CITRUS PULP IN FORMULATED DIETS

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SUMMARY

Most of the citrus fruits grown worldwide are oranges of various varieties. More than half of these are processed and have their juice extracted. The resultant wet citrus waste has been used for over 60 years as a source of feed for livestock. Most citrus pulp is now dried for convenience of storage and transport prior to feeding to ruminant livestock. Brazil and the U.S.A. are the largest exporters of dried citrus pulp in the world. Significant quantities are produced and utilized in Australia. Citrus pulp is primarily a low protein feed with a carbohydrate profile very different to the usual raw materials used by stockfeed manufacturers. It is a high energy feed, but contains virtually no starch and has more in common with dried spring forage, sugarbeet pulp or root crops than with cereal grains. As such it has advantages over cereal grains, particularly in formulated diets for ruminant animals. As a by-product feed citrus pulp from different sources may vary considerably in chemical composition, palatability and nutritive value. This variation is a characteristic of virtually all by-Product feeds.

The level of utilization of citrus pulp in formulated feeds is very much dependent on availability and relative cost effectiveness of alternative raw materials. Dried citrus pulp from the Murrumbidgee Irrigation Area (MIA) is in strong demand for live sheep export pellets and general sheep, beef and dairy cow supplements with a limited quantity being included at low levels in sow feeds. Virtually none is used in rations for poultry, growing pigs or horses in Australia.

INTRODUCTION

The current annual world production of oranges is estimated at 43 million tonnes of which 65% are used for orange juice production. Around 12.5 million tonnes are produced in Brazil and 10 million tonnes in the U.S.A. in the former 85% and in the latter 60% of oranges are used for juice production.

Australia is a relatively small producer. The total citrus fruit produced is estimated at about 650 thousand tonnes. Almost a third of these (30%) are used for fresh home consumption. A relatively small quantity of quality fruit (about 6%) is exported and the majority (64%) are used for juice. Oranges make up the major part (over 80%) of the Australian crop with lemons (7.5%), grapefruit (5%) and mandarins (around 5%) making up the remainder. Most of the oranges grown in Australia are in the South-east (N.S.W. 38%, Vic. 25%, S.A. 32%) with relatively minor contributions from Queensland (4%) and Western Australia (1%). Most of the orange crop in N.S.W. is grown in and around Leeton and Griffith in the MIA.

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wet citrus waste at 80% moisture represents approximately half the weight of fresh oranges and in the MIA has traditionally been dumped or fed to sheep, cattle and more recently goats as produced with no further processing and with no protein nor mineral supplementation. However there is now considerable production of dried citrus pulp from the wet citrus waste by the Biocon Division of Ricegrowers' Co-operative Limited (RCL) at Griffith.

In the MIA the potential amounts to around 8,500 tonnes dried orange pulp for stockfeed (dry matter 92%) in contrast to 50,000 of dumped wet waste. This is not a lot when compared to the dried citrus pulp exported out of Florida annually which amounts to around half a million tonnes and has been as high as 1 million tonnes in the late seventies and the early eighties before unseasonal frosts devastated production. However it represents around half a million Australian dollars in value as stockfeed. It is of special interest in the MIA because heat used to dry it is produced from combustion of rice hulls. Rice hulls are another MIA waste product which has caused disposal problems in the past. Over 120,000 tonnes of rice hulls are produced by the N.S.W. rice industry annually. Combustion of 110 tonnes of rice hulls can provide enough heat to produce 100 tonnes of dried citrus pulp and the residual silica ash (20% of original hulls) has many industrial applications and can be readily sold. The main outlets for ash are as a refractory agent in the steel industry and as a filter aid in the production of glucose syrups for the food industry. The integrated production of dried citrus pulp in the MIA using heat from combustion of rice hulls adds value to both the citrus and rice crops while aiding in the prevention of two separate by-product waste disposal problems.

It is the intention in this paper to look at citrus pulp production in the MIA and the utilization of dried citrus pulp particularly in the area of formulated diets for livestock and poultry. These results will be discussed in the light of extensive research and practical experience from all over the world.

CITRUS PRODUCTION AND PROCESSING

In any consideration of utilization of by-products for livestock feeds, particularly where products of the livestock fed are destined for human consumption it is important to be aware of all production and processing conditions associated with the particular by-product in order to eliminate any risks which may be associated with use of the material. For example the raw material may contain toxic factors which are concentrated in the by-product. These may be naturally occurring enzyme inhibitors or antimetabolites in the raw material such as occur in raw soyabeans, cottonseed and rapeseed which reduce animal, performance. There could be residues associated with control of weeds, fungus diseases and insect pests during growth and storage which could be concentrated in the by-product and later in animal products such as meat, milk or eggs and be potentially harmful to consumers. There may also be breakdown products resulting from oxidation and rancidity which may be equally harmful to livestock and consumers. There is increasing awareness of moulds and mycotoxins. Such contaminants affect palatability and feed conversion efficiency and may also affect reproductive efficiency and thus profitability. At worst these residues may be carried through to the consumer level. All livestock producers, stockfeed manufacturers and professionals associated with livestock production must always be fully aware of these potential dangers in utilizing by-products and continually monitor husbandry, storage and processing methods and end product quality to eliminate all risks.

Chemical spray recommendations are under strict control of State Departments of Agriculture. In the MIA the N.S.W. Department of Agriculture Orchard Spray Calendar details recommendations for citrus. The list covers treatments for control of various viruses, fungus diseases, moulds, mineral deficiencies, snails, mites and insects. There are also chemicals recommended to control fruit drop and post harvest decay.

