The Foothills Farm Fermented Feed Study

Quantifying the impact of feed hydration and fermentation on poultry nutrition and farm economics

A Farmer-Rancher project funded by Western SARE
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Final report

Abstract

Feed is the single largest cost in poultry-raising, including in pastured flocks. Small and mid-scale producers, many of whom use higher-priced specialty feeds, need strategies to minimize feed wastage and maximize flock performance. Fermented feed may help to address both these concerns, but there is little information available to help farmers weigh costs against the prospective benefits of fermented feed relative to dry feed for commercial pastured poultry. In this study, we carried out a rigorous on-farm feeding trial using pastured laying hens to compare the performance of (i) Dry, (ii) Hydrated and (iii) Fermented poultry feeds. Trial design was a Latin Square design with three replicates of ten hens per treatment. Feed consumption and egg production were measured and used to calculate dry-basis feed consumption and a feed efficiency index (grams feed per marketable egg) at regular intervals between 3 March and 9 October 2019. Results show that hens fed with a Fermented diet laid 9% more eggs over the year than hens on a Dry diet, while hens on a Hydrated diet laid 11% fewer eggs. Fermented- and Dry-diet birds consumed similar amounts of feed, resulting in significantly smaller feed per egg values in the Fermented-diet group. Birds on all three diets consistently produced USDA Extra-Large grade eggs. An economic model was assembled from feed consumption and egg production data generated in the experiment, together with labor requirements estimated from Foothills Farm's experience of providing wet and dry feed to its commercial flock. The model indicated that the Fermented feed system was the most profitable owing to greater egg production, despite extra labor costs. Results from this study represent the first quantitative on-farm data relating to feed fermentation for poultry.

1. Background

Feed is the single largest cost in poultry-raising, including in pastured flocks (Vaillancourt 2013). Organic or other specialty feeds are typically the most costly of all; but such feeds are preferred by many small and mid scale producers trying to improve their environmental and social sustainability, optimize flock health and connect with the growing number of consumers who share the same concerns (Agricultural Marketing Resource Center 2017). Strategies to minimize feed wastage and maximize feed performance are needed to support the profitability small and mid scale pastured poultry systems. Fermented feed may help to address both these concerns. Fermentation is the action of microbes to break down complex molecules in feed ingredients and may make it easier for animals to absorb nutrients from their feed, improving feed efficiency. Feed can be fermented simply by soaking in water for a 24 to 48 hours and allowing microbes from the atmosphere and on the surface of grains to become active.

Laboratory studies have shown that fermented feed can perform better than dry feed in poultry, supporting health and enhancing productivity of both broilers (Yasar et al. 2016; Uchewa and Onu 2012) and laying hens (Engberg et al. 2009). But the laboratory is a controlled environment; it is not clear whether differences detectable in a laboratory setting are also detectable in a commercial pastured flock. Furthermore, providing fermented feed to a large flock entails substantial extra labor and infrastructure adaptations. As yet, there has been little information available to help farmers weigh costs against the prospective benefits of fermented feed relative to dry feed for commercial pastured poultry.

2. Objectives

The Foothills Farm Fermented Feed Study was established in 2018 to compare the performance of dry and fermented feeds in terms of feed efficiency (ratio of feed inputs to units of outputs such as eggs laid) and whole-season productivity in pastured laying hens. A hydrated feed treatment was included to help distinguish the effect of simply adding water to the feed from the effect of the fermentation process. The study includes an economic analysis in which labor inputs and egg outputs of each feed system are compared.

3. Methods

All diets in this study were prepared from the same complete mixed ration, a whole-grain mash (Naturally Free Organic Layer, 16% protein, from Scratch and Peck Feeds). The diets and their preparation methods were:

- Dry feed, presented to the birds as-is;
- Fermented feed, soaked in water at a ratio of 3.2 parts feed to 4 parts water for 48 h prior to feeding;
- Hydrated feed, soaked in water at a ratio of 3.2 parts feed to 3.3 parts water just prior to feeding.

The birds used for the study were Golden Sexlink laying hens. One hundred chicks arrived at Foothills Farm on 10 Oct 2018, at one day of age. They were brooded together and fed with dry feed. At 13 weeks, the birds were transitioned to pasture. At 16 weeks, on 30 Jan 2019, feeding of the experimental diets began.

The birds were separated into nine experimental groups. One group consisted of ten hens in a pasture house. Each pasture house was assigned to be fed with Dry, Fermented or Hydrated feed. There were three houses (replicates) assigned to each type of feed. The houses were arranged in a 3 x 3 grid with each feed type represented once in each row and each column, i.e., a Latin Square design (Fig. 1).

