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THE FEEDING VALUE AND NUTRITIVE PROPERTIES OF CITRUS BY-PRODUCTS

I. The Digestible Nutrients of Dried Grapefruit and Orange Cannery Refuses, and the Feeding Value of the Grapefruit Refuse for Growing Heifers.

W. M. NEAL, R. B. BECKER and P. T. DIX ARNOLD

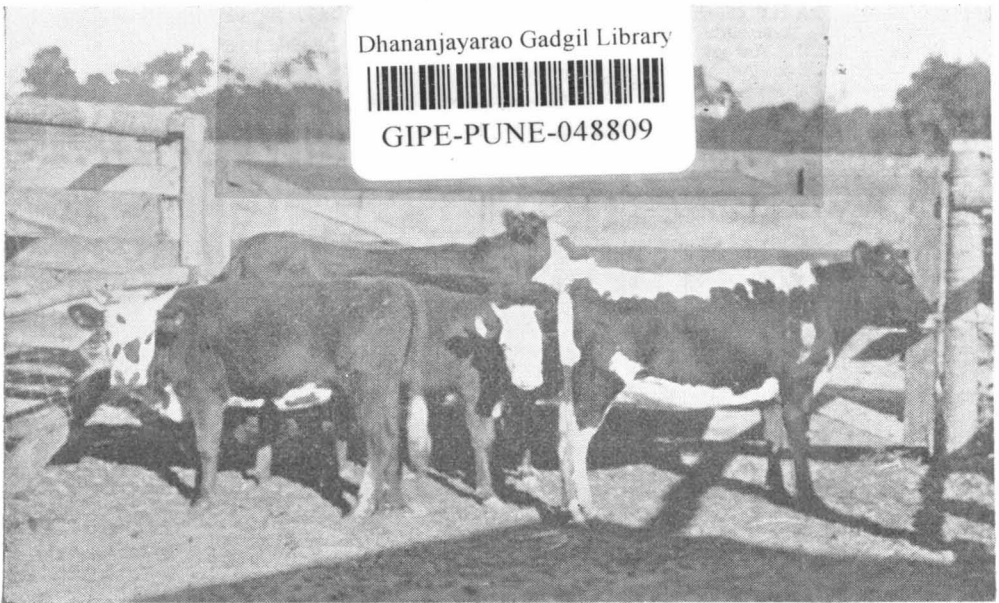


Figure 1.—These heifers show the good condition and gloss of the hair produced by 120 days on a ration of sugarcane or sorghum silage, dried grapefruit refuse, and cottonseed meal.

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TABLE 4.—THE COMPOSITION, COEFFICIENTS OF DIGESTIBILITY, AND DIGESTIBLE NUTRIENTS OF DRIED ORANGE REFUSE.

	Dry Matter	Crude Protein	Crude Fiber	N-Free Extract	Crude Fat	Ash
	percent	percent	percent	percent	percent	percent
Composition	86.05	5.84	10.64	64.74	0.69	4.13
Coefficients of digestibility	Steer					
	E-49	44.30	90.18	89.35	-30.45	
	E-50	26.41	84.92	86.64	11.80	
	E-51	31.21	89.36	86.38	11.84	
	E-52	44.36	111.16	91.65	33.15	
	Ave.	36.57	93.91	88.51	6.59	
Digestible nutrients		2.14	9.99	57.30	0.05	T.D.N. 69.55

The composition of the dried orange peel was: 86.05 percent dry matter, 5.84 percent crude protein, 10.64 percent crude fiber, 64.74 percent nitrogen-free extract, 0.69 percent crude fat, and 4.13 percent ash. The dry matter, nitrogen-free extract, and crude fat were lower than in the dried grapefruit refuse, the ash nearly the same, and the crude protein slightly higher. The digestibility of the crude protein varied with the individual steers from 26.41 percent to 44.36 percent, the crude fiber from 84.92 percent to 111.16 percent, the nitrogen-free extract from 86.38 percent to 91.65 percent, and crude fat from —30.45 percent to 33.15 percent. The apparent high digestibility of the fiber with one steer and the negative coefficient for crude fat with one of the others were not surprising when the small proportion of crude fiber and crude fat in the total ration derived from the dried orange peel are considered. Averages were: 36.57 percent of crude protein, 93.1 percent for crude fiber, 88.51 percent for nitrogen-free extract, and 6.59 percent for crude fat.

The nutrients in the dried orange peel as calculated from the above composition and digestibility were: 2.14 percent digestible crude protein, 67.29 percent digestible carbohydrates, and 0.05 percent digestible crude fat, or a total of 69.55 percent digestible nutrients. This latter amount is equivalent to 80.82 pounds of digestible nutrients per hundredweight of dry matter.

Discussion of Digestion Trials.—Coefficients of digestibility varied most for the crude fiber and crude protein in both sets of trials, and for crude fat in the dried orange peel trials. Variations in these cases can be explained by the small proportion of the total intake of these constituents in the ration that were derived from the citrus by-products. The apparent low digestibility of the crude protein may be due to several factors, namely:

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The use of dried citrus fruit by-products for livestock feeding was suggested by F. A. McDermott, holder of a Florida Citrus Exchange fellowship at the Mellon Institute, in 1916. Since that time the matter has received attention in California, and more recently in Florida. At the present time there is a limited amount of dried grapefruit cannery refuse reaching the market.

The citrus industry is one of the principal sources of income to the state through the marketing of fresh and canned fruit. However, there is a proportion of the crop that drops in the grove, is not fit to pick, is culled out in the packinghouse, or remains as refuse at the canning plant. Much of this part of the crop has not been utilized in any manner, except as fertilizer. Some outlet is needed for this part of the crop that will return more than fertilizer value to the grower, especially when it is remembered that a large part of the groves in the state have not reached their mature yields, and the crop is increasing year by year.

A method of utilization of citrus cannery refuse that would change this material from a liability to an asset to the cannery, and also provide an outlet for cull fruit, would be of inestimable value to the citrus industry. If, at the same time, a valuable

feed for livestock were produced, less feed material from other sections of this country and from foreign countries would be needed. The fact that a valuable feed could be produced from citrus cannery refuse should stimulate investigations on the mechanical problems of drying these products. Much work remains on this phase of the problem.

