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PASSION FRUIT BY-PRODUCTS

Nutritive Values and Utility of Passion Fruit By-Products

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Passion fruit rinds and seeds, by-products of the juice industry, present a serious disposal problem. Experiments involving milch cows, wethers, and rats were conducted to determine the nutritive value of passion fruit by-products as animal feeds. Milk production, feed efficiency, digestion test, and growth data were used as criteria of evaluation. The oil from passion fruit seed was chemically and physically characterized. The by-products were satisfactory for supplementing or supplanting the carbonaceous feedstuffs for dairy cows. The seed oil can also be used to supply the fat requirements of animals.

Commercial processing of juice from the passion fruit (*Passiflora edulis flavicarpa*) (Figure 1) for nectar, sherbet, punches, and other food products has been developed during the past years in Hawaii (*16*, *17*). The fragrantly aromatic and pleasingly tart juice is marketed primarily as a frozen product. Commercial vineyard acreage has grown from practically nothing to approximately 1000 acres (*1*) within the past 3 years. Scott (*15*), after surveying the United States (mainland) market potential, estimated that juice from 5000 acres can be marketed annually.

Approximately one third of the weight of the fruit is juice. The rest is composed of about 90% rind and 10% seeds. The processing of fruit from 5000 acres, with an average yield of 10 tons per acre, will result in an annual production of about 60,000,000 pounds of rind and one ninth as much of seeds. The quantity of by-products presents an economic as well as a disposal problem. Thus, some satisfactory solution for the utilization of the residues is needed by the industry. Sherman, Cook, and Nichols (*17*) explored the possibility of extracting pectin from the rind but found that the market for this product can be supplied more economically by other sources. A preliminary investigation on the utilization of the rind as a feed constituent showed considerable promise (*12*).

Passion fruit rind is high in carbohydrates, low in ether-extractable material, and fair in crude protein. It compares favorably with pineapple bran, which is used chiefly as a carbonaceous feed for diary animals in Hawaii. The seeds yield a clear bland oil of good quality which is characterized by a high linolein content.

The experiments reported in this paper were designed to evaluate the nutritive values of passion fruit rind and seed oil as animal feeds.

Experimental Methods and Procedures

Dehydration of Passion Fruit Rind. Passion fruit rind was passed through a modified beet slicer and chopped into pieces approximately $^1/_2$ to $^3/_4$ inch in length and $^1/_4$ inch in thickness. The sliced pieces were then passed through a rotary alfalfa dehydrator (Heil triple-pass dehydrator) with inlet and outlet temperature ranges of 900° to 1700° F. and 345° to 390° F., respectively. Approximately 15 to 20 minutes were required for the material to pass through the dehydrator. The dried material was collected and stored. Proximate analysis by the AOAC method (*2*) was made on a representative sample of dehydrated rind.

Extraction, Clarification, and Characterization of Passion Fruit Seed Oil. Passion fruit seeds were thoroughly washed, air dried, and crushed by passing through a hand-operated coffee grinder. The oil in the crushed seeds was expressed with a Carver laboratory press. The oil was decolorized by heating to 90° C. with activated carbon. The mixture was centrifuged, and the supernatant oil was filtered through a Büchner funnel.

The physical and chemical constants of the clarified oil were obtained by the AOAC methods, except for the unsaturated fatty acids, which were measured by the ultraviolet spectrophotometric method (*3, 10*).

Nutritive Value of Passion Fruit Rind. The nutritive value of passion fruit rind was measured in terms of milk production and feed consumption. A 12-week, double change-over design of Cochran, Autrey, and Cannon (*4*), was used with 12 Holstein-Friesian cows in different stages of lactation. The animals had calved at least 7 weeks prior to the start of the experiment and were in no more than their 24th week of pregnancy at the end of the experiment. The experiment consisted of three 4-week periods. The first week of each period was allowed for adjustment to minimize the carry-over effects of the previous ratio. The cows in the different groups were kept in separate vegetation-free paddocks.

The chief carbonaceous feed in ration 1 (control ration) was pineapple bran. In ration 2, dehydrated passion fruit rind was substituted for 50% of the pineapple bran. In ration 3, an equal level of pineapple stump residue was used to replace pineapple bran as a comparative feed ingredient. Pineapple bran is composed of the outer shell, core of the fruit, and other canning residues. Pineapple stump residue is the fibrous material remaining after bromelin is extracted from the stump. The composition of these rations is shown in Table I. The concentrates were fed *ad libitum* in sheltered community bunkers. In addition, chopped Napier grass (*Pennisetum purpureum*) was made available to limit of appetite. Water was available at all times except during the milking period.

