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Citrus Feedstuffs for Dairy Cattle [1]

J.M. Wing, Editor[2]

In 1911 the Florida Citrus Exchange established a fellowship for research into uses of citrus waste and thus launched an area of investigation which remains strongly productive. The first publication was in 1917 (20). Although much has been learned since, progress continues, and this bulletin will by no means be the final word.

In 1972 (5) research relating particularly to beef cattle was assembled for a publication which remains relatively complete; many of its data are shared in principle with dairy cattle. Much specific dairy-cattle research was in progress, however, at the time of publication, and thus the purpose of this bulletin is to bring the subject matter up to the present.

Involved primarily is citrus pulp, consisting mainly of the rag, peel, and seeds of oranges with minor amounts from other fruits. This waste collects on concrete slabs or in open pits at canneries. Cattle will eat citrus pulp in the fresh state, but it accumulates too fast for current consumption, and it ferments and spoils too rapidly to save as it is produced. A small amount of fresh pulp is used, however, and cattle consume it readily. They will, in fact, eat whole fruit as shown in the cover illustration.

The obvious solution to spoilage was dehydration, and this was tried first by Seth S. Walker using hardware cloth over boilers at the Florida Citrus Exchange. The resulting product was fed to dairy cattle by John M. Scott (15), and potential value began to be understood. Further work by R. B. Becker (4) heightened interest to the point that a citrus drying plant employing a rotary drum and direct flame was established in Tampa.

Cannery residues went into the drum with no preparation other than cutting. Charring and incomplete drying were common, and the product often became moldy. Yet, even in this form, citrus pulp was utilized readily by ruminants (11).

The process clearly needed improving. To this end, in 1934, calcium carbonate was added to ground grapefruit peel. Within a few minutes bound water was released from the residue. This method of bound water release has been used ever since, with added improvements (9). The residues are passed through shredders or hammermills reducing them to pieces of about 1/4 by 3/4 inches. Calcium hydroxide or oxide is added before, during, or after cutting. This causes some desireable chemical changes in the pectins and peel, resulting in release of the bound liquids.

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Pressing reduces the moisture to 65% to 75%. Drying takes place in rotating drums - as developed at Suni-Citrus Products Corporation (4) - then dust is removed, and the remainder is separated into pulp or meal. Most of the meal is pelleted and added to the pulp. These hard conventional pellets, which often are mixed in small quantities in conventional pulp, are not to be confused with pelleted citrus pulp consisting of whole pieces which are compressed tightly but never ground.

Chemists at Pasco Cooperative converted the press juice to molasses about 1943. This product was investigated at the University of Florida, and its use as a new feedstuff was described in 1946 (2). Often 20% to 50% of molasses is incorporated with the pulp. It darkens the color somewhat and increases the content of soluble carbohydrates, with corresponding percentage decreases in fat, fiber and protein.

Citrus molasses also serves as a substrate for fermentation in the beverage-alcohol industry. The remaining distillery waste can be condensed to a very acceptable feedstuff high in pentose sugars and, because of yeast used for fermentation, high in good quality protein. The distillers solubles so produced may be incorporated into citrus pulp, just as is whole molasses, or they can serve directly as an ingredient of feed mixtures.

Citrus pulp usually is used as a source of energy because of its composition, as shown in Table 1 . Fat and protein of citrus pulp vary with the seed content, which ranges from 1.0% to 17.7% depending upon the variety of fruit (9). The seeds are used efficiently (1). In fact, all parts are utilized well (21), yet reports from the field persistently suggest a limit to the use of citrus pulp, although there has been little agreement on just what the limit is. This need for more precise information prompted the following series of experiments in which each succeeding one was based on previous results.

FUNDAMENTAL OBSERVATIONS

The investigations began with determinations of how citrus pulp was used in the reticulorumen (first stomach compartment), because this gives clues as to what one may expect in the way of animal production responses. Subjects were rumen-fistulated steers. All diets in the first experiment were 1/3 chopped alfalfa hay and 2/3 concentrates. Citrus pulp in the concentrate portion varied from 0% to 60% (Table 2). All were fed to the limit of appetite with water offered free choice.

Digestibility was determined for dry matter, protein, and energy by the chromic oxide method. Results are shown in Table 3 .

Digestibility appeared normal for high concentrate diets. Citrus pulp had no significant effect on digestibility of the feed mixtures. Likewise, no significant differences in rumenal acids occurred as a function of time. Therefore, all samples from each diet were combined. Mean molar percentages for all treatments were acetic or C_2, 65.9; propionic or C_3, 14.8; butyric or C_4, 14.4. Only traces of other acids were observed. Acetates were somewhat high in all cases, and there were no detectable differences due to citrus pulp level. This is important because the acetates, or acetic acid (also referred to as C_2), are important precursors of milkfat. Thus, citrus pulp in the diet may help keep the milk normal even when roughage is poor in quality and/or is supplied at a low level. It should be noted, however, that this experiment did not include a diet which was particularly low in fiber.

It seemed possible, however, that pelleting of the pulp could affect rumenal functions. The next experiment (21), therefore, involved the effects of physical form of citrus pulp on fermentation patterns in the rumen. All rations were 1/3 hay and 1/3 citrus pulp plus other ingredients (Table 4). In diet 1, the pulp was in the conventional form. Treatments 2, 3, and 4 involved replacing 1/3, 2/3, or all conventional pulp with pellets which were made without previous grinding. Rumen-fistulated steers were used in each of the next two experiments. There were four feeding periods in which each of eight animals was assigned during each period to a diet which was different from the one consumed previously by that particular animal. There also were two replications of a 4 X 4 latin square which was balanced for carry-over effects. Thus, each steer received each diet during two different experimental periods.