Nutrient supplements used to control mineral deficiencies are taken up through the tree leaves and residual levels wash off the fruit with rain. Trace amounts used are most unlikely to cause a problem in citrus waste.

Fungicides are usually only used for post harvest packing. The quantity of citrus fruit treated with fungicides and subsequently used for juicing is therefore likely to be extremely low and there is not much risk associated with these chemicals in citrus waste.

The use of pesticides in the MIA is not as widespread as in other places such as the coastal citrus growing areas. Although the Orchard Spray Calendar mentions around 13 pesticides for use with citrus most MIA farms use routinely only white oil for control of scale which is of no danger to stock or consumers. Chlordane is a particularly toxic chemical used on some young citrus trees to control ants, but such trees are not of fruit bearing age. As the spray is applied to the ground beneath the trees chlordane should not be a problem. Biological control with insect predators is preferred in the MIA and this is not compatible with use of insecticides.

In addition to control of spraying all citrus fruit is thoroughly washed and scrubbed prior to juicing. Most juice factories use town water and a stiff brush but some use a sorbate bath to remove fungal spores. It follows that if the fruit is suitable for production of juice for human consumption then the resulting waste material is highly unlikely to be unfit for livestock feed use.

Following the removal of juice the wet citrus waste is transferred to the citrus pulp plant for further processing. All wet citrus waste destined for production of dried citrus pulp in the MIA is processed within 12-24 hours of juicing ensuring that rancidity and mould growth are virtually zero.

At the RCL Biocon plant wet citrus waste is tipped into a receival bay and conveyed to a vertical shredder following addition of a slurry of slaked lime which' facilitates water removal in a press prior to dehydration in a rice hull fired rotating drum dryer. Dehydrated citrus pulp is then pelleted while still hot and stored following cooling in bulk pellet storage silos prior to despatch to RCL Coprice Division Feedmill and other stockfeed mills.

BY-PRODUCTS OF CITRUS

The raw by-product of citrus juice manufacture is the wet citrus waste which includes everything from the citrus fruit except the expressed citrus juice. Wet citrus waste has caused disposal problems in the past. The major use for this material has been livestock feeding. It has been used for many years as produced with no further processing or as silage following a period of silo storage. Field dumped wet citrus waste is readily eaten by livestock but it does ferment readily, it attracts flies, smells strongly and cannot be easily stored and transported. Consequently dried citrus pulp has been produced in commercial quantities for over 50 years in Florida in an effort to overcome these problems (see Kesterson and Braddock 1976). In preparation of dried citrus pulp lime has to be added first to the wet waste to overcome the water holding capacity of the complex carbohydrates in the residue. The resultant material is then pressed to remove as much water as possible prior to drying. The press liquor from this process contains mostly soluble sugars and can be concentrated to produce citrus molasses which may then be added back to the pulp prior to pelleting. In the RCL Biocon process no molasses is recycled at present but awareness of the potential pollution problem and value of the press liquor will probably result in production of citrus molasses or utilization of the press liquor in some other way in the near future.

Although most citrus waste finishes up as livestock feed there are many alternative commercial uses but no one method is envisaged as a competitor for stockfeed citrus products. In the MIA pectin for the food industry is being commercially produced at Griffith and in the U.S.A. there are a variety of items produced as added value products from citrus waste. For example the monocyclic terpene d-limonene is extracted for further use in the chemical industry. Synthetic odour materials including l-carvone, a synthetic spearmint oil flavour, are produced from d-limonene. In the plastics industry d-limonene is converted into resins and adhesives. As a solvent it is used in soaps and perfume manufacture and in the manufacture of rubber. There are many other applications for limonene and other citrus peel oils. Citrus oils are used in beverages, food, perfume, cosmetics, soap, pharmaceutical, paint, confectionery, condiment, ice cream, insecticides, rubber and textile industries and are also used for flavouring and scenting many other types of products. The major outlet is for flavouring.

A group of compounds known as flavonoids also occurs in citrus. Hesperidin is a biologically active flavonoid used as a therapeutic agent in the pharmaceutical industry. It is also used as a base material for azo-dye wood stains. Naringin is the predominant flavonoid in grapefruit and is extracted for use as an additive to beverages. Like hesperidin it too is used in azo-dye manufacture. Natural sweetening agents up to a thousand times sweeter than sucrose can also be extracted from citrus waste. Kesterson and Braddock (1976) have described in detail the history of the citrus industry in Florida and reviewed thoroughly the major developments and uses of by-products and speciality products of Florida citrus including fermentation products and waste disposal.

COMPOSITION OF CITRUS PULP

Wet citrus waste containing around 20% dry matter represents about half of the weight of fresh oranges, but this can vary from 50-70% depending on species, variety, husbandry and processing techniques. The dry matter comprises mainly peel (60-65%) and segment pulp (30-35%) with some residual seeds (040%). Variation depends largely on species and varieties within species.

Chemical analyses have been used to give some indication of quality and feeding value of citrus waste for livestock and most of the published values have come from research carried out in U.S.A. (see Harris _et al_. 1982). The average nutrient composition of dried citrus pulp shown in Table 1 summarizes results mainly obtained in Florida over a wide range of samples. These values are not markedly different to values obtained in our own laboratory for MIA dried citrus pulp produced at RCL Biocon.