This report presents the composition, coefficients of digestibility, and the digestible nutrients of dried grapefruit cannery refuse, and of dried orange peel, and the results of a short feeding trial with growing heifers in which dried grapefruit cannery refuse was the principal source of digestible nutrients.

STATEMENT OF THE PROBLEM

At the present time the peel, rag and seed of the fruit which constitute cannery refuse are a liability to the cannery, due to the necessity for their disposal. A very small amount is fed to livestock in the fresh state; some is returned to the groves as fertilizer, and a considerable amount is dumped in the woods to decay. There is some evidence that the citrus peel oil in the fresh refuse will flavor milk when fed to cows in production, so that the feeding of this fresh product to dairy cows, except dry cows, cannot be advised.

The amount of this refuse from the canneries in this state is indicated from the data in Table 1, compiled from data by the Bureau of Foreign and Domestic Commerce, U. S. Department of Commerce.

Almost one-fifth of the grapefruit crop is canned as either juice or hearts each season. Two-thirds of this part of the crop constitutes the refuse of which the canneries must make some disposition. This grapefruit refuse together with the small amount of orange refuse amounts to about 65,000 tons in an average season. This quantity will increase as the demand for canned fruit is developed.

Dr. C. V. Noble, Agricultural Economist of the Florida Agricultural Experiment Station, has supplied the authors with data for the 1931-32 season, which was considered normal. Based on nine estimates for oranges, 10 for grapefruit, and four for tangerines, there were 8.0 percent, 13.7 percent, and 10.0 percent, respectively, of these fruits left in the groves. Based on 37 estimates for oranges and 36 estimates for grapefruit and tangerines, it was estimated that 2.75 percent of the oranges, 3.37 percent of the grapefruit, and 4.01 percent of the tangerines taken to the packinghouses found their way to the cull pile.

TABLE 1.—CITRUS CANNERY REFUSE AVAILABLE IN FLORIDA DURING THE FIVE SEASONS OF 1929-34.*

Season	Field Boxes to Canneries	Percent of Fresh Fruit as Refuse	Total Amount of Cannery Refuse** pounds
GRAPEFRUIT			
1929-30	1,639,923	74.2	109,580,934
1930-31	2,892,705	69.4	180,667,298
1931-32	932,864	64.9	54,505,898
1932-33	2,525,992	67.6	153,696,759
1933-34	2,369,058	66.6	141,950,574
Average.....			64,040 tons
ORANGES			
1929-30	36,514	70.9	2,328,684
1930-31	61,351	71.8	3,963,285
1931-32	36,362	71.7	2,345,349
1932-33	60,720	70.0	3,824,666
1933-34	55,848	70.7	3,555,531
Average.....			1,602 tons
Total per season.....			65,642 tons

*Computed by Dr. C. V. Noble, Agricultural Economist of the Florida Agricultural Experiment Station from data compiled by the Bureau of Foreign and Domestic Commerce, U. S. Department of Commerce.

**This represents the difference between the weight of the field boxes received, and the net weights of the canned products.

Leading fruit men estimate that 10 percent of the fruit now marketed is of such low grade that it does not pay the marketing expenses. The market for fruit of higher quality is injured by this competition of low grade fruit. Considering (a) the amount of fruit that drops or is left in grove, (b) the amount that reaches the cull pile, (c) the refuse from the canneries, and (d) the low grade fruit that reaches the market, there is from one-fifth to one-fourth of the citrus crop that would be available for the production of livestock feeds. The cannery refuse and the cull pile at the packinghouse are the parts of this supply that first merit attention, due to the problem of their disposal.

The method of drying cannery refuse remains near the experimental stage. The product now on the market in Florida is passed through corrugated rollers that tend to disintegrate the fibrous structure of the peel and express a part of the water.

Also, a part of the citrus peel oil is expressed in this operation. From the rollers the refuse is conveyed to a five-compartment drier which is heated by a fuel oil furnace. Circulation of the heated air is assured by means of pressure and suction fans. In the first compartment the material is heated to near the boiling point as it is agitated by rotary paddles. It is passed from compartment to compartment with continuous agitation until discharged at the outlet with a moisture content of 10 percent or less. The dried product takes up atmospheric moisture slowly.

The physical condition of this feed is determined by the processing method. The fresh refuse is cut into narrow strips as it passes through the corrugated rollers. The length of these strips varies due to the size of the pieces of peel, and the amount of breaking as they pass through the drier. The final product consists of flakes and shreds of the dried refuse, somewhat coarser than beet pulp. The pieces are hard and slightly brittle; however, dairymen state that when soaked like beet pulp, the fresh texture is recovered. In the dry state it can be ground into a meal with a hammer mill, although there is nothing to indicate that such is desirable for cattle feeding.

In color, the dried grapefruit refuse varies from a golden brown to a bright gold. The dried orange peel has a more reddish tint. The brightest product is secured by the use of lower drying temperatures.

The characteristics of this material that set it aside from the usual stock feeds are: high content of citric acid, pectin, and soluble sugars, and the presence of glucosides, pigments, and essential oils. The physiological effects of these constituents on large animals remain to be investigated. The first concern of the stock feeder is the palatability of a product and the amount of digestible nutrients that it contains.

In addition to knowing the palatability and digestible nutrient content, it is necessary when making the final evaluation of a feed, to compare the value of the nutrients in actual feeding practice with those of the most similar known feed, and to study the effects of long continued feeding of the product to determine any special beneficial or harmful effects on the animal. Further, it is desirable to study the effects that specific constituents might have on the animal. None of this information was available for dried grapefruit cannery refuse, and very little for any of the dried citrus by-products.

REVIEW OF LITERATURE

McDermott (7)¹, holder of a Florida Citrus Exchange fellowship with the Mellon Institute, suggested in 1916 that the dried by-product from the manufacture of various products from cull fruits might have a place as livestock feed.