Results were much like those of the previous experiment. Mean molar percentages of rumenal acids for all treatments combined were C_2, 67.7; C_3, 15.6; C_4, 14.2; C_5 (valeric), 1.0; IC_5 (isovaleric), 0.8. All feeds were accepted readily, and all subjects appeared normal concentrates in general to maintain a relatively high throughout the trial. It was interesting that citrus pulp appeared, because of its rumenal fermentation pattern (high and persistent C_2 and more tendency than pH), to have roughage qualities. For this reason experiment 3 compared citrus pulp to corn silage (13). Diets for experiment 3 are displayed in Table 5 . A single 4 X 4 latin square, balanced for carry-over effects, was used to determine apparent digestibility of protein, dry matter, and energy by means of total collection using mature, rumen-fistulated Jersey steers. Preliminary adjustment periods were 16 days, and collection periods were 5 days. Diet 1 consisted entirely of corn silage; its consumption when fed once daily to the limit of appetite was used to standardize the consumption of other diets. Thus 1/3, 2/3, or all dry matter of diet 1 was replaced by citrus pulp in diets 2, 3, and 4.

Protein, dry matter, and energy were determined by standard methods. An in vivo (in the living animal) cellulose procedure was employed to study cellulose digestion. Two grams of dry ground forage were placed in small nylon bags which were suspended for 24 hours in the rumen with nylon cord. Cellulose which disappeared was considered to be digested, as shown in Table 6 .

To study rumenal fermentation the same steers were randomized into another 4 X 4 latin square. There were two replications. During the last 3 days of each test period, rumen samples were taken before feeding and 1, 2, and 4 hours after feeding. They were analyzed for rumenal volatile fatty acids as before.

Digestibility of diet 1 was significantly less than were digestibilities of diets 2, 3, and 4. There were no significant differences between diets 3 and 4. Replacing 0%, 33%, 67%, and 100% corn silage with citrus pulp resulted in diets with average apparent protein digestibilities of 69.1%, 69.1%, 69.8%, and 62.4%. Statistical analysis indicated that there was no evidence that diets 1, 2, and 3 differed, but that they were higher than diet 4. Citrus pulp alone is a poor source of protein. When citrus pulp is combined with corn silage, however, it appears that complementary functions make it adequate in protein quality.

Apparent digestibilities of energy for diets 1 through 4 were 62.4%, 69.1%, 75.1%, and 74.9%. Expressed as kilocalories of digestible energy per kilogram of dry matter, corn silage alone yielded 2,830 and citrus pulp alone yielded 3,468. At the 1/3 replacement level, citrus pulp appeared to yield 4,127, assuming that digestibility of the silage remained static. With the same assumption, it appeared to yield 3,884 at the 2/3 level. It was evident, therefore, that there was a complementary effect between the two feedstuffs, as suggested by Keener, et al. (10). Thus, citrus pulp seems to enhance and/or to be enhanced by other feed ingredients with respect to ability to supply productive energy and protein to cattle.

Figure 1 shows also the changes in molar proportion of acetic acid due to time after feeding. Mathematical equations for the curves were used to analyze the results for possible significant differences. The equations are shown in Table 7 . These data show that for diets containing various levels of citrus pulp, the molar percent of rumenal acetic acid was equal to or greater than the rumenal molar percent acetic acid of an all-corn-silage diet. This showed again that although citrus pulp is a concentrate by definition, it has some important roughage properties.

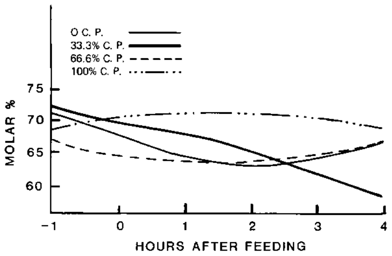

Figure 1 .

Generally, it is agreed with respect to molar proportions of VFA's that high levels of acetate usually occur in animals fed diets containing large amounts of roughage, whereas lower levels are associated with concentrates. However, it appears that citrus pulp does not resemble other concentrates with respect to the molar percent acetic acid produced (Figure 1). Previous publications (5) showed also that citrus pulp fed in ruminant concentrate diets caused a marked increase in the molar percent of acetic acid.

The regression equation for treatment 1 was significantly different from the regression equations for the other three treatments (Figure 2). The only significant difference among the treatment means was between treatments 3 and 4, four hours after feeding. Treatment 3 produced a higher molar percent of propionic acid (14.84) than those usually reported for other feedstuffs, but present levels are similar to trends noted previously (5).

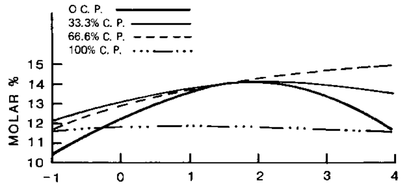

Figure 2 .

The acetic to propionic acid ratio displayed in Figure 3 was significantly higher for treatment 4 (6.15) than for treatment 3 (4.66) four hours post-feeding. There were no other treatment differences in the acetic to propionic ratio. The maintenance of the relatively high acetic to propionic acid ratio by feeding citrus pulp is in partial agreement with the findings of Drude et al. (8), who reported combinations with citrus pulp to be superior to roughages alone in maintaining both milk production and milk-fat percent.

