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Nutritional Value of Agricultural By-Products of the Hawaiian Islands to Be Used as Animal Feeds

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Introduction

The increasing demand for corn and other grains for international trade and conversion into ethanol and biodiesel has caused a dramatic rise in the price of feed for livestock production in the United States. Due to limited land availability in Hawai'i, the use of large parcels of agricultural lands for production of grain for animal feed is economically unfeasible. As a result, local swine and poultry producers are forced to rely on expensive imported feed. Due to this mounting cost, the number of livestock producers in Hawai'i is on the decline. We have determined the nutritional value of some of the local feedstuffs such as macadamia nut cake, cassava root chips, cassava silage, taro, wheat millrun, barley brewer's grain, okara, and sweet potato, be used in animal rations (Tiwari and Jha 2015, 2016, 2017). In addition, large numbers of other alternative products are being evaluated as potential feedstuffs for swine and poultry.

At the same time, wet food waste disposal in Hawai'i is generating dangerously high levels of methane gas in local landfills and is becoming a public health nuisance in many Hawai'i counties. The use of wet food waste as feed may present a solution to the feed problems for local livestock producers as well as mitigate the negative environmental effects on local landfills. This practice has been extensively used in the past and continues, though on a lesser scale, to be used in the present day. The feeding of food waste to swine is an approved practice throughout the state of Hawai'i as long as the waste is 1) heat treated by boiling (100°C at sea level) for thirty minutes and 2) agitated during cooking as mandated by the 1980 Swine Health Protection Act. Properly processed and nutritionally balanced cooked food waste for hog production may provide a remedy for Hawai'i's dependency upon expensive imported concentrate feeds, as it has for certain farmers. Fruit, vegetable, and root crops play an important role as staples in the human diet in the Islands. These foods generate a wide range of potential by-products and residues from food crops that are often underutilized or wasted. This fact sheet provides practical nutrient information for producers to help develop an economically and nutritionally balanced animal ration using local feedstuff available in Hawai'i.

Nutrition plays an important role in the health and productivity of agricultural animals. Providing proper nutrition management involves more than purchasing a bag of feed or putting animals on pasture. The producer should be knowledgeable about the fundamentals of animal nutrition, physiology, and husbandry. The six most important groups of nutrients are water, protein, carbohydrates, fats, minerals, and vitamins. The nutritional needs of the animal will vary according to different life stages such as age, pregnancy, and usage. By understanding the nutritional requirements of an animal and how the digestive system functions, this will enable producers to manufacture a balanced ration. The utmost goal of any animal producer is an economical balanced ration that convenes with the animal's nutritional requirements.

Balancing Rations Using the Pearson Square

It is very important to work on a uniform basis. Use a 100% dry-matter basis for nutrient composition of ingredients and requirements and then convert to an as-

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fed basis after the formulation is calculated.

The Pearson's Square or box method is a simple, quick way to calculate the amounts of feed necessary to meet a nutrient requirement of livestock and other animals. This method is the most effective when only two feeds are being used. For example, when two grains are mixed for part of a total mixed ration (TMR) or as a supplement to pasture feeding, a Pearson's Square can be used to determine what quantity of each component would be needed to achieve a specific nutrient percentage in the mixture.

Several numbers are in and around the square. One of the most important numbers is the number that appears in the middle of the square. This number represents the required percent of an animal for a specific nutrient. Subtracting the nutrient value from the nutritional requirement on the diagonal and gives a numerical value entitled parts. Disregard any negative numbers calculated on the right side of the square. Treat them as positive numbers. Summing those parts and dividing by the total gives the percent of the ration that each ingredient should represent in order to provide a specific nutrient level.

- Use 100% dry matter
- Put required amount in center
- Put ingredients on side
- Subtract on the diagonal (ignore negative numbers)
- Divide by total parts
- Multiply by 100 to find percentage

This example shows Pearson's Square being used to determine the ratio of grain to supplement to create the 16% protein ration needed in our example. Pearson's Square shows that you need to mix 85% grain with 15% of the protein supplement to make a 16% protein grain ration.