The only feeding trial reported with cattle using dried grapefruit cannery refuse was conducted by Scott (14) at this station in 1925-26. He used a product, furnished by the Florida Citrus Exchange, that analyzed 18.00 percent moisture, 5.25 percent fat, 5.31 percent crude protein, 61.69 percent nitrogen-free extract and ash, and 9.75 percent crude fiber. The six Jersey cows to which this product was fed gave increased milk yields as a result of additions of the dried grapefruit refuse to their rations.

Studies concerning the composition, coefficients of digestibility, and digestible nutrients of dried fruit by-products have been conducted at the California (8, 9) and Virginia (5) stations. The data from these studies are summarized in Table 2.

TABLE 2.—THE COMPOSITION, COEFFICIENTS OF DIGESTIBILITY, AND DIGESTIBLE NUTRIENTS OF CITRUS AND OTHER FRUIT BY-PRODUCTS.

Dried Fruit By-Product	Dry Matter percent	Crude Protein percent	Crude Fiber percent	N-Free Extract percent	Crude Fat percent	Ash percent
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COMPOSITION OF THE PRODUCT

Orange pulp (8)	87.50	7.70	7.81	66.96	1.68	3.35
Lemon pulp (9)	92.90	6.39	15.00	65.24	1.23	5.04
Raisin pulp (8)	88.68	9.58	19.32	45.57	10.54	3.67
Pineapple pulp (9)	83.60	3.81	13.88	61.94	0.71	3.26
Olive pulp (9)	92.02	5.91	36.45	31.54	15.63	2.49
Olive pulp* (9)	95.11	13.99	19.27	31.04	27.39	3.43
Apple pomace (5)	86.68	4.31	17.03	69.76	5.13	3.77

COEFFICIENTS OF DIGESTIBILITY

Orange pulp	89.33	78.54	83.73	95.40	48.89	
Lemon pulp	81.43	46.18	60.33	92.01	27.44	
Raisin pulp	44.78	24.13	18.54	52.01	90.16	
Pineapple pulp	74.56	20.75	69.62	79.75	neg.	
Olive pulp	19.09	neg.	neg.	20.27	86.02	
Apple pomace	67.	37.	54.	80.	32.	

DIGESTIBLE NUTRIENTS

T.D.N.

Orange pulp	6.05	6.54	63.88	0.82	78.31
Lemon pulp	2.95	9.05	60.03	0.34	72.80
Raisin pulp	2.31	3.58	23.70	9.50	50.98
Pineapple pulp	0.79	9.66	49.40	0.00	59.85
Olive pulp	0.00	0.00	6.39	13.44	36.63
Apple pomace	1.59	5.79	55.81	1.64	66.88

* Prepared from pitted olives.

¹ Figures in parentheses (*Italic*) refer to "Literature Cited", page 20.

The orange pulp referred to in Table 2 was the dried residue from the manufacture of orange juice, orange oil, or other orange extracts. Dried lemon pulp was the rind, pulp, and seeds after the extraction of citric acid. Dried raisin pulp consisted of the various wastes with most of the sugar extracted. Pineapple pulp contained the outer skin, trimmings, and cores after juice extraction. The first analysis of olive pulp represented a sample from the commercial preparation of olive oil. This pulp contained the pits, and was used in the digestion trials. The second sample represented a pit-free pulp and hence was lower in fiber. Dried apple pomace was the dried residue from cider manufacture.

Digestion trials at the California station were conducted with five wethers, using a basal ration of alfalfa hay. Preliminary periods were 10 days in length and experimental periods 15 days. A basal ration of mixed grain and corn silage was used with cows at the Virginia station in the studies with dried apple pomace.

These citrus and apple by-products are seen to be low in protein and fiber, and high in nitrogen-free extract. They are essentially carbohydrate feeds and are highly digestible. One trial at the California station (13) with dried orange pulp showed it to be equivalent to beet pulp for milk production. Fresh pulp was not found to have any effect on percent of fat in the milk. Nothing was mentioned of any flavor being imparted to the milk when as much as 20 pounds of the fresh pulp was fed daily, nor was mention made of the particular extracts from which this pulp was a residue. The citrus peel oils may have been removed in the process of manufacture.

EXPERIMENTAL METHODS

The palatability of the dried grapefruit refuse was tested in the dairy herd of the Florida Agricultural Experiment Station by offering small portions to the individual cows of the dairy herd after they had received the usual offering of corn silage and grain feed.

The methods used in conducting the digestion trials were essentially as recommended by Forbes and Grindley (3). The basal ration per day consisted of one pound of prime cottonseed meal and enough No. 1 federal grade alfalfa hay to supply slightly more than the requirement of total digestible nutrients for maintenance. In the trials with the feeds to be tested, one-half of the alfalfa hay was replaced by the particular feed. In

every case the requirement for digestible crude protein was exceeded by the total ration. Preliminary periods were 10 days in length, and the experimental periods consisted of four successive five-day periods.

Four steers, three Jerseys and one grade Hereford, ranging in weight from 450 to 700 pounds, were used in all the trials. The individual feeds for an entire trial were weighed into separate bags on a solution balance before the beginning of a trial. Samples were taken at that time. The feed was given in two equal portions at 6:00 a.m. and 6:00 p.m. The steers were held in a dry lot for the first nine days of the preliminary periods and then stanchioned in a barn. Water was provided in buckets. Salt was offered in small boxes. Each animal was brushed vigorously for one hour daily as a substitute for exercise.

Feces collections were manual. The daily collections of feces were weighed and sampled separately at 9:00 a.m. each day. Triplicate five to 10 gram samples were taken in weighing bottles for the determination of nitrogen, thus avoiding volatilization of any ammonia. A twentieth aliquot was taken in pyrex dishes, dried, and used in the preparation of five-day composite samples, for the determination of the other constituents.

Proximate analyses were made by the methods of the Association of Official Agricultural Chemists (1). Calcium, magnesium, and phosphorus were determined by the method of Morris, Nelson, and Palmer (10).

Indirect calculations were made of the digestibility of the nutrients. The coefficients of digestibility for cottonseed meal, as compiled by Henry and Morrison (4), were used for that feed. Coefficients for the alfalfa hay were calculated from the trial on the basal ration of cottonseed meal and alfalfa hay, and were used in the calculations with the dried grapefruit cannery refuse, and with the dried orange peel. The crude protein as determined in the fresh feces was used in all calculations to avoid any error due to the volatilization of ammonia.