TABLE 1 Estimated nutrient composition of dried citrus pulp

Nutrient	Percentage as fed	Reference
Moisture	8.6	Harris _et al_. 1982
Ash	4.7	"
Ether extract	3.7	"
Crude protein	6.2	"
Crude fibre	12.3	"
Nitrogen free extract	64.6	"
Calcium	1.4	"
Phosphorus	0.1	"
Acid detergent fibre	24.0	Pascual and Carmona 1980a
Neutral detergent fibre	27.0	Welch and Smith 1971
Acid detergent lignin	1.5	Pascual and Carmona 1980a
DE (pigs) MJ/kg as fed	10.6	Farrell _et al_. 1983
ME (poultry) MJ/kg as fed	5.5	Scott _et al_. 1982
ME (ruminants) MJ/kg as fed	11.7	Bartsch and Wickes 1979

A study of the composition of citrus pulp in Spain indicated that Spanish dried citrus pulp is similar to Florida and MIA material and added acid detergent fibre and acid detergent lignin analyses which are also shown in Table 1.

Furthermore the Spanish research indicates that addition of lime and heating during processing increased acid detergent fibre markedly from 16% in fresh material dry matter to 24% a value close to that obtained for dried citrus pulp by other reseachers (Pascual and Carmona 1980a).

Cell wall constituents or neutral detergent fibre levels in ruminant animal feeds appear to be a major factor in determining rumination time, at least as far as hays are concerned. Data on citrus pulp is limited but a level of around 27-28% neutral detergent fibre or CWC in dried citrus pulp has been found overseas (Welch and Smith 1971) and confirmed in Australia.

Although citrus pulp is primarily used as a source of digestible energy in stockfeeds it does contain a significant amount of crude protein. Consequently it is of value in evaluating citrus pulp as a livestock feed to have some idea of the nature of this crude protein material. Amino acid profile data are limited and Table 2 shows a summary of data available at the present time. Only about half of the nitrogen in citrus pulp appears to be contributed by true protein.

TABLE 2 Estimated amino acid composition of dried citrus pulp

Amino acid	Percentage as fed	Reference
Lysine	.31	Bhattacharya and Harb 1973
Histidine	.17	"
Arginine	.46	"
Aspartic acid	.91	"
Threonine	.30	"
Serine	.36	"
Glutamic acid	.83	"
Proline	.90	"
Alanine	.39	"
Valine	.37	"
Methionine	.08	"
Isoleucine	.49	"
Tyrosine	.30	"
Phenylalanine	.29	"
Cystine	.11	Scott _et al_. 1982
Tryptophane	.06	"
Other amino acids	no data	

Although there are other chemical constituents in citrus pulp which may be of nutritional significance the analyses given in Tables 1 and 2 are those currently accepted by the majority of advisers and extension officers as being of most significance in comparing various feed ingredients as sources of nutrients for livestock.

CITRUS PULP FOR LIVESTOCK AND POULTRY

One of the continuing responsibilities of nutritionists is to determine the potential value of new or improved feed ingredients. Almost every ingredient has some limitations, but often they can be overcome. Soyabean meal for example was considered almost useless as a feed ingredient for poultry until it was discovered that proper heating inactivates the antinutritional factors in it. Chemical analyses are the firststage in nutritional evaluation. They are however of little use in predicting animal performance without animal acceptability data, digestibility trials and comparative feeding trials. The following section is concerned with trials carried out with live animals.

Dried citrus pulp for poultry

There is very little data on the use of citrus pulp in poultry diets, however a figure of 5.52 MJ/kg has been documented as a metabolizable energy value for use in formulating poultry feeds (Scott et al. 1976). It has been suggested that pullets and laying hens can utilize 5% dried grapefruit pulp with no effect on rate of growth or egg production, whereas even this low level gave unfavourable results with young poultry. Dried citrus pulp meal has been used in broiler diets up to 40% but feed consumption and feed conversion were both increased while weight gain was depressed when the inclusion of citrus pulp meal was raised from 20 to 40% (see El Moghazy and Boushy 1982).

The pigment in orange and tangerine flavedo showed a 30.1% utilization for egg yolk pigmentation (see Kesterson and Braddock 1976) in one laboratory. However it has also been claimed that 2.5-5% dried citrus pulp can depress yolk colour even in the presence of 7.5-10% lucerne meal. Australian data suggests that MIA dried citrus pulp at a dietary level of 5% had neither beneficial nor adverse effects on egg yolk pigmentation either in the presence or absence of synthetic oxycarotenoids. However there was 8 tendency for decreased egg production, egg weight and feed intake in these trials, the magnitude of which is cause for caution, with hens fed 5% MIA dried citrus pulp (Karunajeewa 1978). The work on yolk pigmentation is further confused by data from trials in which citrus sludge was fed to layers. Yolks were described as "more orange" as dietary citrus sludge levels were increased. No significant flavour differences were detected by a taste panel for either yolk or albumen in these experiments (Angalet et al. 1976). Dried citrus pulp is not generally used in poultry feeds in Australia.

Dried citrus pulp for pigs

As in the case of poultry very little work has been done on the use of citrus waste in pig diets. A digestible energy figure of 10.6 MJ/kg has been determined with pigs in metabolism cages (Farrell et al. 1983) which equates with a total digestible nutrients figure of 58. This is considerably higher than the figure of 45 total digestible nutrients for swine quoted in the Feedstuffs Yearbook. However it is much lower than the digestible energy value of 15.1 MJ/kg quoted by Taverner (1984) for pigs which is even higher than would be expected for cattle. The figure of 10.6 MJ/kg for the digestible energy content of citrus pulp for pigs does not appear unreasonable and in the absence of any other data must be taken as the figure of choice.