Developing Feeding Trials

As a rule of thumb, most animal feeding trials should be conducted on farms, since the objectives are usually to test interventions in a situation where conditions of management and resource availability are typical of the

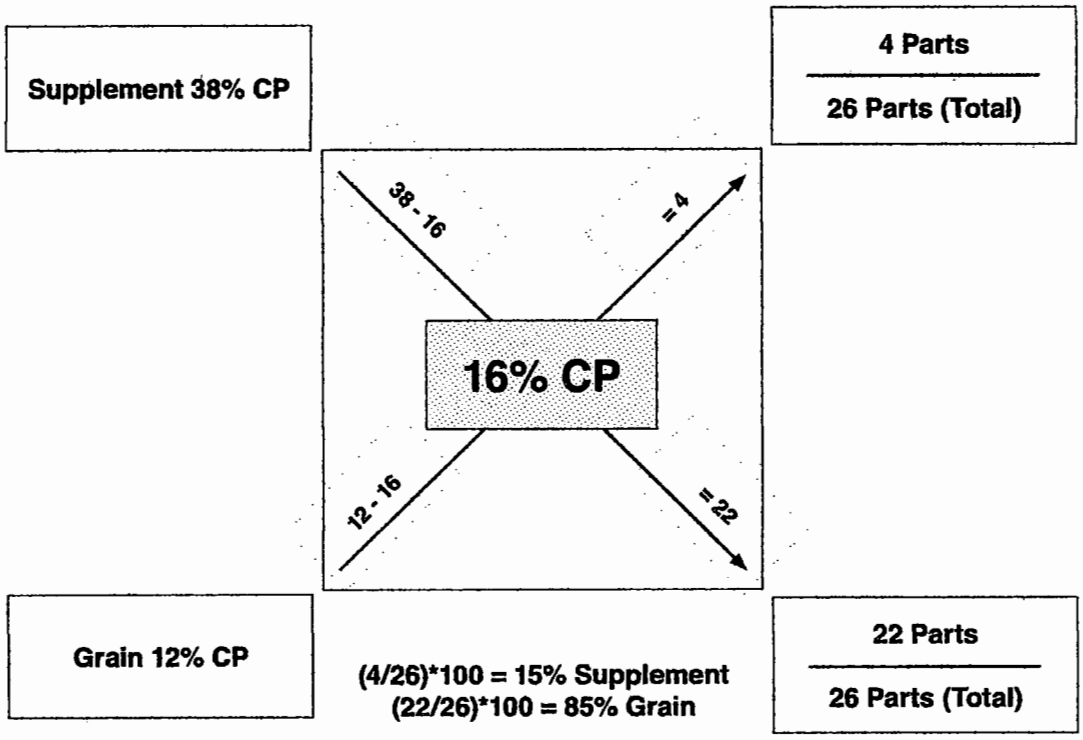

Fig. 1. Pearson's Square calculation of amounts of feed necessary for livestock.

real-life farmer situation. The farm and the farmers serve as a forum for discussions of practical problem solving and provide the appropriate setting for participatory adaptation of technologies. By contrast, experiments performed on a research station will have the aim of studying new feed resources in-vitro under controlled environments (e.g., with the nylon bag method of assessing rumen degradation potential). Both approaches serve a function when conducting animal feedstuff trials.

Experiments on Farms

There are four main activities that on-farm experiments should facilitate before starting a nutrition trial:

- Economic evaluation of an intervention (e.g., use of molasses–urea blocks for cattle or use of molasses in the fermentation process of silage).
- Biological and economic assessment of a nutritional manipulation (e.g., defining a response curve for a given nutritional input or feedstuff)
- Demonstration of appropriate technologies (e.g., bio-digesters, dehydration of feedstuff, or silage making).
- Establishing a forum for discussion for planning joint participatory activities and as an interface between farmers and scientists (demonstration farms, field days).