To secure some information as to the general feeding qualities and effect of the dried grapefruit refuse on the animal, a feeding trial was conducted with eight native and grade Hereford heifers. The ration used was 30 pounds of sugarcane silage, 15 pounds of dried grapefruit refuse, and 5 pounds of prime cottonseed meal daily per thousand pounds liveweight. The cottonseed meal supplied the requirement for digestible crude protein. Sorghum silage was substituted for the sugarcane silage at the end of 80 days. These feeds were mixed and fed to the lots in equal offer-

ings, morning and evening. Water and salt were available at all times. Finely ground feeding bonemeal was offered to Lot 1.

Blood samples were taken at the beginning of the trial and at the end of the first, second, and fourth 30-day periods. These samples were analyzed for calcium and inorganic phosphorus in the blood plasma by the methods of Kramer and Tisdal (6), and Fiske and Subbarow (2), respectively. Hemoglobin determinations were made by the Newcomer method (12).

The heifers were weighed on three successive days at each 30-day interval. Feed records were kept, and feed samples taken and analyzed for the calculation of the efficiency of the ration. General observations were made on the condition of the animals.

PRESENTATION AND DISCUSSION OF THE DATA*

Palatability of Dried Grapefruit Cannery Refuse.—One pound of dried grapefruit refuse was offered to each of 31 cows in the dairy herd after they had eaten their regular evening offering of corn silage and mixed grain. The refusal was weighed. Only one individual refused the product on all six occasions. Fourteen cows tasted it when first offered, their appetites for this product increasing progressively. The refusal decreased from 29.8 pounds to 6.0 pounds out of the 31 pound daily offering over the six-day test.

Four steers used in the digestion trials refused a small part of their feed at the first offering when it was used to replace a part of the alfalfa hay in the ration of alfalfa hay and cottonseed meal. At no other time during the 30-day period was there any refusal.

Eight heifers, just off grass pasture, were used in the feeding trial. A 10-day preliminary period was allowed in which to determine their appetites for a ration of sugarcane silage, grapefruit refuse and cottonseed meal. When the bulk of their rations was reduced to the quantities fed in the actual trial, they refused only 60 pounds of feed in the entire trial. This refusal consisted almost totally of coarse pieces of silage.

Digestibility of Dried Grapefruit Cannery Refuse.—The four steers used in the digestion studies refused no feed after the first offering of the preliminary period. They maintained their weight or made slight gains. The composition of the grapefruit refuse, digestibility of the nutrients by each of the four steers, and the digestible nutrient content of the product are given in

* A preliminary report appeared in a recent press bulletin (11).

Table 3. Feed intakes per day, digestibility of the nutrients by 5-day periods, weight and composition of the feces, and composition of the feeds are given in Appendix Tables A, C, E and F.

TABLE 3.—THE COMPOSITION, COEFFICIENTS OF DIGESTIBILITY, AND DIGESTIBLE NUTRIENTS OF DRIED GRAPEFRUIT REFUSE.

	Dry Matter	Crude Protein	Crude Fiber	N-Free Extract	Crude Fat	Ash
	percent	percent	percent	percent	percent	percent
Composition	91.77	4.94	11.94	69.60	1.06	4.23
Coefficients of digestibility	Steer					
	E-49	24.46	67.51	92.11	74.01	
	E-50	19.32	73.81	92.39	88.78	
	E-51	33.07	81.04	93.19	79.31	
	E-52	22.48	63.72	92.04	75.38	
	Ave.	24.83	71.52	92.43	79.37	
Digestible nutrients		1.23	8.54	64.33	0.84	T.D.N. 75.99

The composition of the dried grapefruit refuse was: 91.77 percent dry matter, 4.94 percent crude protein, 11.94 percent crude fiber, 69.60 percent nitrogen-free extract, 1.06 percent crude fat, and 4.23 percent ash. The digestibility of the crude protein as shown by the individual steers varied from 19.32 percent to 33.07 percent, crude fiber from 63.72 percent to 81.04 percent, nitrogen-free extract from 92.04 percent to 93.19 percent, and of crude fat from 74.01 percent to 88.78 percent. Respective averages were: 24.83 percent (protein), 71.52 percent (fiber), 92.43 percent (N-free extract), and 79.37 percent (fat).

As determined from the above composition and digestibility, the dried grapefruit refuse contained 1.23 percent digestible crude protein, 72.87 percent digestible carbohydrates, 0.84 percent digestible crude fat, or a total of 75.99 percent digestible nutrients. The total digestible nutrients per hundredweight of dry matter were 82.80 pounds.

Digestibility of Dried Orange Peel.—The same amounts of dried orange peel were fed as of the dried grapefruit refuse. Live weights of the steers were maintained and no feed was refused after the initial offering. The composition of the dried orange peel, digestibility of the nutrients by each of the four steers, and the digestible nutrient content of the product are given in Table 4. Feed intakes per day, coefficients of digestibility by five-day periods, weight and composition of the feces, and composition of the feeds are given in Appendix Tables A, D, E and F.

(a) the heating of the protein during the drying process which tends to make it less digestible, (b) the presence of non-protein nitrogen compounds in the citrus fruit that are not digestible, or (c) an apparent depression of digestibility as observed at the Virginia station (5) when a high carbohydrate feed such as apple pomace was added to a basal ration low in protein. This last factor should not be of importance in these trials, since the intake of digestible crude protein was more than adequate in all cases.

The coefficients of digestibility as determined for the nitrogen-free extract were remarkably consistent. As this constituent made up 75 percent of the dry matter in both citrus by-products, the variations observed in the digestibility of the other constituents had but a small effect on the measure of the total digestible nutrient content of these feeds. The low content of digestible crude protein precludes either dried grapefruit refuse or dried orange peel from being an important source of this nutrient.