A predetermined weight of feed was delivered to each house daily. At weekly or two-week intervals, leftover feed was collected and weighed, allowing the calculation of feed consumed during that period. Hens had access to drinking water *ad libitum*. Eggs were collected and counted daily. Between June and October 2019, on nine occasions, a sample of eggs was collected from each house and weighed to estimate egg size in each treatment. Feed and egg measurements reported in this document were taken between 3 Mar and 10 Oct 2019.

The statistical significance of diet as a predictor of variation in each observed parameter (days to full egg production; days at full egg production; average egg production; feed consumption; feed per egg) was tested using linear mixed effects models implemented in R version 3.3.1 (R Core Team 2016). In the full model, diet was treated as a fixed effect and row and column numbers in the pasture-house layout as random effects. A full model with all terms included was compared to a null model with intercept = 1 and random effects. The p-value associated with this comparison is reported and can be interpreted to represent the probability that the full model does not describe the observed data any better than the null model. For model comparisons where $p < 0.05$, pairwise contrasts between treatments were tested for statistical significance ($\alpha \leq 0.05$) using the parameters extracted from the linear mixed effects model.

4. Results

All data represent 'period' averages adjusted to per-day basis. Periods, the time between leftover feed collection dates, ranged in length from six to 13 days. Data collection is considered to have begun on 3 Mar 2019. Some data are aggregated by season, in which cases ‘Spring’ was designated as 3 Mar – 7 Jun; ‘Summer’ as 8 Jun – 5 Sep; and ’Fall’ as 6 Sep – 9 Oct.

4.1 Egg production

Egg production was monitored daily from 3 Mar to 9 Oct 2019. Average production per bird was calculated for the same period. 'Full production' was designated as 0.8 eggs per bird per day (i.e., eight eggs per day for a house with 10 hens; Table 1).

Days to full production was the number of days from the start of the study (10 Oct 2018, when the one-day-old chicks arrived at the farm) to the average date on which the three houses in a given diet treatment first attained full production. Hens on the Dry diet reached full production in 153 days on average. This was significantly faster (p = 0.009) than hens on the Fermented diet, and 14 days faster than hens on the Hydrated diet (Table 1).

Birds on the Fermented diet sustained full production longest: 155 days, compared to 125 days for Dry-diet hens and 92 days for Hydrated-diet hens. Dry vs. Hydrated and Hydrated vs. Fermented differences were significant (p = 0.043 and p = 0.005 respectively), and the Dry vs. Fermented difference bordered on significance (p=0.053).

Table 1. Egg production statistics*

	Dry	Hydrated	Fermented
Days to full production	153 ± 3 **a**	167 ± 6 **b**	164 ± 2 **b**
Days at full production	125 ± 20 **a**	92 ± 11 **b**	155 ± 16 **a**

*Values in the same row bearing different letter subscripts are significantly different from one another according to an alpha threshold of 0.05.

Eggs per hen per day ('Eggs per hen-day^{-1}', Table 2) was calculated by dividing the number of eggs collected from each house by the number of hens in the house at the time (i.e., accounting for mortalities or escapes). Taking the year as a whole, egg production was significantly greater in Fermented-diet birds than in Hydrated-diet birds by a wide margin (0.77 eggs per hen-day^{-1} in the Fermented treatment versus 0.63 in the Hydrated treatment). Dry-diet birds produced at a somewhat lower rate than Fermented-diet birds (0.71 eggs per hen-day^{-1}) and the difference was near significant (p=0.063).

Signs of lower production in the Hydrated-feed birds emerged in the spring, although differences across diets were not statistically significant at that time; by summer, all diets were significantly different from one another, with production being the greatest on the Fermented-feed diet (0.87 eggs per hen-day^{-1}).

Table 2. Eggs per hen-day^{-1}, average by season, mean ± standard deviation*

	Dry	Hydrated	Fermented
Spring	0.67 ± 0.20	0.58 ± 0.23	0.66 ± 0.24
Summer	0.73 ± 0.12 **b**	0.65 ± 0.11 **c**	0.84 ± 0.12 **a**
Fall	0.79 ± 0.12 **b**	0.68 ± 0.07 **c**	0.87 ± 0.13 **a**
Whole year	0.71 ± 0.17 **a**	0.63 ± 0.17 **b**	0.77 ± 0.20 **a**

*Values in the same row sharing the same letter subscript are not significantly different from one another according to an alpha threshold of 0.05.

4.2 Egg weights

Eggs laid by Hydrated-diet birds were heavier than those laid by Dry- or Fermented-diet birds. This difference was significant (p<0.0001) when data from the whole season were analyzed together: Hydrated-diet eggs averaged 71.6 g, versus 68.4 g for Dry-diet birds and 69.3 g for Fermented-diet birds (Table 3). Separate analyses indicated that Diet was a significant factor both in the first part of the production season (22 Jun – 21 Aug; p=0.0043) and in the second (22 Aug – 9 Oct; p<0.0001). Eggs from Hydrated-diet birds were significantly heavier than those from Dry- and Fermented-diet birds throughout the season, while eggs from Fermented-diet birds were significantly heavier than eggs from Dry-diet birds in the second half of the season.

