THE USE OF SUGAR IN DIETS FOR MONOGASTRICS

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SUMMARY

The use of sugar (sucrose) in commercial diets for monogastric animals is discussed. Emphasis is placed on the potential for the use of such an energy source in conjunction with high fibre vegetable proteins. A brief economic appraisal of the use of sugar cane juice as a pig feed is outlined together with areas for further research.

INTRODUCTION

Cereal grains constitute the principal energy source in monogastric diets. They are generally grown in the more temperate regions of the world and have to be imported into tropical areas to meet the needs for intensive animal production. This is of course expensive and moreover results in a loss of foreign exchange for many countries.

At the present time the Australian Sugar Industry, based entirely in Queensland and northern New South Wales, is suffering as a result of low world prices for raw sugar. In view of the need to diversify the use of sugar cane, an evaluation of the use of sugar as an alternate energy source in diets for monogastrics has been carried out recently at the Department of Agriculture, University of Queensland.

By-products of the sugar industry in the form of molasses, syrups and filter mud have been used previously as cereal substitutes. However only molasses has been successfully incorporated (to a limited extent) into pig diets (Preston et al. 1968). At levels higher than 20-30% of dietary DM, final molasses has been reported to cause severe diarrhoea (Velazquez et al. 1969). Ly and Castro (1984) attributed the reduced performance of molasses-fed pigs to excessive water intakes due to the hypertonic nature of the diet, changing the digestive patterns of the animals.

Recently, total substitution of cereal grains by sugar cane juice in pig diets has been reported by Mena et al. (1981; 1982) and Fermin et al. (1984). Pigs fed the sugar cane juice exhibited greater carcass yields, increased area of the L. dorsi muscle and thinner layers of subcutaneous fat, compared to pigs fed cereal based diets.

Similarly, Schumacher et al. (1986) found that raw mill sugar was also an acceptable source of dietary energy for growing/finishing pigs. Carcass characteristics were equal to, if not superior to, those of pigs fed cereal (sorghum) based diets.

As early as 1970 the practice of feeding raw sugar to poultry has been widespread in Cuba (Gonzalez and Fernandez 1975). Optimum sucrose levels in broiler diets were found to be ca. 50% of DM and extra supplementation of the B group vitamins was essential (Gonzalez et al. 1975). Gutierrez (1974) found that optimum protein levels of broilers given diets containing, high levels of raw sugar were ca. 19% and that methionine supplementation was needed to optimize growth particularly when the diet contained high levels of yeast.

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In contrast to the use of raw sugar, molasses inclusion in diets at levels greater than 25% of DM severely impaired growth and development of young broilers (Ibanez et al. 1980).

ADVANTAGES TO THE USE OF FIBRE-FREE LIQUID ENERGY SOURCES

The use of fibre free energy sources such as raw sugar or sugar cane juice permits greater use of cheaper vegetable protein sources which are not usually included to a great extent in conventional diets because of their high fibre content. High fibre diets for pigs have frequently resulted in decreased dressing percentages (Cole et al. 1968; Batterham 1979; King 1981). The decreased dressing percentage associated with increasing levels of dietary fibre levels has been attributed to increased "gut contents". Kass et al. (1980) found that the empty weight of al 1 segments of the gastrointestinal tract of pigs (excluding the stomach) increased with increasing levels of dietry fibre.

Two vegetable protein sources which could be of great value in pig diets based on sugar are sunflower meal and cottonseed meal. Both products contain high levels of fibre (ca. 13-15% DM) but exhibit a good complement of amino acids except for lysine. Conventional feed formulation programs limit the use of such material to ca. 10% maximum in order to maintain total dietary fibre levels below 5% and avoid palatability problems. The use of cottonseed meal is also limited by the presence of gossypol. However, this compound does not affect production until levels of free gossypol exceed 100 ppm (Tanksley and Knabe 1981) , and this level is only reached if cottonseed meal is included at levels of 20% or more in the diet. Many producers do feel that the use of these vegetable protein supplements should be kept at low levels in the diet because of adverse palatability factors.