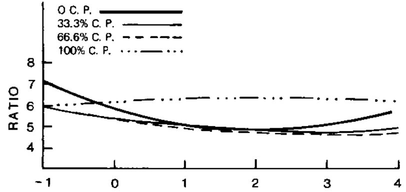

Figure 3 .

Molar proportions of butyric acid were not affected by any of the treatments, as shown in Figure 4 . The only difference in molar percent of butyric acid was 1 hour after feeding between treatment 3 (21.78) and treatment 4 (16.70 molar percent).

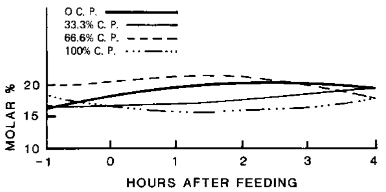

Figure 4 .

RUMENAL FLUID pH

Significant differences in rumenal fluid pH were limited to treatments 1 and 2 (Table 8). Treatment 1 resulted in pH values (7.26, 7.14, 7.06, 7.03) which were significantly higher than the other three treatments for all sampling times. The pH of rumenal contents produced by treatments 1 and 2 was significantly higher than for 3 or 4 at 1, 2, and 4 hours post-feeding, but was not significantly different for the pre-feeding sampling. The treatment means of rumenal pH appear in Table 8.

Replacing corn silage with 67% or 100% of citrus pulp in the diet effected a reduction in the rumenal pH. As a general rule, it was higher in animals fed a roughage-type diet than in those fed concentrates. Increasing the levels of citrus pulp caused reduction in the rumenal pH to an average of 6.81 for treatment 3 and 6.77 for treatment 4, compared to values above 7 for treatment 1. These values are not nearly as low as those generally resulting for high concentrate diets. Thus, citrus pulp, though not considered a roughage in the strictest sense, does contain roughage-like properties which, along with relatively high concentrations of C_2, promote a relatively high rumenal pH as compared to concentrates in general.

EFFECT ON UTILIZATION OF NON-PROTEIN NITROGEN

It seemed possible that the particular pattern of citrus pulp fermentation in the rumen may be conducive to efficient use of ammonia and thus of protein and non-protein nitrogen sources, such as urea. Coombe et al. (6) suggested that a highly fermentable substrate minimized the rise in pH associated with rapid urea hydrolysis. This may be pronouced if the fermentation pattern favors production of acetate (7). It appears (14, 21) that citrus pulp is highly fermentable, and that acetic acid is produced at a high and enduring level by its rumenal digestion. Thus, it seemed possible that citrus pulp would reduce the possibility of toxic effects of ammonia from diets which are high in urea through some means of combining with it. Citrus pulp may be conducive to efficient utilization of ammonia and thus the efficient use of protein and non-protein nitrogen.

The subjects for the next phase of this work (experiment 4) were eight rumen-fistulated steers (12). They were distributed randomly into two 4 X 4 latin squares balanced for carry-over effects. Diets fed in experiment 4 are in Table 9 . Citrus pulp in square 2 was pelleted without being ground, whereas conventional unpelleted pulp was used in square 1. All animals ruminated normally. Each steer consumed 15 pounds (6.8 kg) of feed daily, thus receiving approximately 0.75 pounds (0.34 kg) urea. Following an adaptation of four weeks, all steers were confined individually to pens in which they could move freely. Before each sampling at 28-day intervals, they were kept in stanchions for 12 hours. On these occasions, they were fed via rumen fistulas. The rations were given in two equal portions during a 1-hour interval.

Time zero was considered to be 30 minutes after the first feeding. Rumenal fluid and jugular blood were sampled at 1 hour before and 2, 4, 7, and 12 hours after time zero. Volatile fatty acids, pH, and ammonia were determined in rumenal fluid. Multiple covariance was used to test for significance of differences among means and time trends. The two squares were analyzed separately and pooled.

No difference between pelleted and nonpelleted pulp was detected, except in ammonia time trends, and these did not result in differences in treatment means. Therefore, the pooled analysis appeared most valid. Rumenal pH for diet 1 was higher (P <.01) than for the other three diets, and time trends also differed in that pH for the control was higher during the first 7 hours (P <.01) (Table 10).

Increasing citrus pulp from 0% to 19%, 38%, or 55% in the diets effected a reduction in rumenal pH (from 6.85 to 6.65, 6.61, and 6.51). These pH values still were higher than usually occurs in ruminants consuming high concentrate diets. The data agreed with previous research in which citrus pulp was substituted for corn silage. Although increasing citrus pulp caused reduction in rumenal pH, the values for these diets were not quite as low as occurred in previous work, probably because of the high urea and resulting ammonia which may have neutralized some of the acid.

Statistical analysis of data for rumenal ammonia-N showed slight differences in means (P <.10) between diet 2 vs 3, 4. The concentration of rumenal ammonia-N was higher in diet 2 than in the others. There also were differences between time trends for diet 1 vs 2, 3, 4 in which ammonia decreased more rapidly (P <.01) with increasing levels of citrus pulp. Rumenal ammonia-N concentration was the oniy response that showed significant differences (P <.05) due to form, and this was in the time trends only. Pelleting resulted in less variation, but this did not affect treatment means. The maximal values for rumenal ammonia occurred between 4 and 7 hours after feeding. Levels as high as 220 mg per 100 mL at 7 hours after feeding resulted in no signs of toxicosis. This may have been due to different pH and/or fermentation patterns which tended to neutralize ammonia through persistent production of acetic acid.