Published work on amino acid availability from citrus pulp fed to pigs appears to be non-existent. Despite the limited published data dried citrus pulp is used in commercial balanced pig diets. A recommendation of 5% maximum is general in the stockfeed industry in Europe with none in creep feeds for baby pigs. RCL Coprice Division has successfully used dried citrus pulp in sow feeds for many years at a 5% level of inclusion. It is however important if using separate dry sow and lactating sow diets to include citrus in both, otherwise palatability problems may occur on changeover. Feedback from clients suggests 5% dried citrus pulp in sow feeds together with some ground rice hulls in dry sow feed aids in the prevention of constipation around farrowing. Furthermore there is no doubt that 5% dried citrus pulp in these fibrous feeds aids in production, enabling better quality pellets with less pellet breakdown to be produced in a shorter time with reduced energy costs.

Dried citrus pulp for horses

Citrus pulp had been fed to horses in Florida for many years without detrimental effect despite the fact that no published palatability data were available and no digestibility trials nor comparative feeding trials had been carried out specifically with horses fed citrus pulp prior to 1979 (E.A. Ott personal communication). However there was already a wealth of published information indicating that citrus pulp was a valuable feed ingredient for dairy cattle, fattening cattle and fattening lambs. Research work carried out at the University of Florida (Ott et al. 1979) has since shown that dried citrus pulp can be incorporated into horse diets as a substitute for oats without adversely affecting digestibility of the energy yielding components of the diet. However protein digestibility was reduced. Two acceptability trials, utilising eight mature horses were conducted to compare coarse grain concentrates containing zero or 30% citrus pulp as a substitute for oats. Acceptability of the 30% dried citrus pulp diet was a problem. Six horses refused the citrus pulp concentrate, consuming less than a tenth of the feed offered.

Four horses were offered 1.75kg/100kg bodyweight of complete pelleted diets containing 0, 15 or 30% dried citrus pulp. Acceptability was good. Three of the horses consumed all the feed offered while one horse refused 3% of the diet containing 30% citrus. Apparent digestibility of organic mutter, ether extract and gross energy for the three diets were not significantly different. However apparent digestibility of acid detergent fibre and nitrogen free extract were higher for the dried citrus pulp diets and crude protein digestibility lower with the 30% dried citrus pulp diet. It was concluded that Florida dried citrus pulp is a suitable ingredient for inclusion in pelleted diets for mature horses at levels up to 15% as a replacement for oats.

Horse feeds are of considerable significance to RCL mainly as an added value product for utilizing broken rice and rice pollard from rice milling operations. Consequently, we have always endeavoured to improve our products where possible and provide products for which there is a strong market demand. During the drought of 1982/83 it became apparent that roughage was so expensive that horse owners in the Melbourne region were feeding very little of it and the ratio of pelleted feed to roughage fed was reaching undesirable levels. Digestive disturbances may occur in horses when supplementary cereal based pellets are fed, particularly in a group feeding situation when roughage is in short supply. In order to overcome this a pelleted high fibre ration of relatively low energy was designed and this was tested by feeding 25 Victorian police horses in a trial at Attwood (Huntington and Hutton 1986). The horses were fed for four months on lucerne hay, grass hay and supplementary high fibre pellets. No untoward effects were noted during the trial and all horses maintained or improved their body condition.

The pellets consisted of 22.5% broken brown rice, 20% rice pollard, 25% ground rice hulls, 10% sunflower meal, 10% dried citrus pulp, 8% lucerne meal, 2% bentonite, 0.5% dicalcium phosphate, 0.5% salt, 1.25% calcium carbonate and 0.25% of a micropremix designed to generously cover all known nutrient requirements. Rice hulls are a very cheap source of fibre continuously available regardless of conditions of drought or plenty. Citrus pulp provides digestible energy without additional starch and is an excellent pelleting aid ensuring high quality pellets. The specification of the high fibre pellets was 9MJ/kg digestible energy, 10% crude protein, 5% crude fat, 18% crude fibre, 1.1% calcium, 0.7% salt and 0.57% phosphorus.

The horses included in the trial were Thoroughbred or Thoroughbred Warmblood crosses of various ages. They included pregnant mares, growing horses, spelling horses and those doing light work. All had access to pasture, but the amount was variable. They were accustomed to a mixed supplementary diet. The basic feed was 4kg pellets and 3kg each of lucerne and grass hay daily. Body condition, pasture availability and type of work were factors leading to variation in this basic pattern.

Feed acceptance was very good and horses were keen to eat the pellets. Initially a number of horses had loose droppings, but these returned to normal quickly. No health problems were encountered throughout the trial.

This work confirms Florida data obtained using citrus pulp in horse feeds and indicates that horses can be fed satisfactorily on a ration which includes ground rice hulls for extended periods. When fed in combination with lucerne and grass hay, high fibre pellets containing considerable quantities of ground rice hulls and dried citrus pulp can provide a convenient, cheap, safe, balanced diet for horses. In group feeding situations and drought conditions such pellets would be much safer to feed than traditional cereal based pellets.