The effects of increasing proportions (0,.10,.20,.30 and .40) of sunflower meal (SFM) or cottonseed meal (CSM) in sugar based diets for rats has recently been investigated (Kloren, unpublished data). Rats fed the diets containing SFM and this was reflected in significantly greater weight gains. As the proportion of CSM in the diet increased from 0.1 to 0.4 there was a linear reduction in weight gain (Table 1). Increasing the proportion of either SFM or CSM did not significantly affect feed intake

TABLE 1 Mean feed intakes and weight gains of rats fed sugar based diets containing increasing levels of either cotton seed or sunflower meal

Diet	Meal total feed intake/rat (LSD = 59.32)	Mean total weight gain/rat (LSD = 15.12)
Control	326.7^{a}	94.1^{ef}
Cotton seed meal 10%	312.9^{ab}	88.8^{ef}
Cotton seed meal 20%	330.6^{ab}	92.0^{ef}
Cotton seed meal 30%	272.8^{abc}	81.5^{e}
Cotton seed meal 40%	244.4^{ac}	47.6
Overall mean CSM	290.2	77.5
Sunflower seed meal 10%	301.5^{a}	98.7^{f}
Sunflower seed meal 20%	328.1^{a}	92.9^{ef}
Sunflower seed meal 30%	329.5^{a}	93.8^{ef}
Sunflower seed meal 40%	341.9^{a}	98.7^{f}
	325.2	96.0

(Values with the same superscript within a column are not significantly different ($P < 0.05$).)

however. However rats offered the diets containing SFM ate significantly more than rats fed the diets containing CSM.

There were major differences in the fatty acid canposition of perirenal fat due to dietary treatment (Table 2). Although oleic acid was the principal fatty acid on all treatments levels in fat from animals fed diets containing either SFM or CSM were markedly reduced.

TABLE 2 Fatty acid composition of perirenal fat from rats fed the sugar based diets containing sunflower meal or cotton seed meal

Diet	Total lipid (g/kg)	Lauric (C12)	Myristic (C14)	Palmitic (C16)	Palmitoleic (C16:1)	Stearic (C18)	Oleic (C18:1)	Linoleic (C18:2)
		Percentage of individual fatty acids						
Control	100.9^{d}	--^{a}	0.4^{a}	7.9^{a}	0.3^{a}	0.0^{a}	91.1^{d}	--^{a}
CSM 10	90.6^{c}	--^{a}	0.4^{a}	7.6^{a}	0.3^{a}	0.2^{a}	91.2^{d}	--^{a}
CSM 20	94.3^{cd}	--^{a}	0.5^{a}	9.8^{a}	0.3^{a}	0.1^{a}	88.9^{d}	0.1^{a}
CSM 30	74.6^{b}	0.5^{b}	1.4^{b}	28.1^{b}	0.6^{b}	0.6^{b}	72.4^{c}	1.2^{c}
CSM 40	59.0^{a}	0.7^{b}	2.3^{c}	38.3^{b}	0.7^{b}	1.5^{b}	54.3^{a}	1.9^{c}
SFM 10	96.8^{d}	0.4^{b}	2.2^{c}	32.5^{b}	1.6^{cd}	0.3^{a}	62.6^{b}	--^{a}
SFM 20	82.2^{c}	--^{a}	1.9^{c}	32.7^{b}	1.7^{d}	0.0^{a}	63.5^{b}	0.0^{a}
SFM 30	84.1^{c}	0.1^{a}	1.6^{b}	30.9^{b}	1.6^{cd}	0.3^{a}	63.1^{b}	0.5^{b}
SFM 40	82.6^{c}	0.5^{b}	2.2^{c}	30.7^{b}	1.5^{c}	1.0^{b}	63.0^{b}	0.7^{b}
LSD(0.05)	3.70	.18	.21	2.52	.13	.41	3.70	.36

(Values in the same column with the same superscript are not significantly different ($P < 0.05$) from each other)

Interestingly, the fatty acid composition of perirenal fat from rats fed diets containing increasing quantities of SFM did not vary but were very similar indeed to the composition of fat from rats fed the highest levels of CSM (0.30-0.40) which provoked gossypol toxicity.

