0%, 6%, 12% and 18% of dried citrus pulp or winery pomace. The results are given in Table 6.

There were no significant differences in feed consumption between treatments, and although 6% and 12% winery pomace in the diet did not reduce growth rate significantly, with the exception of the 6% WP diet, FCR increased compared to chicks on the control diet. Citrus pulp at all three levels gave an increased FCR but growth rate on the diet containing

12% citrus pulp was less but not significantly different to that on the control diet. Although the tannin content of grapeseed cake may be sufficiently high to impair growth rate (Bo Gohl 1975) this may not be the case with winery pomace (Table 1). In the distillation process of winery pomace for the production of fortifying spirit (Williams and Strauss 1978) tannins are probably largely extracted (Amerine et al. 1972).

TABLE 6 Feed intake, growth rate and feed conversion ratio (FCR) of male broiler chicks over 12 days on diets containing winery pomace (WP) or citrus pulp (CP)

	Control	6% WP	12% WP	18% WP	6% CP	12% CP	18% CP
Feed consumption	26.3	26.3	26.5	26.8	25.9	26.7	25.7
Growth rate (g/d)	15.9[a]	15.0[a]	14.8[a]	13.7[b]	14.3[b]	15.0[a]	13.2[b]
FCR	1.65[a]	1.75[a]	1.80[b]	1.96[b]	1.81[b]	1.78[b]	1.95[b]
Calculated							
Metabolizable energy (MJ/kg DM)	13.15	12.90	12.38	11.91	12.93	12.46	11.98
Crude protein (%)	22.5	22.2	21.5	20.5	22.2	21.5	21.0
Crude fibre (%)	3.6	4.4	6.1	7.7	3.4	4.0	4.7

Means with different superscripts are significantly different ($P \leq 0.05$)

Layers

A trial was conducted at the University poultry farm for 20 weeks (21 weeks of lay). The experiment compared two diets containing hexane-defatted rice bran at 25% inclusion, with a diet containing wheat bran and pollard (wheat bran 20%, wheat pollard 5%) and a commercial layer diet (Fielders Stockfeeds, 17% CP, layer crumbles). One rice bran diet contained bran from the 1980 crop and the other bran from the 1981 crop. Sheel grit was added during the first 7 weeks of the experiment, stopped for the next 7 weeks, then recommenced until the end of the trial.

The experiment initially involved 384 laying hens of two strains, medium bodyweight (MW) and light bodyweight (LW), in individual cages. These birds were reared on an *ad libitum* feeding regime and at about 18 weeks of age were divided into groups of 12 and allocated to alternate banks of 12 cages. These were then allocated randomly to the 4 dietary treatments (replicated 4 times) in a Latin square design. This meant that within each replicate there were 24 birds (12 of each strain).

Feed intake, egg production and mortality for each group of 12 birds were recorded weekly. Egg weight, shell quality and liveweight of the birds were monitored regularly. Anlaysis of the diets for metabolizable energy, crude protein, acid-detergent fibre, ash and dry matter were carried out (Table 7). Calculated calcium content of all diets was 30g/kg. Mortality on the diets containing rice bran was higher than on the other two diets (Table 8). Post mortem examinations indicated that mortality was of *ten* related to a calcium insufficiency. However there were no apparent differences in shell quality among the dietary treatments. Mortality was highest (16 birds) during the 7 weeks without shell grit. Egg production by the hens on the two rice bran diets was lower (Figures 1 and 2) and this may also relate to a reduced calcium availability in the diet. Feed intake and liveweight of the birds did not differ significantly