Diet 2 (19% citrus pulp) caused slightly higher blood urea-N than did diets 3 or 4 (38% and 55% pulp) (P <.10), but the time trends were not significantly different. It appears that high concentrations of rumenal ammonia as such result in a net absorption of nitrogen, conversion to urea, and loss from the animal via urinary excretion (19). According to this concept, diets containing adequate nitrogen but which result in low blood urea-N should result in retention of relatively large quantities of nitrogen. The present data suggest that citrus pulp at 38% to 55% increased nitrogen utilization since it decreased urea nitrogen in blood. Thus, citrus pulp may help keep ammonia in contact with the rumenal organisms which can convert it to protein. No differences were detected in the molar percent of rumenal acetic acid due to citrus pulp in the diets (Table 11). The time trend for the control diet was different from those containing 19%, 38%, and 55% citrus pulp, and that of diet 2 was different from 3 and 4 (P <.05).

Table 12 shows the pooled effects of citrus pulp on rumenal acids. As expected high concentrate diets resulted in higher than usual propionate levels and less acetate. Both effects were less for diets containing citrus pulp than for those with corn, but unlike previous results, the effect on acetate was not significant statistically. This may have been because so much of it had combined with ammonia produced from the very high urea levels in all diets.

Treatment means for butyric acid did not differ, but the time trend for diet 1 was different (P< .01) from those of 2, 3, and 4. Molar percent butyric acid was not affected by citrus pulp in the diet at any percentage. Ratios of rumenal acetic to propionic acid in steers fed diet 1 were lower than those for diets 2, 3, and 4 (P <.01). This explains somewhat the results published previously by Drude et al. (8), who showed that citrus pulp helped maintain normal milkfat tests.

Analysis of variance of total rumenal VFA showed that diet 1 gave lower values than 2, 3, and 4 (P <.01), and diet 2 produced lower rumenal VFA than 3, 4 (P <.05). Results are in Table 12. Following the ingestion of a readily fermentable feedstuff, microbial activity increases. Thus, the data suggest that, under conditions of this experiment, citrus pulp served as a stimulus to rumenal fermentation as compared to corn.

There were no differences between pelleted and nonpelleted citrus pulp except for time trends in rumenal ammonia-N (P <.05). The data agree with previous work (12) which indicates that pelleting does not have the same general effect on citrus pulp as on other concentrate feedstuffs. In this case, however, it must be remembered that the pellets were made by compressing whole pulp which, when wet, as the pellets become in the rumen, tend to resume the original form of the conventional pulp.

EFFECT OF CITRUS PULP ON MILK PRODUCTION

Keener et al. (10) showed that citrus pulp was a good source of energy but possible effects of pelleting needed clarification. To this end the milk production and composition were compared under two regimens which were drastically different in roughage portion of the diet and in the form of citrus pulp (Table 13). Although different animals were used in each trial, it was not possible to conduct simultaneous trials. Thus, the marked difference in milkfat between roughage groups may not be as important as indicated by data displayed in Table 14 . In all cases milk was normal, and no difference could be attributed to physical form of citrus pulp. In general, data in Table 14 show that citrus pulp should be limited for dairy cattle rations only by economic considerations and composition of other ingredients. It may be especially valuable in low roughage diets because citrus pulp tends to produce a large proportion of acetate. Nutritionally, pelleted pulp and the conventional form appear to be the same.

MILK PRODUCTION ON COMPLETE DIETS

The principles discovered during the earlier experiments were exciting, but there remained a need for developing them into practices of feeding. To this end, citrus pulp level was factored into yet another investigation of complete diets for lactating cows (16). The levels were 43.1% or 8% of citrus pulp as a component of complete diets. Milkfat was 4.16% for the diet containing 43.1% pulp whereas it was only 3.57% for the diet containing 8% pulp. This effect was expected from previous work. Rumenal fermentation patterns were not determined, but it seemed quite likely that the role of citrus pulp in maintaining the fat test was a function of the high and enduring levels of rumenal acetates which are a function of dietary citrus pulp. This confirms further the similar results of Drude et al. (8), who reported the same phenomenon but without an explanation, since the fundamentals of rumenal digestion of citrus pulp were not known to them. In a further experiment (13) with sugarcane bagasse complete rations, the results were more like those of experiment 5, which were not analyzed for significance of the effect of roughage on fat test (Table 13). The acetate/propionate ratio was normal in the latter experiment, but, as in the previous one, low fat tests occurred throughout. Thus, factors other than the rumenal fermentation pattern observed in these experiments appear to affect milk composition in cows fed complete rations which are high in sugarcane bagasse. The role of citrus pulp with respect to milk fat production appears to be through maintenance of normal acetate, and that is not always enough to prevent abnormalities, since other factors also may be involved with diets containing poor-quality roughage.

EFFECT ON YOUNG CALVES

The next experiment was based in part on reports from the field which suggested that citrus pulp should be limited for small calves, although a low level had been shown to be desirable (22). Diets containing 30% of citrus pulp with and without cottonseed hulls were formulated as shown in Table 15 . These were fed from birth through 80 days. Consumption of diet 2 containing 15% hulls and 15% pulp significantly exceeded all others as shown in Figure 5 . It is interesting, however, that as the experiment progressed past 60 days, diet 1, which contained 15% cottonseed hulls and 30% citrus pulp, was consumed in increasing amounts, and thus its total consumption for the entire experimental period closely approached that of diet 2. The growth of calves on diet 1 improved even more than should be expected from the increased feed consumption (Figure 6), thus showing again the previously demonstrated complementary effects. Citrus pulp appears to be advisable in rations for calves over two months old, but because of acceptability factors not for younger ones, at least under conditions of this experiment.