Standard Operating Procedures When Conducting an Alternate Feeds Swine Trial

Weighing Animals

All animals will be initially weighed and randomly assigned by weight and sex to two treatment groups, control and test ration. During the trial, animal weights will be taken every two weeks. All animals will be started at a given initial weight (20kg) and grown out to 100kg in a 16-week trial.

Pre-Trial Feeding

The test ration will be gradually introduced over 10 days to those animals in treatment groups receiving the alternate feed, replacing a larger portion of their commercial swine ration each day. The feed will be weighed and fed to the animals at the rate of 3% of body weight once a day, and water will be available *ad libitum*. Each day, any uneaten food will be collected and weighed to determine maximum consumption.

Table 1: Feed Protein Levels Required by Swine Ration

Life stage	Protein %
Creep feeding (piglet)	18–20%
Growing (50–125 lbs)	15–16%
Finishing (125–240 lbs)	13–14%
Young gilts-boars	15–16%
Older sows-boars	13–14%

Table 2: Approximate Daily Water and Feed Consumption (In Pounds)

Pig	Water	Dry Feed
50	8.0	4.0
100	11.0	5.5
150	14.0	7.0
200	17.0	8.5
250	20.0	10.0

Note: 8 pounds of water is about one gallon.

Table 3: Dietary requirements for trace minerals (in mg)[a]

	Piglet	Growing Pig	Finishing Pig	Breeding Sow
Minerals	**Body weight (lb)**			
	< 20	**50–125**	**125–240**	**240+**
Zinc	100	60	50	50
Manganese	4	2	2	20
Iron	100	60	50	80
Copper	6	4	4	5
Iodine	0.14	0.14	0.14	0.14
Selenium	0.30	0.15	0.15	0.15

[a]Values represent the highest value quoted by NRC (2012) 90% dry matter

Table 4: Dietary requirements for vitamins[a]

Vitamins	Body Weight (lb)						
	11–15.5	15.5–24	24–55	55–110	110–165	165–220	220+
Vitamin A (IU/kg)[i]	2,200	2,200	1,750	1,300	1,300	1,300	1,300
Vitamin D (IU/kg)[i]	220	220	200	150	150	150	150
Vitamin E (IU/kg)[i]	16	16	11	11	11	11	11
Vitamin K (menadione, mg/kg)	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Vitamin B_6 (mg/kg)	7.00	7.00	3.00	1.00	1.00	1.00	1.00
Vitamin B_{12} (mcg/kg)	20.00	17.50	15.00	10.00	5.00	5.00	5.00

[a] Because of the variability of vitamins in natural swine feedstuffs and the relatively low cost of commercial vitamins, it is recommended that producers provide the following vitamins completely from the vitamin premix and disregard amounts in the feed.

Trial Feeding

As during the pre-trial period, the feed will be weighed and fed to the animals at the rate of 3% of body weight once a day; water will be available *ad libitum*. Each day, any uneaten food will be collected, weighed, and sampled for nutrient analysis.

Animal Observation

Animals will be observed daily for signs of sickness or stress. Weight changes will be assessed after each weighing, and feed will be adjusted if weight loss is greater than 5%. If any animal is observed not to be eating for 48 hours, it will be removed from the trial and, if receiving the test ration, put back on commercial swine ration, and the veterinarian will be called if the animal does not resume feeding within 4 hours.

Feed Preparation and Storage of Test Ration

The test ration should be stored in plastic covered barrels and sub-sampled daily as it is weighed out for feeding. The feed sample will be submitted for nutrient analysis. Only the amount of feed needed for 10–14 days will be prepared per batch to ensure that it is fed and consumed before shelf life expires.