Individual weights of cows were recorded at the beginning and at the end of each period for 3 consecutive days. Complete records were maintained on milk production. Milk yields were expressed as 4% fat-corrected milk (7).

Digestion Coefficients of Passion Fruit Rind. Four wethers were transferred from a paved feedlot to metab-

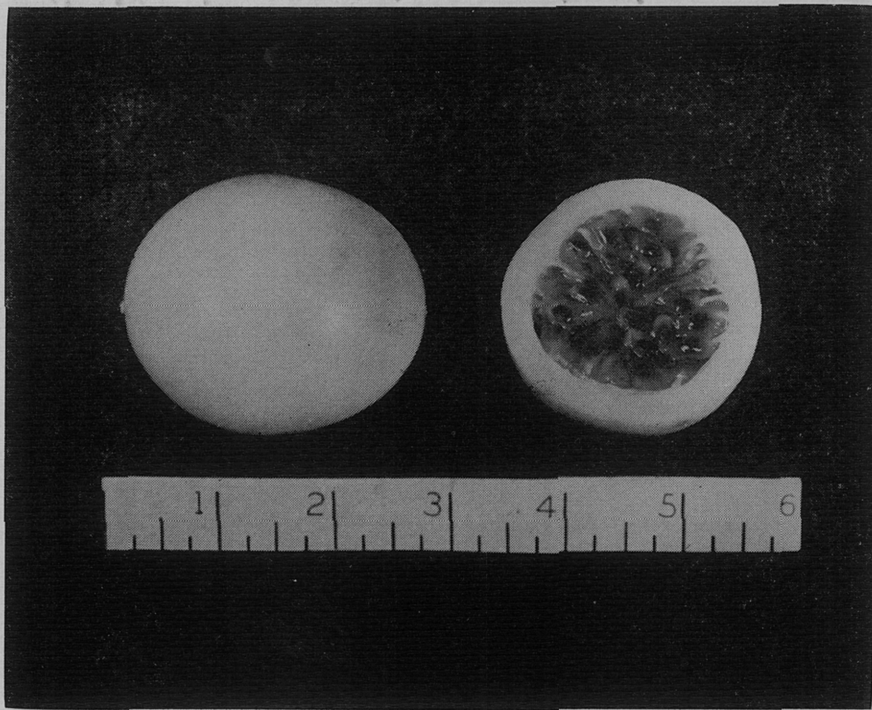

Figure 1. Passion fruit and section showing seed cavity. Seeds are enclosed in juice sacs. Rind is covered by hard coating

Table I. Composition of Concentrate Rations

Feed Ingredient	Rations 1	2	3
Passion fruit rind	...	22.0	...
Pineapple bran	44.0	22.0	22.0
Pineapple stump residue	...	...	22.0
Cane molasses	25.0	25.0	25.0
Soybean oil meal	20.0	20.0	20.0
Alfalfa pellets	7.0	7.0	7.0
Stabilized beef tallow	2.0	2.0	2.0
Salt	1.0	1.0	1.0
Steamed bone meal	1.0	1.0	1.0
Total	100.0	100.0	100.0
Calculated			
Total digestible nutrients	67.7	67.7	67.7
Digestible crude protein	8.6	9.0	8.6

Table II. Composition of Passion Fruit Rind, Pineapple Bran, and Pineapple Stump Meal

	Passion Fruit Rind, %	Pineapple Bran, %	Pineapple Stump, %
Moisture	16.80	13.64	13.00
Crude protein	4.58	3.79	2.80
Ether extract	0.33	1.94	1.00
Ash	6.76	2.59	7.00
Crude fiber	25.66	19.83	25.00
Nitrogen-free extract	45.87	58.49	51.20
Pentosans	15.70	10.50	...
Lignin	6.50	6.70	7.50
Pectin	20.00	...	...

olism cages and fed dehydrated passion fruit rind exclusively for 20 days. Feed intake was adjusted to a constant level in order to eliminate feed weighbacks. The sheep were fed once a day and given water twice a day. Trace-mineralized salt was available at all times.