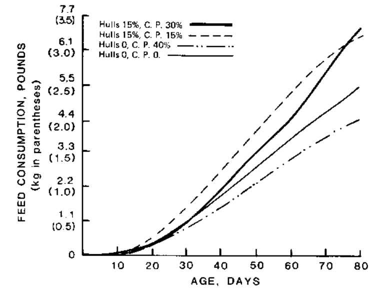

Figure 5 .

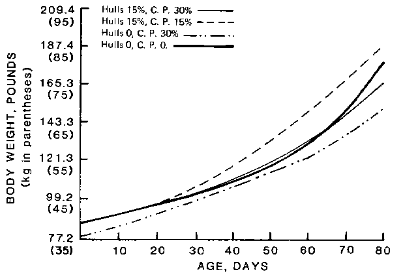

Figure 6 .

SILAGE PRESERVATIVES

Citrus pulp, meal, and molasses alone and in various combinations have served as silage preservatives (2). The molasses was used effectively at levels of 40 pounds per ton for grasses and 70 pounds for legumes. This is similar to the effects of other types of molasses. Citrus products also added to acceptability of the final product and improved efficiency of preservation. Pulp and meal are very absorptive, and thus citrus pulp in the present research absorbed as much as 145% of its original weight in juices containing valuable nutrients which otherwise would have seeped out of the silo and been lost. Absorption increased with each increment of citrus pulp to 250 pounds per ton. The increase dropped off rapidly above 150 pounds, however, and, therefore, 150 pounds per ton appeared to be the most feasible level.

DISTILLERS SOLUBLES

Large and increasing amounts of citrus molasses are used for production of beverage alcohol. The remaining sugars, which are pentoses, cannot be used by the beverage industry, but they are an excellent source of energy for cattle. In addition valuable minerals and residual yeast from fermentation made the material left after distilling a potential feedstuff. It is condensed to the consistency of molasses and is thus designated as citrus molasses distillers solubles (CMDS).

In common with citrus pulp but unlike many other liquid feedstuffs, CMDS resulted in improved digestibility of other ingredients of the diet. Since the effect occurred only at a level of 6% of dietary dry matter, one may consider 6% optimal (Table 16).

Ruminal fluid was assayed for acetic, propionic, and butyric acids, ammonia nitrogen, and pH. Significant treatment effects were found for all. Molar percent of acetic acid increased linearly with increase in CMDS percent ($P < .05$). Propionic acid responded with peak values reached at the 6% level. Acetate/propionate ratios also showed significant effects with the most favorable values at the 6% treatment level (Table 17).

In the last experiment of the present series the main objective was to determine the effects of CMDS on daily milk production and composition and on dry matter intake. CMDS caused increased milk production as shown in Figure 7 . At the 6% level of CMDS, dry matter intake and intake as a percent of live body weight increased ($P <.05$) and milk composition was unaffected.

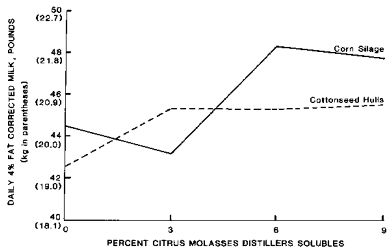

Figure 7 .

CONCLUSIONS AND RECOMMENDATIONS

Experimental results and observations warrant the following conclusions and recommendations for use of some citrus by-products in dairy cattle feeds.

1. 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.

2. Citrus pulp is not a roughage and cannot be so used even in diets for small calves.

3. Citrus pulp, although a concentrate, has roughage-sparing qualities. Thus, because of its tendency to keep acetate levels and pH in the rumen high, it tends to prevent low milkfat and metabolic problems on fiber-deficient rations.

4. 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 milkfat tests.

5. 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.

6. 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.

7. Citrus pulp is a good ingredient in rations for calves from two months of age but not always for younger ones. It is highly acceptable to older animals, but it depresses feed intake of young calves when used to replace cottonseed hulls or to supplement them.

8. Citrus pulp is highiy compatible with urea in cattle rations and thus in rations containing urea, it may be used in about the same way as is corn.

9. Except for small calves, citrus pulp is a positive factor in acceptability, since cattle like it, and it tends to mask undesirable flavors such as that of urea.

10. Citrus pulp is a good source of energy as such, 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.

11. Citrus molasses is somewhat different from cane molasses, but in general it may be used for the same purposes and in about the same way as by-product molasses from other industies.

12. Citrus molasses distillers solubles at 6% of the total diet promotes digestion, a favorable type of fermentation, and the proper rumenal environment for utilization of other ingredients, including non-protein nitrogen. This feedstuff is an excellent source of protein, probably because of residual yeast. There is no significant effect on milkfat, milk protein, or on body weight changes.

It appears that the effect on milk production results at least in part by stimulation of appetite by the distillers solubles.