In addition to the research at Attwood on high fibre diets for police horses, it was decided to trial our standard mature horse pellets with either 15% citrus pulp or 7.5% citrus pulp replacing broken rice. These trials were designed simply to assess consumer acceptance and palatability of the pellets for horses under commercial conditions. In the first series of trials the 15% citrus pellets were supplied to 8 owners and trainers for feeding a total of 27 horses. Horses included Appaloosas, Showhacks (Thoroughbred), Dressage horses (Thoroughbred) and Standardbreds. All horses were being worked, the work ranging from light exercise to heavy race training. Virtually all of the horses had been receiving our standard mature horse pellets prior to the trials. Most of the horses accepted the 15% citrus pellets initially but 8 horses did not and 4 of these refused completely. With the horses that did accept the 15% citrus pellets we noticed that feed was being left after 4-5 days and after a few more days at least half of these horses were refusing the pellets. In some cases if the experimental pellets were mixed 50:50 with our standard horse pellets acceptance was improved. Many trainers commented that the pellets tasted bitter and that was the reason for rejection after a number of days.

In the second series of trials the 7.5% citrus pellets were supplied to 16 different trainers. Close on 70 horses were involved. The majority of these were Standardbreds but some Thoroughbreds and German Warmbloods were included. Initial acceptance was good with only 5 horses proving difficult. It maybe significant that 3 of these were yearlings. The only horses to completely reject the 7.5% citrus ration were yearlings. However in two cases trainers actually preferred the 7.5% citrus ration to the standard ration. After two weeks very little rejection occurred and the majority of the pellets were being consumed. In 12 cases rejection of the 7.5% citrus pellets was noticed after a period of a few weeks. In all cases when the standard ration replaced the experimental pellets all horses accepted the feed change. Furthermore when the 7.5% citrus pellets were reintroduced they were readily accepted only to be rejected later by a few horses. Other horses which had not previously rejected 7.5% citrus pellets did so occasionally and with one horse rejection did not occur until 3 months later. However the majority of horses showed no indication of any problems. Dried citrus pulp even at the 7.5% level offers major benefits in feedmill efficiency. Throughput in our mill was doubled with 7.5% dried citrus pulp replacing 7.5% ground broken rice. Furthermore pellet durability was improved from 92.8% for the standard mature horse pellet to 95.8%. Despite these advantages and the observations from Florida that dried citrus pulp is a nutritious feed for horses it is clear that some horses do not appear to like it. Consequently as the horse feed market in Australia is so sensitive our policy is now not to use any citrus pulp in branded horse rations.

Citrus pulp for beef cattle

In a digestion trial with dried grapefruit refuse with 4 steers, Neal et al. (1935) at the Florida Station found 24.8% of the crude protein, 71.5% of the crude fibre, 92.4% of the nitrogen free extract and 79.4% of the crude fat to be digestible. The dried grapefruit used yielded 1.2% digestible protein and 76% total digestible nutrients and was palatable. It was also noted that dried orange peel seemed to be as palatable as dried grapefruit refuse and that dried grapefruit and orange cannery refuses have a laxative action when fed as a large proportion of the ration. The general effects of the dried grapefruit refuse were noted as being favorable as indicated by thrifty appearance, gloss of the coat of hair, and improvement in thickness of flesh.

These results were supported by Texas Agricultural Experiment Station (Jones et al. 1942). Dried citrus pulp, when fed to replace not more than 25% of the ear corn chop with husk, resulted in the production of practically equal gains but slightly higher finish than groups fed ear corn chop with husk as the carbohydrate concentrate portion of the ration.

The replacement of as much as 60% of the daily allowance of ear corn chop with husk by dried citrus pulp produced a feed which was less palatable, and had slightly greater laxative effect, and reduced feed consumption, gains and finish. In these tests a mixture of 75 parts ear corn chop with husk and 25 parts dried citrus pulp as the carbohydrate concentrate produced satisfactory results.

There were no distinguishing differences in the colour of fat between the check groups fed ear corn chop with husk and those which received the dried citrus pulp as replacement of varying amounts for ear corn chop with husk.

Numerous trials have been reported since the pioneering studies from Florida, Texas and also California (see Jones et al. 1342) and they have consistently reported favourable results (Peacock and Kirk 1969; Kirk and Koger 1970). Furthermore a reduction in digestive disturbances with cattle on full feed including dried citrus pulp has been reported. Dried citrus pulp either loose or as pellets was found to result in reduced rumen ammonia levels for cattle fed urea supplements (Pinzon and Wing 1976). The data from this trial suggested that citrus pulp at 38-55% increased nitrogen utilization since it decreased urea nitrogen in the blood of these cattle. The inclusion of dried citrus pulp to replace corn meal in beef cattle rations was also shown to affect the fatty acid composition of carcass fat through its effect on the volatile fatty acid production in the rumen (Cabezas et al. 1965). Citrus pulp favoured acetate production at the expense of propionate and resultant carcase fat as measured over the ribs was harder for citrus fed cattle then those on corn diets. All these trials relate to trials from U.S.A. Material from Cyprus appears to be no different (Hadjipanayiotou and Louca 1976). The pattern of digestion of citrus pulp in ruminants whereby a highly digestible material promotes an acetate fermentation rather than the propionate fermentation associated with highly digestible starch based diets is interesting. In this context it has been observed recently that monensin which promotes propionate type fermentation in ruminants and decreases acetate was equally effective whether the primary energy source in beef cattle diets was corn or dried citrus pulp (Vijchulata et al. 1980). Our own trials in the MIA have been somewhat limited. However it does appear that young growing cattle 8-12 months old weighing 250-350kg will gain 1.25kg per head/day on good winter pasture with supplements of 3kg/head/day hay and 2kg/head/day of 14% protein pellets containing 25% dried citrus pulp. This rate of gain is similar to feedlot performance and was required to take purebred Red Poll cattle into the keenly sought 350-420kg yearling steer weight range in our trial. It is also worth noting here that wet citrus pulp is still fed to beef cattle in the MIA. Cattle appear to like it and eat it in the presence of fresh green irrigated feed or on dry feed in upland paddocks. Even when it has been standing around for days, or even weeks, in the hot sun and becomes hard and dry it appears to be readily eaten by beef cattle.