Fecal samples were collected for 10 days after a preliminary feeding period of 10 days was allowed for the elimination of feed residues from the previous ration and for rumen microbial adjustment. The collected material was oven-dried, ground, and stored for analysis.

Nutritive Value of Passion Fruit Seed Oil. The nutritive value of passion fruit seed oil was evaluated on the basis of growth performance of rats. An oil–skim milk diet similar to that of Deuel (*5*) was used. Twenty per cent passion fruit seed oil and 80% mineralized skim milk was compared with a control diet of 20% cottonseed oil and 80% mineralized skim milk. Both rations were supplemented with fat-soluble vitamins.

Two groups of nine albino rats, each group consisting of five males and four females, were fed the oil–skim milk ratios *ad libitum* for 6 weeks. Each animal was kept in a separate cage. Weekly weight and feed-consumption data was kept.

Digestion Coefficient of Passion Fruit Seed Oil. The digestion coefficient of passion fruit seed oil was determined by the method of Deuel (*6*). The same nine albino rats and diet used for the study of the nutritive value of passion fruit seed oil were used for this experiment; therefore, a preliminary adjustment period was not necessary. The feces were collected for 9 days, then the oil in the diet was replaced with an equal quantity of sucrose. After a 3-day adjustment period, feces were again collected for 9 days. The feces were oven-dried, ground, and analyzed for fats and oils.

Table III. Chemical and Physical Constants of Passion Fruit Seed Oil

Specific gravity (25° C.)	0.9208
Refractive index (25° C.)	1.5729
Saponification number	191.3
Iodine number	137.5
Reichert-Meissl number	0.17
Polenske number	0.25
Thiocyanogen number	84.2
Acetyl number	14.9
Unsaponifiable matter	0.77
Fatty acids, %	
Arachidonic	0.9
Linolenic	2.6
Linoleic	67.5
Oleic	13.0
Saturated	16.0

Results

Passion fruit rind contained 12 to 15% moisture as it came out of the dehydrator. Dry matter represented about 17% of the original rind. It had a high quantity of carbohydrates and fiber and a low quantity of ether extractable materials as shown in Table II. The figures for passion fruit represent determinations of a composite sample collected periodically as the dried rind emerged from the dehydrator. The analyses of pineapple bran and pineapple stump are given in the same table. The rind contained a fair quantity of pentosans and the presence of flavonoids was also established.

The chemical analysis of the passion fruit seed oil gave an iodine number of 137. The unsaturation is due primarily to a high linolein content. This gives the oil some drying quality. Some chemical and physical constants of the oil are shown in Table III. The percentage of total saturated fatty acids was calculated by difference.

Dehydrated passion fruit rind was highly palatable when incorporated into the ration of the milch cow at a level of 22%, as indicated by the consumption data presented in Table IV. The mean daily feed consumption was 27.8, 31.0, and 24.6 pounds per animal per day for ration 1 (pineapple bran), ration 2 (passion fruit rinds), and ration 3 (pineapple stump meal), respectively. Concomittant Napier grass intake averaged 16.6, 18.0, and 19.0 pounds per animal per day.

Table IV. Average Daily Feed Consumption, Nutrient Intake, and Milk Yield

	Pounds		
	Ration 1	Ration 2	Ration 3
Concentrates consumed	27.8	31.0	24.6
Napier grass consumed	16.6	18.0	19.0
Total digestible nutrients required[a]	22.8	22.8	22.8
Total digestible nutrients consumed	18.8	21.0	16.7
Total digestible protein required[a]	2.8	2.8	2.8
Total digestible protein consumed	2.4	2.8	2.1
4% fat-corrected milk yield	38.0	39.7	37.0

[a] Nutrient requirements (upper levels) for 1300-lb. cow producing 40 lb. of 4% milk according to Morrison's feeding standards (*11*).

Table V. Coefficients of Digestibility of Dehydrated Passion Fruit Rind

Nutrient	%
Crude protein	45.23
Ether extract	6.38
Crude fiber	76.42
Nitrogen-free extract	84.92
Total digestible protein	2.07
Total digestible nutrients	60.70

The results showed significant difference ($P = 0.05$) in milk production between cows fed passion fruit rind and those on pineapple stump. No difference was found between passion fruit rind and pineapple bran. Persistency in milk production for the experimental cows was 76.5, 80.8, and 79.1% for rations 1, 2, and 3, respectively, when compared with milk production at the start of the experiment.