Conclusion

The greatest part of a livestock ration is made up of protein and energy, for which animals have the highest demands if they are to remain healthy, grow strong, and be productive. The Pearson Square is a fast and simple way to calculate the desired amount of crude protein or energy for a mixed ration using basic math. However, one disadvantage is that the method does not account for vitamins or minerals of a feedstuff being tested and incorporated in a total mixed ration. The benefits of using a balanced ration far outweigh the disadvantages, but each farm has different goals and capabilities that may or may not adapt well. Feed cost can be reduced by replacing some of the high-priced grains with local agricultural by-products. However, each by-product should be analyzed to see how well it can serve as an alternative to some imported grain replacement when creating locally produced feeds. It would be valuable for a livestock producer to experiment with a free and user-friendly ration-balancing program in order to create a least-cost ration. Since grain prices will likely continue to increase in price, as they have done recently, it may be the only way to remain profitable in the future. For more information, contact your local Extension office.

Table 5. Nutrient profile of common agricultural products in Hawai'i (on dry-matter basis)

Feed Ingredient	Dry Matter %	Ash	Crude Protein	Crude Fat	NDF	ADF	Lignin	Cellulose
Albizia fodder	48.77	4.49	9.58	1.77	69.60	36.23	8.89	6.87
Avocado leaves	44.57	1.78	11.47	2.12	58.46	49.95	29.09	20.87
Bamboo leaves	49.46	7.42	12.41	1.82	71.05	45.68	15.81	29.87
Banana fruit	20.41	0.96	3.78	11.08	14.26	12.65	7.82	7.63
Banana stumps	8.25	0.50	2.08	2.13	56.83	26.80	5.65	6.68
Breadfruit fruit	9.66	0.53	16.20	6.49	40.00	33.14	9.90	23.24
Breadfruit leaves	24.96	2.97	12.54	3.45	43.06	32.66	11.05	21.61
Cecropia	27.51	2.64	16.28	2.99	50.23	43.29	22.75	20.55
Ginger	16.92	1.71	13.31	5.78	59.09	27.61	7.16	20.45
Gorse	91.56	3.07	9.77	1.65	63.72	39.33	14.77	24.56
Gorse + oats	87.57	2.55	9.46	2.01	54.03	32.79	13.15	19.64
Gorse + oats + corn	86.82	1.66	12.38	0.73	29.03	10.18	3.15	7.03
Grass (Hawn dutch dairy)	35.70	2.71	7.90	1.77	68.43	40.89	10.89	8.34
Grass- upper leaf	94.45	7.92	6.84	1.29	66.31	36.38	14.72	21.66
Grass stem, lower Leaf	94.62	5.09	2.12	0.63	71.18	47.08	15.43	31.64
Guava leaves	39.09	2.35	8.16	5.32	54.28	53.74	32.77	20.97
Gunpowder leaves	34.53	6.21	13.84	4.84	44.81	38.46	19.52	18.94
Hau leaves	32.14	2.98	12.93	4.47	53.97	44.65	20.18	24.48
Hibiscus	20.68	2.57	9.79	4.35	34.31	23.29	7.69	15.60
Honohono grass	13.89	1.51	10.33	2.54	51.82	33.08	8.27	24.81
Kalo leaves (lu'au)	11.65	1.52	28.47	6.77	40.20	24.28	7.38	16.90
Kukui leaves	29.87	3.29	16.03	3.82	50.60	47.22	25.03	22.19
Leucaena	35.63	1.58	24.60	2.01	45.42	28.44	11.50	16.95
Melochia	27.31	2.35	16.21	3.18	37.63	32.64	16.95	15.69
Moringa leaves	20.46	1.61	NA	4.83	23.29	15.19	4.88	10.31
Mulberry leaves	43.55	3.62	15.96	3.20	38.63	26.29	7.60	18.69
Noni fruits	10.27	0.46	5.40	6.18	25.91	24.27	6.05	18.21
Noni leaves	18.95	1.25	17.02	5.13	35.03	24.05	11.79	12.25
Papaya	11.47	0.64	9.61	6.56	17.21	16.35	5.94	8.07
Sugarcane	28.44	0.71	4.32	1.96	64.67	37.15	8.72	28.43
Sweetpotato mix	84.58	3.38	9.75	2.41	46.45	5.50	1.06	0.90
Sweetpotato	45.66	1.71	3.69	1.23	48.38	4.25	0.81	0.71
Sweetpotato vines	11.92	1.68	21.50	4.05	47.58	30.29	10.37	19.92
Ti leaves	25.18	1.53	13.35	6.98	38.63	28.21	8.70	19.51
Trefoil	15.06	1.03	19.08	3.17	60.67	35.41	11.28	24.13