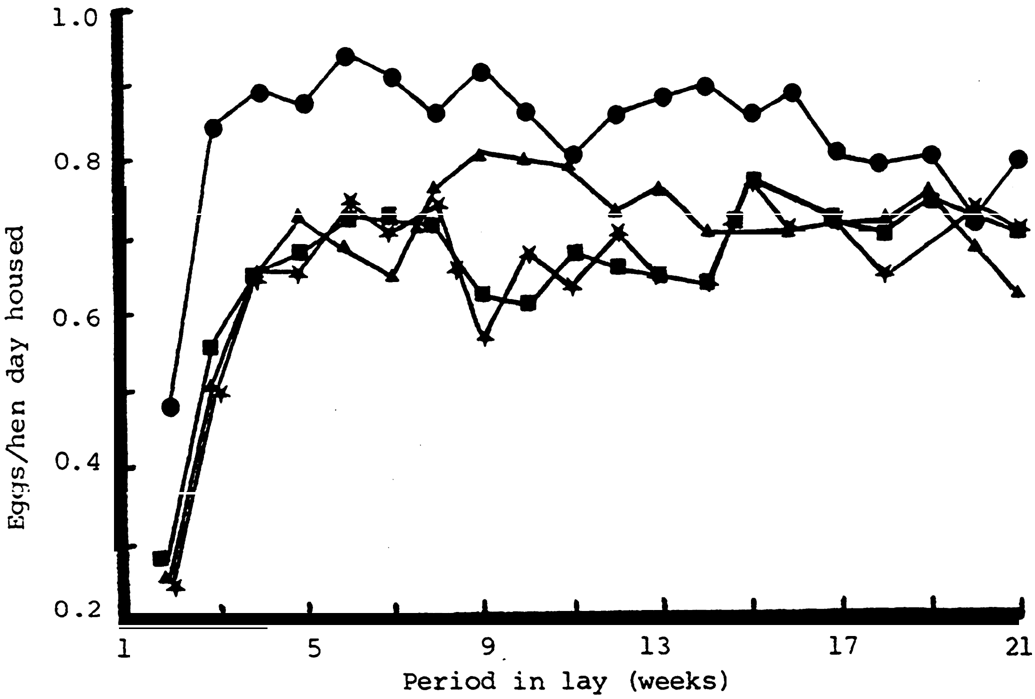

Figure 1 Egg production (eggs/hen day housed) of light bodyweight hens on commercial (▲—▲), wheat bran (●—●), and two rice bran diets (DFRB-1980 ✶—✶, DFRB-1981 ■—■)

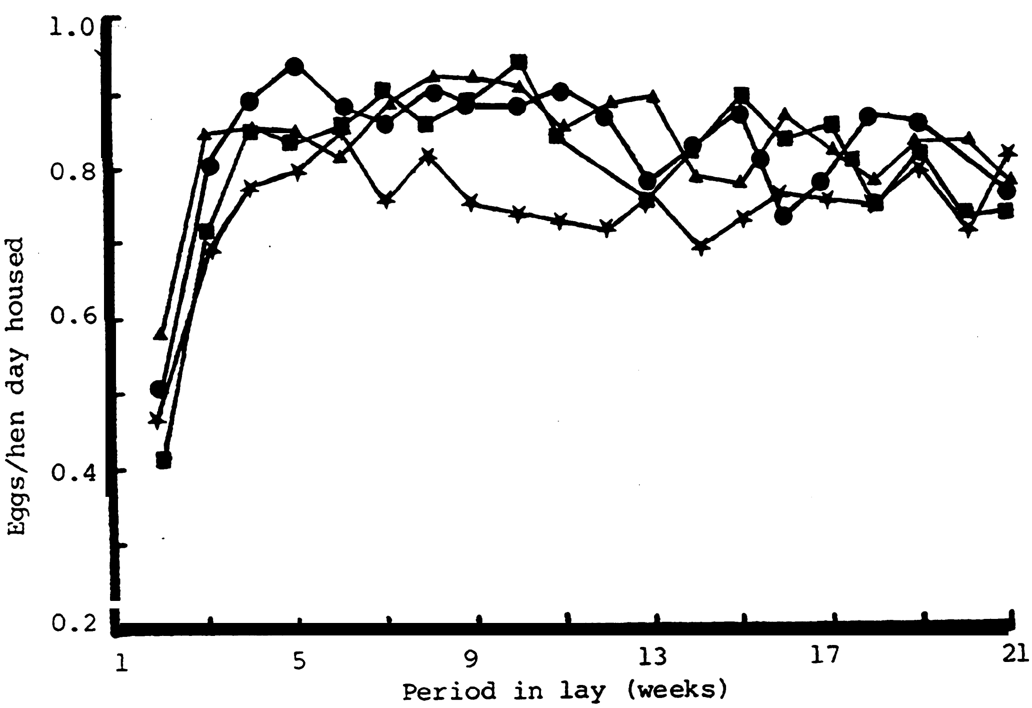

Figure 2 Egg production (eggs/hen day housed) of medium bodyweight hens on commercial (▲—▲), wheat bran (●—●) and two rice bran diets (DFRB-1980 ✶—✶, DFRB-1981 ■—■)

between birds in the different treatment groups.

TABLE 7 Determined analyses of diets for layer trial on DM basis

Group	1 Wheat bran	2 Rice bran	3 Rice bran	4 Commercial diet
Harvest	1981	1980	1981	
Metabolizable energy (MJ/kg)	13.0	12.9	13.0	13.3
Crude protein (g/kg)	166.6	168.5	172.4	190.8
Acid detergent fiber (g/kg)	7.2	6.3	6.5	5.7
Lipid (g/kg)	5.3	3.9	3.3	3.7

TABLE 8 Mortality (%) of laying hens on defatted rice bran (DFRB), wheat bran and commercial layer diets

Diet	1 Wheat bran	2 DFRB 1980	3 DFRB 1981	4 Commercial layer	Total
Period in lay					
1- 8 weeks	1	3	3	2	9
9-15 weeks	1	8	5	2	16
16-21 weeks		2	1	-	3
Total	2	13	9	4	28

The light bodyweight (LW) strain of birds was significantly lower ($P \leqslant 0.05$) in egg production on all diets, and at each period, than the medium bodyweight (MW) strain. (Table 9). There was a reduction in egg production on the rice bran diets ($P \leqslant 0.05$) in the period (9-15 weeks of lay) when shell grit was not offered.