All animals maintained body weights throughout the experiment, with the exception of two animals troubled with tender feet due to constant exposure to muddy pens.

The average apparent coefficients of digestibility for the various components of dehydrated passion fruit rind are shown in Table V. Palatability was good as evinced by the fact that the ration consisting solely of passion fruit rind was consumed even after 20 days. The results of the digestion data between animals were uniform with the exception of the ether extract. The variability in ether extract digestibility may have been due, at least in part, to the very low amount (0.33%) of ether-extractable material found in the rind.

Passion fruit seed oil was utilized as well as cottonseed oil by growing rats. There was no indication that it contained any toxic or growth-inhibiting substance. The relative growth performance of the animals of the two groups are shown in Table VI. The data are expressed in terms of weight gained in grams per

Table VI. Ratio of Gain to Food Intake of Albino Rats Grown on Oil–Skim Milk Diet

Oil	Weeks 1	2	3	4	5	6
Male						
Passion fruit seed	0.62	0.53	0.47	0.39	0.39	0.27
Cotton seed	0.59	0.47	0.42	0.39	0.40	0.27
Female						
Passion fruit seed	0.50	0.41	0.39	0.28	0.28	0.24
Cotton seed	0.56	0.44	0.43	0.27	0.24	0.21

gram of feed consumed per week. The oil of passion fruit seed was found to be highly digestible. The average coefficient of digestibility was 98.4%. There was no more than 0.4% difference between any of the values.

Discussion

The passion fruit is berry-like and often called granadilla or water lemon. The rind is composed predominantly of spongy tissues and is similar to citrus peel except for its smooth, thin, hard outer coating. Passion fruit rind is easily dehydrated, as it requires no pretreatment with lime, as in the case of orange peel, even though passion fruit rind contains approximately 20% pectin (*17*). This difference in drying quality may be due to the high fiber content and low ether extractable material.

The nitrogen content of the rind varies considerably—from 1.22 to 3.50% in one fertilization experiment (*18*). Passion fruit rind can probably accumulate a considerable quantity of nonprotein nitrogen.

For milch cows, there is no difficulty in formulating a satisfactory ration with dehydrated passion fruit rind. In the experiment reported here, only 50% of the pineapple bran in the ratio was replaced with passion fruit rind. Complete replacement may be possible in view of the ready acceptance of the products by the animals. Higher milk production appears to have been possible if the total intake of digestible nutrients and digestible protein had been greater as shown in a later investigation (*13*).

The coefficients of digestibility of the various nutrients of passion fruit rind compare favorably with citrus pulp and pineapple bran. The apparent digestibility of proteins in passion fruit rind is approximately three times greater than that of proteins in pineapple bran.

MacDougall and DeLong (*9*) reported that the initial drying temperature affects the lignin yield of plant tissues. This was also true in the dehydration of passion fruit rind. Rinds dehydrated at a low temperature on a laboratory scale contained only a small quantity of lignin, while those processed in a commercial dehydrator at a higher temperature showed two- to threefold higher lignin content.

There is some charring when the rinds are dehydrated at high temperatures. With improvement in the dehydrating procedure the digestibility of the rinds should increase. The greatest benefit is expected to be gained in the carbohydrates fraction.

The physical and chemical characteristics of the oil from the yellow passion fruit (*Passiflora edulus flavicarpa*) seed and the purple passion fruit (*Passiflora edulis*) seed are similar (*8*). The oil can be used satisfactorily as food, as its feeding value and digestibility compare favorably with cottonseed oil. Pruthi and Girdhari (*14*) have also demonstrated the digestibility of the ether-extractable substances to be in excess of 98%, although in their work the oil was used at a 5% level. The seed "press cake" or residue remaining after the oil had been expressed is unsuitable for feeding purposes as it contains approximately 60% fiber and 30 to 35% lignin.

The conversion of passion fruit rind into ruminant feedstuff offers an excellent possibility for solving the by-product disposal problem of the juice industry. The suggested utilization of the passion fruit by-products does not require any change in the feeding practices of the dairymen.

The major factor in determining the usefulness of this approach to the problem appears to be the cost of processing the by-products. This is not insurmountable as the dehydration process may be eliminated by the use of other methods of preservation. Laboratory-scale ensiling studies showed that good quality silage can be produced.

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