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REFERENCES

1. Ammerman, C. B., and J. M. Wing. 1963. Fla. Agr. Exp. Sta. Dairy Science Mimeo 63-5.
2. Becker, R. B., P. T. D. Arnold, G. K. Davis, and E. L. Fouts. 1946. "Citrus molasses." Fla. Agr. Exp. Sta. Press Bul. 423.
3. Becker, R. B., J. M. Wing, P. T. D. Arnold, J. T. McCall, and C. J. Wilcox. 1970. "Silage investigations in Florida." Fla. Agr. Exp. Sta. Bul. 734.
4. Becker, R. B. 1978. "Personal communication."
5. Chapman, H. L., Jr., C. B. Ammerman, F. S. Baker, Jr., J. F. Hentges, B. W. Hayes, and T. J. Cunha. 1972. "Citrus feeds for beef cattle." Fla. Agr. Exp. Sta. Bul. 751.
6. Coombe, J. B., D. E. Tribe, and J. W. C. Morrison. 1980. "Some experimental observations on the toxicity of urea to sheep." Aust. J. Agr. Res. 11:249.
7. Davis, G. K., and H. F. Roberts. 1969. "Urea toxicity in cattle." Fla. Agr. Exp. Sta. Bul. 611.
8. Drude, R. E., J. R. Escano, and L. L. Rusoff. 1971. "Value of complete feeds containing combinations of corn silage, alfalfa pellets, citrus pulp and cottonseed hulls for lactating cows." *J. Dairy Sci* . 54:773.
9. Hendrickson, R., and D. W. Kesterson. 1965. "By-products of Florida citrus." Fla. Agr. Exp. Sta. Bul. 698.
10. Keener, H. A., N. F. Colovos, and R. B. Eckberg. 1957. "The nutritive value of dried citrus pulp for dairy cattle." New Hampshire Agr. Exp. Sta. Bul. 438.
11. Neal, W. M., R. B. Becker, and P. T. D. Arnold. 1935. "The feeding value and nutritive properties of citrus by-products. 1. The digestible nutrients of dried grapefruit refuse for growing heifers." Fla. Agr. Exp. Sta. Bul. 275.
12. Pinzon, F. J., and J. M. Wing. 1976." Effects of citrus pulp in high urea rations for steers." *J. Dairy Sci.* 59:1100.
13. Randel, P. F., H. H. Van Horn, C. J. Wilcox, H. Roman-Ponce, S. P. Marshall, and K. C. Bachman. 1975. "Supplemental nitrogen by the metabolizable protein concept." *J. Dairy Sci* . 58:1109.
14. Schailbly, G.E., and J. M. Wing. 1974. "Effects of roughage concentrate ration on digestibility and rumen fermentation of corn silage citrus pulp rations." *J. Anim. Sci* . 38:697.
15. Scott, J. R. 1926. "Grapefruit refuse as a dairy feed." Fla. Agr. Exp. Sta. Ann. Rept. 25R-26R.
16. Van Horn, H. H., S. P. Marshall, C. J. Wilcox, P. F. Randel, and J. M. Wing. 1975. "Complete rations for dairy cattle. III. Evaluation of protein percent and quality and citrus pulp-corn substitutions." *J. Dairy Sci.* 58:1101.
17. Sklare, S. D. 1981. "Nutritional evaluation of citrus molasses distillers solubles for dairy cattle." Unpublished.
18. Van Horn, H. H., M. B. Olayiwole, C. J. Wilcox, Barney Harris, Jr., and J. M. Wing. 1976. "Effects of housing, milk feeding management, and ration formulation on calf growth and feed intake." *J. Dairy Sci.* 59:924.
19. Waldo, D. R. 1968. Symposium: Nitrogen utllization by the ruminant. "Nitrogen metabolism in the ruminant." *J. Dairy Sci* . 51:265.

20. Walker, S.S. 1917. "The utilization of cull citrus fruits in Florida." Fla. Agr. Exp. Sta. Bul. 135.

21. Wing, J. M. 1975. "Effects of physical form and amount of citrus pulp on utilization of complete feeds for dairy cattle." *J. Dairy Sci* . 58:63.

22. Wing, J. M. 1965. "A new way to feed calves." *Feedstuffs* 37:28.

Table 1. Average nutrient composition of dried citrus pulp (5). [a, b]

Nutrient	Number of Samples Analyzed	Content
Moisture, %	1728	8.58
Ash, %	1728	4.68
Ether extract, %	1728	3.74
Crude protein, %	1728	6.16
Crude fiber, %	1728	12.28
N.F.E., %	1728	64.56
Calcium, %	82	1.43
Phosphorus, %	82	0.11
Magnesium, %	82	0.12
Potassium, %	82	1.09
Sodium, %	82	0.096
Sulfur, %	10	0.066
Iron, ppm	35	98.72
Copper, ppm	35	6.19
Zinc, ppm	35	9.94
Manganese, ppm	35	5.70
Cobalt, ppm	10	0.073

[a] Analyses were obtained by the Feed Laboratory, Division of Chemistry, Florida Department of Agriculture, Tallahassee.

[b] All mineral values are expressed on a dry matter basis.

Table 2. Air-dry composition of diets, experiment 1.

	Diet				
Ingredients	1	2	3	4	5
	-----------------------%------------------------				
Citrus pulp, dried	0	10.0	20.0	30.0	40.0
Corn, ground	32.7	22.0	11.2	0	0
Wheat bran	6.5	6.5	6.5	6.5	0
Cottonseed meal, 41% protein	19.6	20.3	21.1	22.3	25.3
Dried brewers grain	6.5	6.5	6.5	6.5	0
Alfalfa, 17%	32.7	32.7	32.7	32.7	32.7
Salt	.7	.7	.7	.7	.7
Defluorinated phosphate [a]	1.3	1.3	1.3	1.3	1.3
	100.0	100.0	100.0	100.0	100.0

[a] 18% Ca, 21% P

Table 3. Digestibility of rations containing various levels of citrus pulp.