Table 6. Nutrient profile of common byproducts in Hawai'i (on dry-matter basis)

Feed Ingredient	Dry Matter %	Ash	Crude Protein	Crude Fat	NDF	ADF	Lignin	Cellulose
Algal	92.26	12.67	33.48	1.87	36.14	8.87	5.32	3.55
Brown rice	88.04	1.31	9.57	4.21	11.81	2.36	0.78	1.58
Chicken feed	71.35	24.52	13.65	5.63	48.17	26.11	21.35	1.48
Grain	89.25	5.44	16.63	5.23	34.13	10.01	2.44	1.97
IMO	81.91	22.45	13.39	0.88	39.44	18.14	9.18	5.60
IMO4 garbage	69.87	4.85	19.63	5.64	38.81	16.27	9.07	6.51
Macadamia nut	88.02	0.99	3.88	12.11	77.28	63.86	40.84	28.13
Macadamia nut w/ grain	90.61	3.43	12.90	11.56	45.17	24.33	12.83	11.50
Macadamia meal	90.47	1.28	6.68	10.43	65.69	55.55	36.26	19.29
Macadamia meal (Pacific Biodiesel Tech.)	95.74	4.18	27.21	20.51	24.98	22.97	9.06	13.92
Macadamia sludge	93.52	1.68	7.65	64.58	38.30	44.05	23.91	20.14
Mill run	85.03	4.04	18.49	0.86	42.82	9.70	2.88	6.82
Mixed feed (dry) (oats, corn, mill run)	79.88	2.47	13.98	2.97	35.00	8.81	2.57	2.45
Silage (oats, corn, mill run)	34.10	1.38	11.55	3.63	31.79	12.78	3.88	5.80
Silage (oats, corn, mill run) w/ soldier fly grubs, green/brown grass, banana stump	36.00	1.19	15.54	3.62	56.13	33.25	8.47	7.09
Silage (oats, corn, mill run) w/ banana	30.89	1.19	11.09	2.88	37.45	15.20	5.73	9.48
Silage (oats, corn, mill run) w/ banana stump	25.61	0.95	11.32	3.26	41.40	17.28	4.14	8.71
Silage (oats, corn, mill run) w/ fresh green grass	39.03	1.23	15.33	4.23	41.52	17.18	3.66	3.10
Silage (oats, corn, mill run) w/ brown grass	37.71	1.14	12.98	2.76	60.21	35.03	7.73	6.17
Silage (oats, corn, mill run) w/ green/brown grass, banana stump	38.02	1.12	14.18	3.13	55.53	32.68	8.32	6.82
Mixed silage (grass and corn)	35.92	1.38	12.23	3.33	36.49	14.13	4.78	3.85
Mixed silage (corn)	42.91	1.19	12.62	3.82	36.44	12.59	3.78	3.47
Corn silage	27.15	1.06	8.60	4.62	43.58	19.89	4.57	4.05
Silage (oats, corn, mill run) w/ sweetpotato	32.82	0.94	7.98	1.57	28.89	9.38	2.43	6.95
Sweetpotato silage mix	83.48	3.81	6.50	1.75	42.29	3.84	0.69	0.56
Sweetpotato silage	80.18	1.59	3.64	1.25	41.28	3.23	0.63	0.55

Table 7. Mineral content of common agricultural products in Hawai'i (on dry-matter basis)