Citrus pulp for dairy cattle

It is clear from the previous discussion that beef cattle eat citrus pulp either wet or dried with no problems. Dairy cows in the U.S.A. have been shown to be no different in this respect. However there is some evidence that although dried citrus pulp has been shown to be a satisfactory ingredient in rations for young dairy calves there are optimum levels which are desirable. In a trial where 0, 15% or 30% dried citrus pulp were included in diets for calves from birth to 80 days of age calves on the 15% citrus pellets ate more and grew faster than the others, particularly in the period to 60 days of age (Wing 1965).

When milk production is studied there are many more factors to consider. Milk composition is of as much significance as milk yield and any undesirable taints in milk may be concentrated in dairy products and result in a reduction in consumer acceptance. Milk production and particularly milk quality are very much dependent on feed quality, composition and intake levels. There is evidence that milk composition is affected significantly by use of citrus pulp in dairy cow feeds and also that a citrus taint may be passed into the milk under certain conditions. Consequently use of citrus pulp in dairy diets should be restricted and monitored. Despite these observations we have observed no problems whatsoever in practice using routinely up to 25% dry citrus pulp in dairy supplements. The reason for this is that supplementation levels are characteristically low under Australian conditions with only around 2kg of supplement being fed per head per day on average. Despite this there are some cows which take up to 5 days to accept the pellets readily. However, once they do we have observed no problems whatsoever.

Results of a series of trials conducted with lactating cows at Texas Agricultural Experiment Station (Copeland and Shepardson 1944) concluded that dried citrus peel and pulp fed in moderate quantities (25% of the concentrate mix) was palatable. It was further observed that in very hot weather citrus pulp had a beneficial effect on appetite of dairy cows. The results of these trials also suggested that no taint was detectable in milk from cows fed up to 3.6kg daily of dried citrus peel and pulp and even at higher levels of intake (50% of the concentrate mix) no extreme laxative conditions were recorded.

Results from a series of trials carried out over a period of almost 60 years at Florida Agricultural Experiment Station have been recently reviewed (Harris et al. 1982). The experimental results and observations support the following conclusions and recommendations.

Citrus pulp has no properties other than its nutrient content, which limits its use in dairy cattle concentrate rations. Thus, it may be used at any level at which it can be included without causing a nutritional imbalance. One must remember, however, that this requires special attention to the calcium-phosphorous ratios, which are extremely wide in citrus pulp because of the calcium added during processing. A level of 40% of the total ration is feasible.

Citrus pulp is not a roughage and cannot be so used even in diets for small calves. Citrus pulp, although a concentrate, has roughage-sparing qualities. Thus, because of its capacity to keep acetate levels and pH in the rumen high, it tends to prevent low milk fat and metabolic problems on fibre-deficient rations. Factors other than the rumenal production of acetate appear to be involved in production of abnormal milk on rations lacking in roughage, and in these cases, citrus pulp may help but cannot entirely prevent low milk fat tests.

Pelleting does not change the nutritional properties of citrus pulp, probably because grinding is not necessary. Thus, after the pellets are soaked in rumenal fluid, they expand, and so their physical properties are not much different from conventional pulp under similar circumstances.

When citrus pulp is added to forage at ensiling, it has three desirable effects: (a) extra energy becomes available; (b) nutrient containing juices are absorbed, and thus their loss is prevented and (c) a desirable medium for bacterial fermentation is supplied. Citrus pulp is highly compatible with urea in cattle rations and thus in rations containing urea it may be used in about the same way as is corn. Citrus pulp at moderate inclusion rates is- a positive factor in acceptability, since cattle like it, and it tends to mask undesirable flavours such as that of urea. Citrus pulp is a good source of energy, and it appears to interact with some other feedstuffs in a way which makes both more digestible. It is not a good source of protein, but it does complement protein utilization of some other feedstuffs.

Most of the published work from U.S.A. has compared dried citrus pulp with corn or corn products. In Australia corn is not widely used as a dairy cow feed and considerable quantities of citrus pulp are still fed wet. As a consequence of this and the uncertainty about milk taint problems particularly with wet citrus pulp (see Marshall 1976) a trial was carried out by S.A. Department of Agriculture to examine the use of dried citrus pulp as an energy supplement for dairy cows. The additional information which resulted from this trial concerned SNF in milk and levels of feeding of dried citrus pulp to prevent milk taint. Higher levels of dried citrus pulp resulted in reduced SNF% and protein % in milk and a change in fatty acid composition of milk fat. There was also an abnormal flavour in cream from cows fed 3.4kg citrus compared to controls fed no citrus and it was concluded that dried citrus pulp (which was referred to as citrus meal in this report) can replace up to 2kg of rolled barley on a dry matter basis in dairy concentrate mixes without any detrimental effect on milk production, cow liveweight or flavour of milk. However citrus does not appear to be a suitable energy substitute for cereal grains in concentrate mixtures fed primarily to increase the percentages of SNF and protein in milk (Bartsch and Wickes 1979).