% Citrus Pulp	Treatment Means		
	Protein	Dry Matter	Energy
	---------------------%---------------------		
0	60.5	65.5	59.5
11	60.0	63.0	61.9
20	57.3	64.5	58.0
30	59.0	64.0	62.6
40	58.0	63.0	59.5

Table 4. Air-dry composition of diets used in experiment 2.

Ingredient	Diet			
	1	2	3	4
	---------------%-------------			
Citrus pulp, plain	33	22	11	-
Citrus pulp, pelleted	-	11	22	33
Soybean meal, 44% protein	26	26	26	26
Alfalfa hay, 17% protein	33	33	33	33
Oats	6.5	6.5	6.5	6.5
Salt	.75	.75	.75	.75
Defluorinated phosphate[a]	.75	.75	.75	.75

[a] 18% Ca, 21% P

Table 5. Composition of diets fed in experiment 3, dry basis.

Item	Treatment			
	I	II	III	IV
	--------------------%-----------------			
Citrus pulp	0	27	55	82
Corn silage	82	55	27	0
Soybean meal	18	18	18	18
Protein	15.6	15.2	15.2	15.0
Energy [a]	4551	4618	4540	4630

Table 6. Digestibility of dry matter, protein, energy, and cellulose determined in experiment 3.

Citrus Pulp	Dry Matter	Protein	Energy	Cellose[a]
0	63.9	69.1	62.4	62.1
33	69.6	69.1	69.1	65.4
66	75.0	69.8	75.1	63.0
100	73.7	62.4	74.9	66.6

[a] Nylon bag technique only

Table 7. Regression equations of VFA for steers consuming experimental rations.[a]

Acetic	4[c]	$Y_{IV} = 69.6 + 1.51 X - 0.47 X^2$	0.09
Acetic	3[c]	$Y_{III} = 64.5 -1.35X + 0.46^2$	0.06
Acetic	2[b]	$Y_{II} =70.0 - 2.30X + 0.21^2$	0.60
Acetic	1[a]	$Y_{I} = 62.2-3.80X+0.84X^2$	0.32
Propionic	4[b]	$Y_{IV} =11.6-0.12X\ 0.02^2$	0.01
Propionic	3[b]	$Y_{III} =12.7+ 0.83X-0.07X^2$	0.12
Propionic	2[b]	$Y_{II} =13.1+0.74X\ 0.15X^2$	0.07
Propionic	1[a]	$Y_{I} =12.3-0.84X-0.04X^2$	0.21
Butryic	4[a]	$Y_{IV} =17.2-0.84X+0.39X^2$	0.10
Butryic	3[a]	$Y_{III} =20.7+1.49X-0.44^2$	0.05
Butryic	2[a]	$Y_{II} =17.3+0.65X-0.35X^2$	0.24
Butryic	1[a]	$Y_{I} =18.8+1.96X-0.35X^2$	0.13
Acetic/Propionic	4[a]	$Y_{IV} =6.18 + 0.23X-0.06X^2$	0.03
Acetic/Propionic	3[a]	$Y_{II} =5.48-0.43X+0.06X^2$	0.16
Acetic/Propionic	2[a]	$Y_{II} =5.60-0.45X+0.07X^2$	0.15
Acetic/Propionic	1[a]	$Y_{I} =5.95-0.95+0.22X^2$	0.36

[a] The regression equations of VFA ratios having different superscripts were judged to be different at the 0.05 level of significance, by use of orthogonal comparisons.

[b] Where Y= molar % of VFA at X hr., -1 x 4.

Table 8. Rumenal pH treatment means for experiment 3.

Treatment[a]	Sampling Time			
	- 1 hr.	1 hr.	2 hr.	4 hr.[b]
1	7.26	7.14	7.06	7.03
2	7.03	7.05	6.95	6.88
3	7.02	6.76	6.70	6.74
4	6.75	6.99	6.60	6.68

[a] Orthogonal treatment comparisons differing at $P < 0.05$: - 1 hr., 1 hr. vs. 2, 3, 4; 2hr. and 4 hr., 1 vs. 3, 4.

[b] 0 at time fed.

Table 9. Air-dry composition of diets used in experiment 4.

Ingredients	Diet 1	Diet 2	Diet 3	Diet 4
	------------------%--------------------			
Corn	60.00	39.00	18.00	-
Citrus pulp[a]	-	19.00	38.00	55.00
Soybean meal	-	2.00	4.00	5.00
Urea	5.00	5.00	5.00	5.00
Sugarcane bagasse	33.33	33.33	33.33	33.33
Ca-P salt[b]	1.00	1.00	1.00	1.00
Trace mineralized[c] salt	.67	.67	.67	.67
	100.0	100.0	100.0	100.0

aThree rations with nonpelleted and three with pelleted citrus pulp (9.5 cm pellets).

bP 21%, Ca 16%, F 21%.

cMn 2500 ppm., Fe 2000 ppm., S 1000 ppm., Cu 330 ppm., Co 100 ppm., I 70 ppm., Zn 50 ppm.

Table 10. Treatment means for squares 1 and 2 for rumenal pH and ammonia-N and blood urea-N (experiment 4).