Feeding Trial With Growing Heifers.—Eight native and grade Hereford heifers ranging in weight from 207 to 520 pounds were available for this trial. They were divided into two lots, the three larger in Lot 1 and five smaller in Lot 2. They were fed 30 pounds of sugarcane silage, 15 pounds of dried grapefruit refuse, and 5 pounds of prime cottonseed meal per day per thousand pounds liveweight. Sorghum silage was substituted for the sugarcane silage at the end of 80 days. Lot 1 was continued on feed for 60 days and Lot 2 for 120 days. Live weights of the individual animals and feed and nutrient intakes for the lots are given in Table 5.

The ration was very palatable, as only 60 pounds of feed were refused during the entire trial. This refusal consisted of coarse pieces of silage. Lot 1 took 14 pounds of salt in 60 days; Lot 2, 18 pounds in the first 60 days, and 22 pounds in the second 60 days, or an average of 2.08 pounds per head each 30 days. Lot 1, allowed bonemeal, consumed 18 pounds in 60 days, or three pounds per head per month.

Rate of gain varied from 0.98 to 2.40 pounds per day, except for No. 26. Fecal examination showed that this animal was infested heavily with stomach worms. Her gain in weight for the 120-day period was only 21 pounds. Since such an infestation interferes with the utilization of feed, her weight and one-fifth of the nutrient intake were deducted from Lot 2, before calculating the economy of gains on this ration.

Digestible crude protein and total digestible nutrient intakes

TABLE 5.—THE LIVEWEIGHT, AND FEED AND DIGESTIBLE NUTRIENT INTAKES OF HEIFERS FED SILAGE, DRIED GRAPEFRUIT CANNERY REFUSE, AND COTTONSEED MEAL.

30-Day Period Number	Lot Number	Animal Number	Initial Weight pounds	Final Weight pounds	Feed Intake			Nutrient Intake		T. D. N. Per 100 Pounds Gain	
					Silage pounds	Grape- fruit pounds	Cotton- seed Meal pounds	Digestible Crude Protein pounds	Total Digestible Nutrients pounds	Total	Net*
										pounds	pounds
I	1	19	520	581	1,188	594	197	71.4	753.6	565.9	321.9
		20	350	395							
		22	432	459							
			1,302	1,435							
II	1	19	581	665	1,544	772	232	85.0	954.9	484.7	299.7
		20	395	437							
		22	459	530							
			1,435	1,632							
I	2	23	207	217	1,188	594	197	71.4	753.6	502.4	277.8
		24	270	309							
		25	277	305							
		26	274	304							
		27	320	363							
			1,348	1,498							

TABLE 5.—THE LIVELWEIGHT, AND FEED AND DIGESTIBLE NUTRIENT INTAKES OF HEIFERS FED SILAGE, DRIED GRAPEFRUIT CANNERY REFUSE, AND COTTONSEED MEAL (continued).

30-Day Period Number	Lot Number	Animal Number	Initial Weight pounds	Final Weight pounds	Feed Intake			Nutrient Intake		T. D. N. Per 100 Pounds Gain	
					Silage pounds	Grapefruit pounds	Cottonseed Meal pounds	Digestible Crude Protein pounds	Total Digestible Nutrients pounds	Total pounds	Net* pounds
II	2	23	217	237	1,526	763	232	84.9	945.8	455.8	281.4
		24	309	347							
		25	305	317							
		26	304	289							
		27	363	399							
			1,498	1,589							
III	2	23	237	279	1,652	826	286	102.2	1,048.1	612.0	374.7
		24	347	387							
		25	317	347							
		26	289	312							
		27	399	424							
			1,589	1,749							
IV	2	23	279	337	1,800	900	330	117.2	1,162.3	426.5	257.9
		24	387	418							
		25	347	395							
		26	312	295							
		27	424	505							
			1,749	1,950							
Average										488.0	298.1

* Net total digestible nutrients per hundred weight of gain were calculated by deducting maintenance at the rate of 7.925 pounds daily per thousand pounds liveweight from the total nutrient intake. The weight of No. 26 and one-fifth of the nutrient intake were deducted before making this calculation for Lot 2.

were calculated from actual analyses of the feeds by applying the coefficients of digestibility for the silage and cottonseed meal as given by Henry and Morrison (4), and for the grapefruit refuse as given in Table 3. Fifty-four percent of the dry matter, and 60 percent of the total digestible nutrients were provided by the dried grapefruit refuse. The digestible nutrient intake per hundredweight gain varied from 426 to 612 pounds, or an average of 488 pounds. The extremes were for periods 3 and 4 with Lot 2, and variations in fill may account for a part of the difference, especially since the periods were successive. When a maintenance requirement (of 7.925 pounds of digestible nutrients daily per thousand pounds liveweight) was deducted from the total nutrient intake, the average net requirement per hundredweight of gain became 298 pounds, with a range from 258 to 375 pounds. This is an economy of gain comparable with that secured with rather heavy grain feeding.

Blood samples were taken on three successive days at the beginning of the trial and at the end of the first, second, and fourth 30-day periods. Calcium and inorganic phosphorus were determined on the composite citrated blood plasma samples, and hemoglobin on the daily samples. Detailed results are given in Table 6.

No significant variations were observed in any of these constituents. Even though Lot 1 consumed bonemeal at the rate of 3.0 pounds per head per month, the inorganic phosphorus was no higher than in Lot 2. Also, the inorganic phosphorus in the blood plasma of Lot 2 did not decrease during the entire trial. However, a decrease would not be expected, since all the heifers had free access to bonemeal on pasture previously. Cottonseed meal also is one of the high phosphorus feeds.

The effect of the total ration was markedly laxative. A soft jelly-like consistency of the feces was observed during the entire trial. Sugarcane silage used in these rations is considered to be moderately laxative, and cottonseed meal relatively constipating. It was presumed that pectin was the constituent having this laxative effect, although the high citric acid content of the feed may have contributed.

All of the animals had a sleek, thrifty appearance, were alert, and had bright eyes. The sleek, oily appearance of the coat of hair was similar to that secured by feeding bran, oats, and linseed meal. Even No. 26 did not seem to be "out of condition", and failure to make gains was the only casual symptom of the parasitic infestation. Every animal except No. 26 improved in

thickness of flesh while on the ration. Figure 1 shows Lot 2 at the end of 120 days on the ration of silage, grapefruit refuse and cottonseed meal.