The validity of the results from the rat growth assay described above was tested in a pig growth experiment. Twenty Large white x Landrace cross pigs (ca. 40Kg initial liveweight) were fed an experimental diet containing 30% sunflower meal and 40% raw mill sugar with conventional protein sources and supplements making up the deficit (Table 3) Growth rates and feed intakes of these animals were compared to those of' 20 pigs fed a conventional cereal based diet. Both diets were formulated to be isocalorific and isonitrogenous (13.4 MJ DE/kg and 170g crude protein/kg) by Cheetham Rural Pty Ltd. Wacol, Queensland.

Although the sugar fed pigs exhibited mechanical diarrhoea during the first three days on the diet, this soon ceased and there were no significant differences in liveweight gains, feed conversion efficiencies or dressing percentages of pigs fed the two dietary treatments (Table 4). Fibre level in the control diet was ca. 4.0% but 8 .0% in the sugar based diet.

TABLE 3 Dietary formulation and nutrient composition of the experimental sugar based diet and control diet (cereal based) fed to finishing pigs (g/kg)

Component	Experimental	Control
Sugar	400.0	0.0
Sorghum	0.0	224.6
Wheat	100.0	200.0
Barley	0.0	120.0
Mill run	0.0	100.0
Sunflower (HP)	300.0	0.0
Safflower	24.0	33.0
Mung bean	68.7	153.5
Blood meal	20.0	20.0
Meat meal 2A (49)	42.5	86.0
Molasses	30.0	50.0
Tallow	10.0	10.0
Mineral and vitamin premix	1.5	1.5
Synthetic lysine	3.3	1.4
Fibre	80.0	47.7
Crude protein	170.0	170.0
Lysine	8.5	8.6
Methionine and cystine	5.2	4.0
Digestible energy (MJ/kg)	13.4	13.4

TABLE 4 Production responses of pigs fed conventional or sugar based diets

	Diet		
Parameter	Conventional	Sugar	Significance
LWG (g/d)	848.04	892.06	N.S.
P_2 at 75 kg (mm)	15.7	16.5	N.S.
Feed intake/pig/d (kg)	2.76	2.59	N.S.
Feed conversion efficiency	3.25	3.02	N.S.
Dressing percentage	73.9	74.6	N.S.

FUTURE RESEARCH INTO THE USE OF SUGAR BASED DIETS

The production data reviewed in the previous section indicate that sugar based diets can support excellent levels of animal productivity. However, there are other factors which could be of importance and which warrant future research.

(1) Changes in lipid composition of carcass

The fat type of pigs fed sugar based diets is characterised by a high level of oleic acid with reduced proportion of the polyunsaturated linoleic and linolenic acids. However Schumacher et al. (1986) reported that a CSIRO taste panel failed to detect noticeabledifferences in aroma, flavour, taste or overall acceptability of meat from sugar fed pigs.

An hypocholesterolaemic effect has been reported by feeding animals with plant fibres, gums and mucilages. Pectins in particular exhibit strong cholesterol clearing properties (Griminger and Fisher 1966; Fisher and Griminger 1967). The use of high fibre vegetable proteins in conjunction with sugar based diets of low lipid content may result in reduced cholesterol deposits in body lipid reserves and this would result in particular marketing advantages. All studies previously reviewed on the use of sugar based diets indicate that such diets do not result in "fat" pigs. the excellent performance of pigs fed sugar based, low lipid diets casts doubts on the requirements of the pig for essential fatty acids.