Item	Diet	Sampling Time (hr.)[a] -1	2	4	7	12	Mean
Rumenal pH	1	7.26	7.23	7.18	6.49	6.06	6.84[b]
	2	7.14	7.00	6.81	6.15	6.10	6.64
	3	7.32	6.85	6.64	6.27	6.03	6.62
	4	7.09	6.64	6.47	6.18	6.16	6.61
Rumenal ammonia-N (mg/100 mL)	1	21.1	84.9	129.4	129.3	97.7	92.5
	2	43.4	126.3	146.6	118.0	98.2	106.5
	3	22.6	105.7	141.3	113.2	78.8	92.3
	4	26.2	110.4	141.0	107.1	70.6	91.1
Blood urea-N (mg/100 mL)	1	42.31	55.33	71.94	84.28	82.06	67.18[c]
	2	45.61	60.04	73.12	81.03	77.51	67.46
	3	40.87	51.20	65.85	74.64	76.14	61.74
	4	39.54	47.25	64.08	71.04	74.87	59.36

[a] Ration given via fistula in two portions at 1-hr. Interval. Time 0 was 0.5 hr. after first portion.

[b] 1 vs. 2, 3, 4 (P < .01).

[c] 2 vs 3, 4 (P < .10).

Table 11. Experiment 4 treatment means for squares 1 and 2 with respect to individual VFA.

Item	Sampling Time (hr.)						
	Diet	-1	2	4	7	12	Mean
		----------------------------molar %------------------------					
Rumenal acetic acid	1	70.5	71.0	69.5	67.5	62.5	68.2
	2	73.0	70.0	71.0	67.0	68.0	69.8
	3	75.0	68.0	76.5	70.5	71.0	72.2
	4	74.0	67.5	68.5	68.0	70.0	69.6
Rumenal propionic acid	1	19.5	19.5	20.0	19.0	19.5	19.5
	2	16.5	19.0	18.5	18.5	17.0	17.9
	3	15.5	19.5	20.5	15.5	15.5	17.3
	4	15.5	19.0	18.5	17.0	16.0	17.2
Rumenal butyric acid	1	10.0	9.5	10.5	13.5	18.0	12.3
	2	10.5	11.0	10.5	14.5	15.0	12.3
	3	9.5	12.5	12.0	14.0	13.5	12.3
	4	10.5	13.0	13.0	15.0	14.0	13.1

[a] Ration given fistula in two portions at 1-hr. interval. Time 0 was 0.5 hr. after first portion.

[b] 1 vs 2, 3, 4 (P < .01).

Table 12. Pooled means for VFA concentration observed in experiment 4.

Diet	Acetate (C_2)	Propionate (C_3)	Butyrate (C_4)	Acetate/propionate	Total %
	-------------------------------------molar				
1	67.87	19.74	12.39	3.435[a]	82.56[a]
2	69.93	17.62	12.45	3.965	100.42[b]
3	70.31	17.27	12.42	4.070	107.95
4	69.25	17.24	13.51	4.015	108.92

[a] Orthogonal comparisons (1 vs. 2, 3, 4) differed at P < .01.

[b] Orthogonal comparisons (2 vs. 3, 4) differed at P<.05.

Table 13. Effects of pelleting citrus pulp in complete rations with different roughage on production and composition of milk from Guernsey cows.

Roughage	Pulp	Milk (kg)	Fat (%)	Protein (%)	Solids Not Fat (%)	Titratable Acidity	Chloride (%)
Sugarcane bagasse	Plain	17.3	3.7	3.2	9.01	.150	.164
	Pellets	17.4	3.7	3.2	9.01	.151	.157
Pangola hay	Plain	14.8	4.4	3.3	9.03	.143	.168
	Pellets	14.6	4.6	3.3	9.17	.147	.163

Table 14. Composition of calf starter rations[a].

Ingredients	Diet			
	1	2	3	4
	------------------%--------------------			
Cottonseed hulls	15.0	15.0	-	-
Citrus pulp	30.0	-	30.0	-
Ground shelled corn	24.0	55.0	41.0	71.0
Soybean meal (48%)	24.0	22.0	22.0	21.0
Molasses	5.0	5.0	5.0	5.0
Salt, trace min.	1.0	1.0	1.0	1.0
Dicalcium phosphate	1.0	.5	1.0	.5
Ground limestone	-	1.5	-	1.5
	100.	100.	100.	100.
Estimated crude protein %	16.5	16.5	16.5	16.5
Estimated crude fiber %	11.2	8.2	5.1	2.0
Estimated calcium %	.80	.81	.77	.79
Estimated phosphorus	.42	.41	.48	.43

[a] All rations were fortified, per 454 g of starter, with vitaman A, 2500 I.U.; vitamin D, 300 I.U.; Aureomycin or Terramycin, 10 mg.

Table 15. Treatment means for coefficients of digestibility for dry matter, crude protein, and acid detergent fiber as a fuction of CMDS level in the diet of steers.

Treatment	% CMDS[a]	Dry Matter	Organic Matter	Crude Protein	Acid Detergent Fiber
1	0	64.38	66.03	53.72	45.39
2	6	68.99[b]	70.43[b]	51.97	43.50
3	12	62.36	63.66	50.40	43.61
4	18	55.27	57.02	49.41	41.19

[a] Citrus molasses distillers solubles, percent of diet dry matter.

[b] Significant at P < .01.

Table 16. Effect of citrus molasses distillers solubles on ruminal acetic acid.[a]

% C-MDS	Hours After Feeding						
	-1	0[b]	1	3	5	7	11
0	61.13	57.04	58.37	52.22	59.39	56.99	57.52
6	65.52	55.12	57.90	57.55	56.13	55.96	58.03
12	63.89	59.35	59.98	60.54	60.52	58.58	60.48
18	65.66	60.75	58.79	64.07	60.64	60.42	61.72
	64.05	58.07	58.76	58.59	59.17	57.98	59.44

[a] Significant linear effect, P <.01.

[b] Immediately after feeding.