TABLE 6.—THE CALCIUM AND INORGANIC PHOSPHORUS CONTENT OF THE BLOOD PLASMA, AND THE HEMOGLOBIN CONTENT OF THE BLOOD OF HEIFERS FED SILAGE, DRIED GRAPEFRUIT CANNERY REFUSE AND COTTONSEED MEAL.

Animal Number	D A T E			
	7/16-18	8/15-17	9/14-16	11/13-15
CALCIUM PER 100 ML. OF CITRATED BLOOD PLASMA				
	mgs.	mgs.	mgs.	mgs.
19	11.66	12.29	10.65	.....
20	11.11	.....	10.59	.....
22	11.88	11.47	10.06	.....
23	11.66	11.35	10.24	11.23
24	12.21	10.76	9.83	11.35
25	11.88	11.00	9.65	11.00
26	11.66	11.35	10.24	10.82
27	11.66	11.12	9.42	11.88
PHOSPHORUS PER 100 ML. OF CITRATED BLOOD PLASMA				
19	7.09	8.13	6.85	.....
20	6.54	7.60	6.02	.....
22	5.56	10.87	6.85	.....
23	5.38	7.78	6.80	7.81
24	5.36	7.49	6.01	6.45
25	6.43	7.14	7.66	8.03
26	5.08	6.76	6.85	7.09
27	5.19	6.76	6.29	5.83
HEMOGLOBIN PER 100 ML. OF BLOOD				
	gs.	gs.	gs.	gs.
19	11.10	9.68	11.35	.....
20	13.37	11.65	12.94	.....
22	10.80	9.68	9.82	.....
23	11.66	8.48	9.01	12.02
24	12.48	11.29	12.49	17.29
25	11.74	9.82	9.52	12.70
26	15.25	11.44	10.20	11.87
27	13.84	12.98	13.29	19.29

GENERAL DISCUSSION

The bitter taste of the grapefruit caused by its narangin (glucoside) content, or the sourness caused by the citric acid, did not seem to detract from the palatability of the product. The effect of the drying process is not known. The grapefruit refuse was consumed with relish by almost all the animals having access to it. Dried orange peel seemed to be equally palatable. This

is contrary to the results of the California station (8, 9, 13) where orange pulp ground into a meal, and lemon pulp from citric acid manufacture, had to be fed in combination with other feeds in order to insure consumption.

Both the grapefruit refuse and orange peel were similar in chemical composition to the orange and lemon pulps studied at the California station (8, 9). They have slightly less fiber and crude fat than the dried apple pomace investigated at the Virginia station (5). The low fiber content and high proportion of nitrogen-free extract place these feeds in the group of concentrates. Their high degree of digestibility was evidenced both by the actual results of the digestion trials, and by the lesser quantity of feces voided by the steers when these feeds were substituted for one-half of the alfalfa hay of the basal ration. There was no indication of a deficiency of roughage when 3.0 pounds of silage and 1.5 pounds of grapefruit refuse were fed per each hundred pounds of liveweight. This is less than the "Rule of Thumb" recommendations for roughage in feeding practice.

It would seem that these feeds could be substituted for such a feed as beet pulp and for at least a part of the carbohydrate feeds like corn.

So far as could be determined from a 120-day feeding trial the general effects of the grapefruit refuse on the animal were favorable. It was fed at a much higher level than would be followed in general feeding practice. The glossy, oily appearance of the coat of hair and the thrift of the animals receiving the grapefruit refuse make it appear that this feed belongs in that group of feeds prized by stockmen for their beneficial effect on the animal. The particular constituent, or constituents, producing this effect is not known.

Even though the results of the digestion trials and the feeding trial indicate that dried grapefruit refuse and dried orange peel are good sources of digestible carbohydrates, longer continued feeding trials and actual comparisons with some of the standard feeds for fattening and for milk production are necessary for a final evaluation. Further studies of the physiological effects on the animal are desirable. Too little is known of the effect of fruit by-products upon animal welfare.

SUMMARY AND CONCLUSIONS

Dried grapefruit cannery refuse and dried orange peel were palatable to cattle, contrary to the findings elsewhere with orange and lemon pulp.

The citrus by-products were low in crude protein, fiber, and fat. They were high in nitrogen-free extract, which was 88-92 percent digestible. Total digestible nutrients per hundred pounds of dry matter were 82.80 and 80.82 pounds for grapefruit and orange refuse, respectively. The results of the digestion trials placed these feeds in the class of high carbohydrate concentrates.

Dried grapefruit and orange cannery refuses have a laxative action when fed as a large proportion of the ration. General effects of the dried grapefruit refuse were favorable as indicated by thrifty appearance, gloss of the coat of hair, and improvement in thickness of flesh.

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APPENDIX

TABLE A.—FEED INTAKE PER DAY OF STEERS USED IN DETERMINING THE DIGESTIBILITY OF THE BASAL RATION, OF DRIED GRAPEFRUIT CANNERY REFUSE, AND OF DRIED ORANGE PEEL.

Animal Number	Trial Number	Alfalfa Hay		Cottonseed Meal		Grapefruit Refuse		Dried Orange Peel	
		Amount pounds	Sample number	Amount pounds	Sample number	Amount pounds	Sample number	Amount pounds	Sample number
E-49	21	8.0	855	1.0	856	.....	.....	.....	.....
E-50	22	10.0	855	1.0	856	.....	.....	.....	.....
E-51	23	10.0	855	1.0	856	.....	.....	.....	.....
E-52	24	6.0	855	1.0	856	.....	.....	.....	.....
E-49	25	4.0	855	1.0	1013	4.0	1014	.....	.....
E-50	26	5.0	855	1.0	1013	5.0	1014	.....	.....
E-51	27	5.0	855	1.0	1013	5.0	1014	.....	.....
E-52	28	3.0	855	1.0	1013	3.0	1014	.....	.....
E-49	33	4.0	1211	1.0	1213	.....	.....	4.0	1212
E-50	34	5.0	1211	1.0	1213	.....	.....	5.0	1212
E-51	35	5.0	1211	1.0	1213	.....	.....	5.0	1212
E-52	36	3.0	1211	1.0	1213	.....	.....	3.0	1212

TABLE B.—THE DIGESTIBILITY OF THE NUTRIENTS OF THE ALFALFA HAY USED IN THE BASAL RATION AS DETERMINED WITH FOUR STEERS IN FOUR SUCCESSIVE FIVE-DAY PERIODS.