(2) Choice feeding

In recent years a good deal of research has evaluated the advantages of choice feeding regimes by poultry, especially at high environmental temperatures. Mastika and Cummings (1981) reported that carcass fat levels were reduced and both growth rates and feed conversion efficiency improved in such a system. However, Black *et al.* (1981) reported that laying hens were unable to overcome the effects of high environmental temperatures by choice feeding. The use of sugar cane juice delivered to birds via a water supply system with protein meals offered separately may be advantageous. Work by Shaobi and Forbes (1985) found that chickens considered a 10% dextrose solution to be the same as water and hence could not detect energy compounds in solution. Recent work in our department confirmed this observation and showed that cockerels readily accept sugar solutions. A total of 21 cockerels were individually caged and fed *ad lib* a basal diet (11.9 MJ ME/kg). Three birds were then given solutions of glucose or sucrose (10% w/v) to replace water during the period 6a.m. to 6p.m. or 6p.m. to 6a.m. Control birds (3) had access to water at all times, two other groups of three birds had access to the glucose solution or sucrose solution at all times but without water. The birds were fed the experimental diets for one week and then intakes of dry feed and sugar solutions were measured over two consecutive days. Both glucose and sucrose supplementation significantly increased total ME intake above that observed in control birds. However, only in birds offered the glucose solutions were the increases statistically significant. It is now planned to utilize sugar cane juice in place of the sucrose solution and to offer birds a protein/vitamin mineral mixture *ad lib* (Table 5).

TABLE 5 Mean daily intakes of ME, feed and liquid for cockerels fed a basal diet with and without sugar solutions

Treatment	ME intake (KJ/bird/day)	Feed intake (g/bird/day)	Liquid intake (ml/bird/day)
Water			
All time	2148[a]	183	566
Glucose			
All time	2374[b]	150	409
Day	2426[b]	160	553
Night	2268[a]	168	513
Sucrose			
All time	2266[a]	122	542
Day*	2275[a]	150	501
Night**	1816[c]	138	461

* Day = 6a.m. to 6p.m.
**Night = 6p.m. to 6a.m.

(3) Long-term use of sugar diets

Bruckdorfer and Yudkin (1973) found that when sugar replaced starch at 50% of DM in pig diets, growth and feed conversion were superior during the initial 9 weeks of feeding. After this period the production of the sugar fed pigs declined below that of the control starch fed group. Most of the experiments carried out in the use of raw sugar or sugar cane juice have lasted approximately 10 weeks and therefore avoided any possible deterioration in productivity. However, the continuous use of sugar for breeding stock has not been investigated. The effect of sugar as a fibre free energy source on the amino acid requirements of growing pigs also warrants close investigation. In view of the differences in gut development of animals fed such diets, it may be that current recommendations are an over estimate of requirements.

ECONOMIC APPRAISAL OF SUGAR FEEDING

The domestic price of raw sugar in Australia is maintained at high levels and it is impossible to consider the use of a "feed grade" product for commercial monogastric production without significant changes in legislation.

However, the use of sugar cane juice is a viable alternative to raw sugar if it can be utilized near to sugar cane mills. The value of sugar cane stalk varies between mill areas and is a function of the sugar content of the juice it contains. It is anticipated that for the next crushing season in Queensland (June-December 1987) cane farmers can expect approximately $23-24 Aust/tonne of fresh cane.

One tonne of cane represents approximately 650-700 litres of extractable juice in the mill. This amount would meet the requirements of one growing/finishing pig from 25-80 kg liveweight (Mena et al. 1981;1982). The cost of protein meal (sunflower meal at ca. $150/tonne) plus vitamin/mineral premix would represent at the most an additional cost of approximately $10 resulting in a total feed cost of ca. $35/pig. The cost of conventional pig feed to cover this period would be ca. $36-40 (Brisbane prices). Cereal grain prices are of course much higher in north Queensland which result in greater cost of pig production. The commercial value of export sugar obtained from 1 tonne of cane of 14 C.C.S. with an anticipated world price of $230/tonne would be approximately $25 to the mill. It would seem, therefore, that it could be more profitable ($2/tonne of cane as sugar vs. $10-15 tonne of cane as pig feed) to divert a proportion of the juice extracted in the mill towards pig production.

The combination of sugar and cheap vegetable protein supplements which can be grown in north Queensland could form the basis of a developing pig industry orientated towards export markets of south-east Asia.

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