Citrus pulp for sheep

Chemical analyses and digestibility of citrus waste using sheep have been determined in Italy. The chemical analyses are of the same general order as determined by other groups in various parts of the world. Digestibility values for dried material components are also of the same order as previously determined using cattle. However it appears that dried material has a carbohydrate digestibility of the order of 10 percentage units lower than the fresh material (Maymone and Dattilo 1958).

High digestibilities of diets containing various levels of dried citrus meal up to 50% of the concentrate feed were also noted in Trinidad by Devendra (1973) who suggested that the significance of the high digestibility coefficients reported from his study needed confirmation by growth trials. It was also shown in this study that digestibility was maximised at 20% citrus pulp inclusion. About the same time dried citrus pulp had been studied as a grain replacement for Awasi lambs in Lebanon. The dried material was prepared at a lower temperature than is normally used commercially and digestibility was extremely high. The average digestible energy of dried citrus pulp used, calculated by difference was 14.63 MJ/kg. However it should be emphasized that the dried citrus pulp used in these trials was whole dried pulp without the extraction of pectic acid or molasses. The analysis showed a higher level of protein than normal and indicated that less than half of this was true protein. Palatability was good and comparable to rations based on corn but when citrus level was above 40% feed intake and energy digestibility' tended to decline (Bhattacharya and Harb 1973).

An extensive and detailed study of citrus pulp for fattening lambs has been reported by Pascual and Carmona (1980b) from Spain. Digestibility, nitrogen retention and energy values of isoproteic rations containing 10% lucerne hay and a concentrate mixture (16% CP) with 0, 15, 30, 45, 60 and 90% citrus pulp, were determined with 13 wethers. In a second experiment, 18 growing lambs (13.5 kg initial weight) were used to determine the values previously cited when fed on rations (16%CP) containing 0, 30 and 60% citrus pulp.

Digestibility coefficients of the various feed fractions were not altered when citrus pulp was added to the diet except that for the acid detergent fibre fraction which increased (P 0.01). Organic matter and fibre digestibility were affected by age, the maximum figures being obtained with mature animals; metabolizable and digestible energy values followed a similar trend. Retention of nitrogen was inversely related to level of citrus pulp and age.

Three growth trials were carried out in which daily gains, feed efficiency, dressing percentage and ruminal keratosis were studied in 108 lambs divided into groups of three and starting the experiment at an average weight of 15kg. The animals were fed on diets containing 0-60% citrus pulp in the concentrate and 10-15% lucerne hay. The parameters were not altered significantly up to 30% incorporation of citrus pulp, but if higher quantities were added the animal response was poorer.

In Australia we have been more concerned with drought feeding of sheep and complete pelleted rations for sheep destined for live export than with feedlot lamb rations. In this context the work carried out at the Animal Research Institute at Werribee has been of most significance (Bogdanovic and Hodge 1978; Hodge and Bogdanovic 1980; Hodge et al. 1986; Watson et al. 1986).

It had been observed in Victoria during drought that young sheep offered 3.2kg citrus pellets and 0.9kg hay/week had not maintained liveweight and it was suspected that because of the highly digestible energy and low digestible nitrogen content of citrus pellets nitrogen may have been limiting. As a consequence of this citrus pellets with 2% urea significantly increased the daily liveweight gain of lambs. The responses were associated with an increased feed intake. Roughage was not provided in the study and a second series of experiments was designed to provide further information when roughage or urea were used as supplements with oats or dried citrus pellets. The results of these trials suggested that voluntary intake and liveweight gain of young sheep fed oat grain were significantly increased by supplementation with pasture hay or lucerne chaff but equal benefits were obtained by supplementing with urea. Similarly in terms of intake and daily liveweight gain of young sheep a response was observed when citrus pellets were supplemented with urea. However an additional and significant response occurred when supplements of roughage were offered. Pasture hay or straw. were equally effective as the source of roughage. Furthermore lambs offered citrus pellets avidly consumed the supplement of hay or straw before eating any of the pellets. The observation that quality of roughage supplement was not important in maintaining the performance of lambs fed citrus pallets suggests that the beneficial effects of roughage were associated with conditions within the rumen which promoted microbial fermentation rather than with the provision of nutrients additional to that supplied by urea.

The scope for improvement of performance of animals via ration formulation has been highlighted recently at an ASAP meeting concerned with research into behaviour, nutrition and health of sheep during live export. Research from Werribee reported at that meeting suggested that the intake of sheep given rations containing 20% citrus pulp and 20% rice pollard was significantly higher in the second week than that of the sheep offered rations containing only wheat, rice hulls and minerals. The mean difference in intake of 205 g/day of pellets was substantial and was probably associated with the more stable rumen fermentation of these rations (Hodge et al. 1986; Watson et al. 1986). The quicker adaptation of the sheep to the diets containing citrus pulp and rice pollard had no apparent influence on the overall performance of the sheep under the conditions of the experiment but maybe important under the high stocking rates and intense competition that exists on board ship. These studies demonstrate that significant quantities of citrus pulp, rice pollard and rice hulls can be included in rations for the live sheep trade and offer considerable advantages. There was less diurnal variation in rumen pH values on rations containing citrus pulp and rice pollard except at the highest level of feeding when the very low rumen pH throughout the feeding cycle on high wheat rations indicated potentially unstable rumen fermentation. Rations containing citrus pulp and rice pollard result in a lower molar proportion of rumen propionate and it may be that the increased digestible neutral detergent fibre reduces the level of amylolytic rumen organisms and stablises the rumen environment in sheep fed pelleted rations containing readily fermentable starchy substrates (Baldwin and Allison 1983).