Animal Number	Trial Number	5-Day Period Number	Coefficients of Digestibility			
			Crude Protein	Crude Fiber	N-Free Extract	Crude Fat
			percent	percent	percent	percent
E-49	21	I	63.19	46.58	72.45	0.37
		II	63.44	39.53	69.06	-4.99
		III	64.09	33.03	79.63	-1.95
		IV	64.80	24.98	68.83	-12.70
		Average	63.88	36.03	69.11	-4.82
E-50	22	I	59.11	45.71	72.28	0.23
		II	62.86	40.00	69.51	2.01
		III	61.12	24.78	61.43	-20.62
		IV	59.45	18.90	65.86	-10.57
		Average	60.64	32.35	67.27	-7.24
E-51	23	I	62.90	47.77	73.91	-12.58
		II	63.67	49.09	72.49	12.80
		III	63.83	50.93	73.05	7.10
		IV	62.45	42.73	69.95	1.94
		Average	63.21	47.63	72.35	2.31
E-52	24	I	62.34	43.63	77.57	6.82
		II	58.69	36.15	68.18	-0.52
		III	59.32	28.45	69.78	-3.94
		IV	55.29	15.72	63.67	-12.00
		Average	58.91	30.99	69.80	-2.41
Average "I" periods.....			61.88	45.92	74.05	-1.29
Average "II" periods.....			62.16	41.19	69.81	2.32
Average "III" periods.....			62.09	34.30	70.97	-4.85
Average "IV" periods.....			60.50	25.58	67.08	-8.33
Grand average.....			61.66	36.75	69.63	-3.04

TABLE C.—THE DIGESTIBILITY OF THE NUTRIENTS OF DRIED GRAPEFRUIT CANNERY REFUSE AS DETERMINED WITH FOUR STEERS IN FOUR SUCCESSIVE FIVE-DAY PERIODS.

Animal Number	Trial Number	5-Day Period Number	Coefficients of Digestibility			
			Crude Protein percent	Crude Fiber percent	N-Free Extract percent	Crude Fat percent
E-49	25	I	-11.01	45.09	91.07	36.22
		II	17.43	20.26	90.90	57.87
		III	61.80	108.06	95.67	108.46
		IV	29.62	96.64	90.79	93.49
		Average	24.46	67.51	92.11	74.01
E-50	26	I	20.69	76.53	92.13	85.52
		II	4.37	55.94	90.32	81.27
		III	36.47	66.47	93.49	101.75
		IV	15.76	96.31	93.62	86.59
		Average	19.32	73.81	92.39	88.78
E-51	27	I	26.86	88.53	94.85	68.27
		II	34.13	60.32	91.52	61.29
		III	37.54	74.68	93.14	93.53
		IV	33.74	100.60	93.23	94.13
		Average	33.07	81.04	93.19	79.31
E-52	28	I	22.81	95.91	94.11	90.80
		II	21.57	42.19	91.64	54.44
		III	21.27	29.16	90.58	75.91
		IV	24.26	87.63	91.81	80.36
		Average	22.48	63.72	92.04	75.38
Average "I" periods.....			14.84	76.52	93.04	70.20
Average "II" periods.....			19.38	44.68	91.10	63.72
Average "III" periods.....			39.27	69.59	93.22	94.91
Average "IV" periods.....			25.85	95.30	92.36	88.64
Grand average.....			24.83	71.52	92.43	79.37

TABLE D.—THE DIGESTIBILITY OF THE NUTRIENTS OF DRIED ORANGE PEEL AS DETERMINED WITH FOUR STEERS IN FOUR SUCCESSIVE FIVE-DAY PERIODS.

Animal Number	Trial Number	5-Day Period Number	Coefficients of Digestibility			
			Crude Protein percent	Crude Fiber percent	N-Free Extract percent	Crude Fat percent
E-49	33	I	49.40	107.98	90.60	-92.42
		II	60.43	102.92	92.98	-75.91
		III	33.24	48.82	84.43	-5.12
		IV	34.13	82.99	89.40	51.65
		Average	44.30	90.18	89.35	-30.45
E-50	34	I	18.85	90.57	84.72	60.41
		II	27.14	73.63	87.29	-12.01
		III	29.19	87.81	86.35	1.56
		IV	30.47	87.65	88.21	-2.77
		Average	26.41	84.92	86.64	11.80
E-51	35	I	30.16	91.60	88.25	30.22
		II	30.83	85.74	82.65	17.25
		III	29.99	101.26	86.55	-4.14
		IV	33.86	78.82	88.09	4.00
		Average	31.21	89.36	86.38	11.84
E-52	36	I	40.04	108.51	90.84	33.99
		II	55.75	114.32	91.50	21.71
		III	51.01	116.25	93.45	48.80
		IV	30.64	105.55	90.81	28.09
		Average	44.36	111.16	91.65	33.15
Average "I" periods.....			34.61	99.67	88.60	8.05
Average "II" periods.....			43.54	98.65	88.61	-25.72
Average "III" periods.....			35.86	88.54	87.70	10.28
Average "IV" periods.....			32.28	88.75	89.13	20.24
Grand average.....			36.57	93.91	88.51	6.59

TABLE E.—THE WEIGHT AND COMPOSITION OF FECES FROM STEERS DURING DIGESTION TRIALS.