TABLE 9 Egg production (egg/hen day housed) of two strains (medium bodyweight MW and light bodyweight LW) of birds during early lay (1 to 21 weeks) on diets based on defatted rice bran (DFRB) and wheat bran (WB).

Diet	Commercial		DFRB-1980		DFRB-1981		WB-1981	
Strain	MW	LW	MW	LW	MW	LW	MW	LW
Period in lay								
1- 8 wks	0.78^{Aa}	0.73^{Ab}	0.82^{Aa}	0.68^{Ac}	0.79^{Aa}	0.63^{Ad}	0.83^{Aa}	0.67^{Acd}
9-15 wks	0.83^{Bae}	0.76^{Ab}	0.76^{Bbc}	0.70^{Ad}	0.81^{Aac}	0.66^{Ad}	0.87^{Ae}	0.77^{Bbc}
16-21 wks	0.78^{Aa}	0.76^{Aa}	0.76^{Ba}	0.69^{Ab}	0.78^{Aa}	0.68^{Bb}	0.83^{Ac}	0.76^{Ba}

Values with different superscripts in the same row (a-e) or column (A-B) are significantly different ($P \leqslant 0.05$).

There was a strain by diet interaction ($P < 0.05$), such that the medium bodyweight hens (MW) had the same hen-day production (1-21 weeks of lay) on the four diets, although production on the wheat bran diet was 0.84 compared to 0.77 and 0.79 on the two rice bran diets, The light bodyweight (LW) birds showed a depression ($P < 0.05$) on the two diets containing rice bran (0.69 and 0.66) compared to that containing wheat bran (0.73) and the commercial diet (0.75) (Table 10).

TABLE 10 Egg production (egg/hen day housed) of medium (MW) and light (LW) birds in relation to diet

Diet	Strain	
	Medium	Light
1	0.80^{Aa}	0.75^{Aa}
2	0.77^{Aa}	0.69^{ABb}
3	0.79^{Aa}	0.66^{Bb}
4	0.84^{Aa}	0.73^{Ab}

Values with different superscripts in the same row (a-b), or column (A-B) differ significantly.

CONCLUDING REMARKS

The incorporation of by-products into pig diets results in a nutrient dilution and a decline in the digestible energy of the diet. The addition of winery pomace to pig diets resulted in higher intakes in order to offset the low energy&tent. In a trial where energy is restricted, the addition of a low energy by-product like winery pomace to the diets of pigs may not necessarily show a significant decline in performance since pigs have the capacity to eat to satisfy their energy requirement. However, on an ad libitum feeding program, it could be that pigs are unable to ingest sufficient needed to gain at the same rate as pigs on a higher energy diet. There is also the possibility of an acceptability factor such that feed is rejected above a certain level offered. In order to practically assess by-products with growing pigs, two basic trials have to be conducted, one with restricted feeding in order to detect any gross by-product nutrient deficiencies, and one ad libitum trial which may identify acceptability and digestibility factors.

Although some by-products mentioned are useful energy sources, their restriction as components in diets may be due to other indirect factors. For example , citrus pulp has a high calcium content (1.5-2.0%), this may restrict its level of inclusion in some diets, Rice bran from particular . harvests appears to impair calcium absorption through an, as yet, unknown mechanism. Rice bran is generally high in phytic acid and in fibre. Both of these factors may cause a reduction in calcium availability. Although egg production was reduced when laying hens were offered diets with defatted rice bran, there was no effect on shell quality. Greatest . effect on production and the highest mortality occurred in the light body-weight strain of birds. This may relate to body calcium stores. Rice bran was incorporated in layer diets at a level which would probably not be commercially acceptable. Further work needs to be carried out to determine the maximum inclusion level at which health problems do not occur.

The whole area of the use of waste- and by-products is complex and there are many difficulties. There is the uncertainty of supply and market demand for conventional ingredients and the associated fluctuations in supply and demand will govern the price. These factors will influence directly the economic worth of the waste- and by-product. In finally deciding what product warrants furhter investigation there is the need to identify present and projected production, moisture content, ease of handling and the appropriate feeding system that can incorporate the product. In some cases it may be economical to locate the pig unit close to the source of production and transportation would then be essentially discounted.

The ability to remove moisture at low cost from waste products is an important consideration, since this could transform them from essentially useless to a useful feed product because of ease of transportation and storage as well as the possibility of modifying the product when dry through removal of inferior material. Removal of moisture does not always mean the . application of heat. A process called reverse osmosis is being used to concentrate whey with great success.

In short what is potentially an important, useful and economic by-product as a pig feed in one location may be of little value in another. Clearly the final choice depends on a range of considerations some of which have been discussed here. Research is a critical factor in determining the nutritive value of waste- and by-products for pigs and the final assessment must be on-farm pig trials.

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