DISCUSSION

The production and processing of citrus and the utilization of citrus by-products has been reviewed. Particular attention has been paid to the use of citrus in rations for farm livestock. Generally it appears that the strong flavour of citrus waste influences palatability and feed intake and can affect the flavour of milk products and other animal performance parameters when used to replace cereal grains. The effect on palatability, feed intake and daily liveweight gain has also been reported with laboratory rats (Farrell et al. 1983) and commercial rabbits (Pascual and Carmona 1980c) and is consistent with farm livestock data. Citrus pulp is a valuable feed when used properly and in ruminant animals can enhance ration palatability. Citrus pulp is a highly digestible source of energy and appears to affect the utilization of other components in ruminant rations. For example as level of citrus. pulp increased in a ruminant diet digestibility of added cellulose increased (see Harris et al. 1982). Total volatile fatty acid concentrations also increased as level of citrus pulp in the diet increased while the ratio of propionate to acetate decreased. These data suggest that citrus pulp may serve as a stimulus to rumen fermentation as compared to cereal grain. Most experiments with citrus pulp have been on fixed intake levels of total mixed feeds, however when roughage was available free choice dietary citrus pulp resulted in asignificant increase in roughage intake which supports the hypothesis of stimulation of rumen fermentation by citrus. Furthermore the rumen volatile fatty acid concentrations associated with citrus pulp go a long way toward explaining the observed effects of citrus pulp on milk composition. There are few materials like citrus pulp available to stock feed mills that are high in neutral detergent fibre and still highly digestible. Sugarbeet pulp is one of these and it is significant that the inclusion of sugarbeet pulp in sheep rations significantly increased the rate of disappearance of straw dry matter in the rumen at 15% of the ration and. higher levels did not result in any further advantage. Cellulolysis was increased and an increase in voluntary intake of straw was, predicted. This was confirmed in a feeding experiment in which the inclusion of 150g unmolassed sugarbeet pulp/kg increased the voluntary intake of straw from 414 to 505g dry matter/day (Silva and Orskov 1985). These observations on the effect of supplements on roughage intake are highly significant in Australia where supplementation is often desirable but traditional supplements based on cereals substitute for forage and increase energy intake at the expense of the cheaper forage. In this context it is of great interest that when supplements were offered to ewes grazing perenial rye grass less than 4.6 cm in the first seven weeks of lactation herbage intakes were not reduced by feeding 500g organic matter per day of molassed sugarbeet pulp. i.e. the substitution rate was zero (Milne and Mayes 1986). On the basis of these data it is hypothesized that substitution occurs because the pH conditions and microbial population in the rumen are modified in such a way that the activity of cellulolytic organisms is decreased in the presence of supplement. It follows that if a highly digestible supplement is used which does not reduce the rumen pH and activity of cellulolytic organisms substitution will be less , zero or even negative, depending on the initial feed intake, characteristics of the forage available and the physiological state of the livestock.

An area of concern is the observed reduction in nitrogen retention in ruminants fed increasing dietary levels of citrus pulp (Bhattacharaya and Harb 1973). As this corresponds to a reduced ratio of propionate to acetate it may be that glucose availability at the intermediary metabolism level is limiting animal performance at the higher levels of citrus inclusion. If this is so then there is room for even better performance on citrus based ruminant rations. It is apparent from this discussion that many factors influence the nutritive value of a ration. The real key to high performance rations is the selection of feedstuffs that produce the levels of end products of digestion most suited to the metabolic requirements for efficient production (see Leng 1985). This is not necessarily the same as basing feeding on food units or metabolizable energy levels in individual feedstuffs particularly when these may have been estimated from chemical analyses (Leng 1986).

CONCLUSIONS

The principal outlet for citrus pulp is in formulated diets for farm livestock. Like all by-products dried citrus pulp is potentially variable depending on original raw material, production process and storage. However in practice in Australia these variations are small and offer no real problems. Citrus pulp is a perfectly safe feed for livestock. Analyses are more like a roughage than a concentrate but as a result of its very high digestibility citrus pulp is considered to be a concentrate feed with some roughage properties. In the rumen volatile fatty acid production is high and acetic acid predominates when citrus pulp is fed. Where low milk fat is a problem citrus pulp may help but it cannot replace long roughage completely for dairy cows. Where low energy intake has resulted in low milk SNF citrus pulp does not appear to be the energy supplement of choice. The relatively high ratio of acetate to propoinate in the rumen of cows fed citrus pulp is not compatible with increased milk SNF and protein percentages.

Citrus pulp will not taint cows milk when fed at less than 2kg/head/day. Citrus pulp may increase utilization of urea nitrogen and increase dry matter intake by ruminants. Substitution is expected to be less with citrus supplements than with cereal grain. Reasons for this conclusion are discussed.

For horses citrus pulp is a highly digestible energy source but some horses find it unpalatable. Palatability is of concern in pigs also but low levels of 5% are used in sow feeds in Australia with no problems. However nothing is known about amino acid availability from citrus pulp. Citrus pulp is inferior to grains for poultry.

Dried citrus pulp has an excellent effect on pellet quality and levels of 5-10% result in cost effective increases in feedmill production of pelleted stockfeeds through increased throughput and improved pellet quality.

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