Feed Ingredient	P	K	Ca	Mg	Na	B	Cu	Fe	Mn	Zn
Albizia fodder	0.45	0.39	0.51	0.13	0.15	5.00	6.00	154.00	75.00	8.00
Avocado leaves	0.16	0.39	1.04	0.43	0.03	50.00	14.00	37.00	27.00	NA
Bamboo leaves	0.14	0.61	0.43	0.49	0.01	7.00	6.00	53.00	382.00	282.00
Banana fruit	0.08	1.69	0.04	0.16	0.00	8.00	7.00	21.00	9.00	9.00
Banana stumps	0.12	2.46	0.58	0.70	0.08	13.00	3.90	62.60	56.80	15.40
Breadfruit fruit	0.30	1.78	0.32	0.33	0.01	17.00	9.00	53.00	6.00	
Breadfruit leaves	0.16	1.06	2.02	0.94	0.04	72.00	4.00	51.00	23.00	NA
Cecropia	0.19	0.83	1.11	0.38	0.04	23.00	8.00	63.00	51.00	17.00
Ginger	0.43	1.50	0.98	1.25	0.01	12.00	6.00	71.00	234.00	NA
Gorse	0.19	1.04	0.48	0.19	0.05	14.00	4.00	226.00	48.00	38.00
Gorse + oats	0.28	0.79	0.44	0.20	0.07	11.00	5.00	166.00	48.00	35.00
Gorse + oats + corn	0.36	0.63	0.13	0.16	0.02	6.00	4.00	74.00	28.00	47.00
Grass (Hawn dutch dairy)	0.16	1.41	0.52	0.41	0.25	9.50	5.30	134.70	148.50	31.40
Grass- upper leaf	0.24	1.71	0.36	0.51	0.01	4.00	10.00	31.00	353.00	267.00
Grass stem, lower leaf	0.16	0.70	0.27	0.53	0.03	3.00	7.00	16.00	376.00	223.00
Guava leaves	0.11	0.49	1.42	0.55	0.02	30.00	8.00	58.00	57.00	NA
Gunpowder leaves	0.20	0.90	3.14	0.73	0.02	45.00	5.00	79.00	129.00	NA
Hau leaves	0.20	0.37	2.16	1.60	0.10	49.00	8.00	65.00	78.00	199.00
Hibiscus	0.83	1.35	5.50	0.62	0.27	50.00	4.00	79.00	38.00	107.00
Honohono grass	0.37	2.14	1.06	0.72	0.05	17.00	5.00	39.00	86.00	161.00
Kalo leaves (lu'au)	0.59	3.97	1.51	0.35	0.01	31.00	10.00	79.00	168.00	NA
Kukui leaves	0.26	0.99	2.10	0.94	0.04	24.00	5.00	85.00	93.00	NA
Leucaena	0.23	0.79	0.81	0.27	0.03	55.00	5.00	56.00	61.00	98.00
Melochia	0.30	2.27	1.76	0.38	0.03	43.00	9.00	76.00	59.00	197.00
Moringa leaves	0.29	2.35	1.04	0.31	0.05	37.00	6.00	73.00	32.00	NA
Mulberry leaves	0.30	1.07	1.40	0.43	0.03	39.00	4.00	48.00	31.00	110.00
Noni fruits	0.16	1.25	0.43	0.27	0.22	16.00	9.00	33.00	17.00	NA
Noni leaves	0.17	0.89	1.61	0.71	0.82	25.00	6.00	55.00	60.00	NA
Papaya	0.21	2.11	0.26	0.20	0.04	16.30	25.50	45.73	16.73	18.45
Sugarcane	0.07	0.78	0.28	0.20	0.02	4.00	5.00	31.00	27.00	NA
Sweetpotato mix	0.35	0.73	0.31	0.17	0.21	5.00	13.00	49.00	62.00	54.00
Sweetpotato	0.14	0.76	0.09	0.09	0.12	7.64	6.29	822.70	22.93	26.14
Sweetpotato vines	0.36	2.94	1.53	0.54	0.27	59.00	8.00	85.00	31.00	NA
Ti leaves	0.27	0.92	1.65	0.57	0.01	19.00	7.00	54.00	62.00	NA
Trefoil	0.21	0.75	0.97	0.43	0.16	20.00	6.00	99.00	50.00	348.00