Animal Number	Trial Number	5-Day Period Number	Fresh Excreta grams	Total Crude Protein percent	Dry Matter percent	Composition of Dry Matter				
						Ash percent	Crude Protein percent	Crude Fiber percent	N-Free Extract percent	Crude Fat percent
BASAL RATION										
E-49	21	I	36,365	2.766	22.59	20.93	10.47	38.12	26.27	3.81
		II	36,785	2.739	23.25	15.30	10.59	41.50	28.73	3.88
		III	37,655	2.634	23.27	11.20	9.90	44.60	30.56	3.68
		IV	39,363	2.477	22.99	10.42	10.09	48.22	27.34	3.93
E-50	22	I	47,644	2.838	23.62	26.26	10.76	35.22	24.27	3.49
		II	48,141	2.758	21.11	12.48	11.40	42.93	29.39	3.80
		III	51,947	2.488	21.30	10.57	10.65	44.39	30.52	3.87
		IV	57,406	2.337	20.62	8.78	10.14	49.33	28.08	3.67
E-51	23	I	42,602	2.910	23.86	20.63	12.06	37.57	25.39	4.35
		II	43,284	2.812	21.32	14.19	12.31	40.38	29.39	3.73
		III	42,923	2.824	20.56	12.80	12.14	40.77	30.14	4.15
		IV	47,077	2.662	20.66	11.73	11.12	42.89	30.29	3.97
E-52	24	I	31,016	2.613	21.83	26.94	10.55	37.94	21.22	3.35
		II	34,917	2.507	19.13	13.75	11.09	42.59	28.97	3.60
		III	36,588	2.362	18.20	10.28	10.68	47.58	27.73	3.73
		IV	44,219	2.116	17.71	10.84	10.57	47.28	27.90	3.41
BASAL RATION PLUS DRIED GRAPEFRUIT REFUSE										
E-49	25	I	31,805	3.460	20.91	16.44	14.70	37.38	28.06	3.42
		II	30,636	3.175	21.14	11.75	13.54	42.54	28.98	3.19
		III	21,523	3.595	22.30	12.74	13.57	37.57	32.83	3.29
		IV	24,342	3.772	22.69	13.65	14.23	34.89	34.11	3.12
E-50	26	I	35,857	3.237	20.28	16.21	13.95	36.46	30.31	3.07
		II	42,433	2.951	18.43	15.59	14.01	37.47	30.01	2.92
		III	30,921	3.467	22.64	13.57	13.75	39.82	29.95	2.91
		IV	35,292	3.367	19.00	15.03	15.01	35.54	31.11	3.31
E-51	27	I	32,451	3.470	21.12	16.55	14.56	36.31	29.02	3.56
		II	36,441	2.978	19.96	12.37	13.73	39.47	30.96	3.47
		III	36,196	2.945	19.16	13.51	14.19	38.59	30.63	3.08
		IV	33,783	3.219	18.98	12.81	14.60	36.26	33.01	3.32
E-52	28	I	22,428	3.338	23.16	20.77	14.75	32.76	28.78	2.94
		II	23,211	3.243	20.17	11.43	13.91	40.97	30.29	3.40
		III	23,378	3.224	21.34	13.01	14.11	40.57	29.43	2.88
		IV	20,978	3.545	20.54	12.92	15.15	35.94	32.73	3.26
BASAL RATION PLUS DRIED ORANGE PEEL										
E-49	33	I	27,570	3.266	20.51	16.99	15.01	33.62	29.73	4.65
		II	23,944	3.593	22.40	16.44	15.59	33.82	29.34	4.81
		III	30,621	3.221	20.99	11.25	15.25	38.47	31.79	3.24
		IV	29,823	3.292	18.44	11.63	14.42	38.96	31.85	3.14
E-50	34	I	39,322	3.289	21.60	22.70	14.75	30.01	29.36	3.18
		II	38,845	3.188	19.80	15.58	15.22	35.80	29.97	3.43
		III	38,629	3.170	19.22	14.02	15.82	34.78	31.97	3.41
		IV	37,720	3.225	18.79	12.81	15.54	36.46	31.57	3.62
E-51	35	I	36,400	3.347	20.92	19.47	14.85	33.31	29.34	3.03
		II	37,883	3.204	20.78	15.38	14.83	33.12	33.61	3.06
		III	35,533	3.432	20.31	14.14	16.07	33.53	32.69	3.57
		IV	35,418	3.371	20.27	12.31	15.42	37.48	31.29	3.50
E-52	36	I	23,876	3.133	20.25	25.09	15.16	30.19	26.67	2.89
		II	19,741	3.472	20.82	14.46	16.85	34.49	30.66	3.54
		III	19,700	3.575	19.94	13.67	17.32	35.73	29.90	3.38
		IV	22,628	3.470	18.36	12.77	17.08	35.65	31.07	3.43

TABLE F.—THE COMPOSITION OF FEEDS USED IN DIGESTION AND FEEDING TRIALS.

Kind of Feed	Sample Number	Dry Matter	Composition of Dry Matter							
			Crude Protein	Crude Fiber	N-Free Extract	Crude Fat	Ash	Ca	Mg	P
		percent	percent	percent	percent	percent	percent	percent	percent	percent
Alfalfa Hay, No. 1	855	92.93	14.03	33.18	43.73	1.83	7.23	1.317	0.126	0.396
	1211	90.41	15.59	35.20	39.10	1.59	8.52	1.290	.118	.225
Sugarcane Silage	1373	23.93	3.34	39.39	50.78	1.76	4.73	.343	.195	.181
	1374	23.32	3.27	36.98	50.68	2.46	6.61	.365	.242	.167
Sorghum Silage	1377	24.17	3.12	29.30	59.40	3.13	5.05	.211	.254	.175
Cottonseed Meal	856	93.55	41.69	12.24	32.78	7.27	6.02	.230	.172	1.097
	1014	93.44	43.74	9.00	34.27	6.60	6.39	.241	.184	1.121
	1213	89.74	43.11	11.74	30.93	7.53	6.69	.236	.187	1.208
	1375	89.62	43.22	13.33	30.03	6.81	6.61	.241	.161	1.175
	1378	91.12	41.93	14.94	29.43	7.08	6.62	.225	.147	1.149
Grapefruit Refuse	1013	91.77	5.38	13.01	75.84	1.16	4.61	.787	.288	.100
	1376	90.54	5.49	12.28	76.25	1.89	4.09	.689	.352	.097
	1379	89.86	5.64	11.93	75.67	1.77	4.99	.746	.378	.107
Dried Orange Peel	1212	86.05	6.79	12.37	75.24	0.80	4.80	.725	.252	.107

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