Table 8. Mineral content of common byproducts in Hawai'i (on dry-matter basis)

Feed Ingredient	P	K	Ca	Mg	Na	B	Cu	Fe	Mn	Zn
Algal	0.70	0.35	0.30	0.52	0.48	6.00	11.00	6088.00	98.00	727.00
Brown rice	0.47	0.41	0.01	0.22	0.00	3.00	4.00	31.00	56.00	134.00
Chicken feed	0.49	0.70	1.50	0.41	0.15	15.33	37.30	3439.67	129.00	65.67
Grain	0.60	0.80	0.79	0.28	0.51	4.00	22.00	90.00	124.50	121.50
IMO	0.36	0.77	0.10	0.49	0.01	0.00	30.30	24243.70	359.30	56.30
IMO4 garbage	0.57	1.07	0.29	0.48	0.20	11.40	12.90	1371.50	172.14	156.86
Macadamia nut	0.08	0.36	0.07	0.06	0.03	5.62	6.38	217.31	34.77	10.69
Macadamia nut w/ grain	0.40	0.78	0.63	0.23	0.19	5.33	50.00	258.67	285.33	121.00
Macadamia meal	0.11	0.39	0.05	0.08	0.01	8.00	7.00	45.00	34.00	13.00
Macadamia meal (Pacific Biodiesel Tech.)	0.54	1.27	0.17	0.35	0.35	29.00	14.00	93.00	86.00	48.00
Mill run	0.95	0.89	0.08	0.41	0.01	3.00	9.50	265.50	127.00	72.00
Mixed feed (dry) (oats, corn, mill run)	0.66	0.78	0.06	0.31	0.01	2.00	7.50	105.30	91.00	52.30
Silage (oats, corn, mill run)	0.42	0.55	0.15	0.23	0.03	4.20	9.60	1465.10	69.22	56.00
Silage (oats, corn, mill run) w/ soldier fly grubs, green/brown grass, banana stump	0.53	1.92	0.82	0.62	0.06	10.50	10.50	942.50	144.00	69.00
Silage (oats, corn, mill run) w/ banana	0.41	0.99	0.10	0.25	0.02	5.00	8.00	1656.50	65.50	44.50
Silage (oats, corn, mill run) w/ banana stump	0.51	0.99	0.20	0.34	0.02	5.80	6.80	689.00	73.00	45.00
Silage (oats, corn, mill run) w/ fresh green grass	0.65	1.20	0.18	0.46	0.01	6.00	9.00	600.00	121.50	53.50
Silage (oats, corn, mill run) w/ brown grass	0.38	1.24	0.38	0.66	0.01	7.50	8.00	817.50	142.00	55.50
Silage (oats, corn, mill run) w/ green/brown grass, banana stump	0.57	1.44	0.30	0.65	0.02	8.00	7.50	532.50	125.50	55.50
Mixed silage (grass and corn)	0.51	0.46	0.13	0.33	0.02	4.00	10.00	1513.50	114.50	115.50
Mixed silage (corn)	0.52	0.59	0.08	0.25	0.01	3.50	7.00	40.50	75.50	52.50
Corn silage	0.35	0.82	0.18	0.21	0.02	5.00	8.00	1264.30	61.25	44.50
Silage (oats, corn, mill run) w/ sweetpotato	0.28	0.55	0.08	0.14	0.04	4.00	6.00	1064.00	40.00	33.00
Sweetpotato silage mix	0.21	0.82	0.16	0.11	0.15	5.00	16.00	44.00	27.00	23.00
Sweetpotato silage	0.14	0.80	0.10	0.10	0.13	5.00	6.00	77.00	16.00	8.00

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