Throughout the season, eggs from all birds were heavy enough to be classified as USDA 'Extra Large' (minimum 63.8 g per egg, Specifications for Shell Eggs, USDA AMS, 2017).

Table 3. Average egg weight, grams, mean ± standard deviation*

	Dry	Hydrated	Fermented
22 Jun – 21 Aug	69.5 ± 2.0 **b**	71.8 ± 1.5 **a**	69.4 ± 2.4 **b**
22 Aug – 9 Oct	67.6 ± 2.1 **c**	71.4 ± 1.6 **a**	69.2 ± 1.4 **b**
Whole season	68.4 ± 2.2 **b**	71.6 ± 1.5 **a**	69.3 ± 1.8 **b**

*Values in the same row sharing the same letter subscript are not significantly different from one another according to an alpha threshold of 0.05.

4.3 Feed consumption

Data indicate very similar feed consumption across groups in spring and summer (Table 4). Consumption was 123-126 grams per hen-day^{-1} in spring; it rose to 140-142 g in summer, reflecting the increased food needs of the hens as they matured. In the fall, daily consumption was 136 g for Hydrated-diet birds, 144 g for Fermented-diet birds, and 159 g for Dry-diet birds. Analyses suggested the higher feed consumption rates in Dry-diet birds in the fall was statistically significant (p=0.00036). When data were analyzed for the season as a whole, there was also no significant effect of diet on feed consumption.

Feed collection was difficult to measure in the field and feed consumption results should be interpreted with caution. Evaporative water loss from Hydrated and Fermented feed treatments may have inflated feed consumption values. Feed was left outdoors in feed troughs for up to 14 days between feed delivery and leftover-feed collection and weighing. During this time, some feed dried and caked onto the feed troughs, but the values recorded by trial staff do not account for this evaporative water loss.

Table 4. Feed consumption by diet and season, dry basis; grams per hen-day^{-1}, mean ± standard deviation*

	Dry	Hydrated	Fermented
Spring	126 ± 19	123 ± 20	126 ± 17
Summer	140 ± 16	140 ± 5	142 ± 6
Fall	159 ± 19 **a**	136 ± 8 **b**	144 ± 9 **b**
Whole season	137 ± 21	132 ± 16	135 ± 15

*Values in the same row sharing the same letter subscript are not significantly different from one another according to an alpha threshold of 0.05.

4.4 Feed per egg

Typically, Feed Conversion Ratio is calculated by dividing the mass of feed consumed by the animal by the mass of its output, whether meat or eggs (Clark et al. 2019). We took a different approach in the present study because egg sizes were consistent across treatment groups and all eggs were therefore marketed in the same way (one of twelve in a dozen-pack sold for $8). We calculated a feed efficiency index by dividing daily feed consumption by daily egg production, obtaining a 'feed per egg' value (Table 5).

The feed per egg parameter was vulnerable to strong skew by egg production values approaching zero. This effect caused extreme outliers to arise in each of the three treatments, particularly at the beginning of the laying season before all hens had started to lay consistently. The most extreme outlier in each treatment was removed (treated as missing data) for analysis and reporting, because it was considered that this approach would be more representative of true patterns in the data.

Table 5. Feed per egg, dry basis; grams, mean ± standard deviation*

	Dry	Hydrated	Fermented
Spring	195 ± 56	225 ± 87	213 ± 94
Summer	196 ± 35 **b**	221 ± 42 **a**	174 ± 30 **c**
Fall	207 ± 42 **a**	206 ± 22 **a**	163 ± 28 **b**
Whole year	197 ± 46	220 ± 63	189 ± 69

*Values in the same row sharing the same letter subscript are not significantly different from one another according to an alpha threshold of 0.05.

An analysis of feed per egg data from the full year which included a treatment × season interaction term indicated a near-significant (p=0.09) interaction, so data were analyzed separately by season. In the spring, there was no significant difference between diets. In the summer, Fermented-diet birds consumed significantly less feed per egg than Dry- or Hydrated-diet birds (174 g versus 196 g for Dry-diet birds and 221 g for Hydrated-diet birds); a similar effect was observed in the fall. Hydrated-diet birds were consuming the least feed (Table 4), so these values reflect the greater egg production of the Fermented-diet birds.

4.5 Economic analysis

Data from the experiment were used to model the economics of a hypothetical 100-bird pastured laying flock, based on per-bird consumption and production values over the course of the season and the labor requirements associated with the different feeds. The assumptions of each component of the analysis were as follows.

1) Feeding
    i) Labor. More time is required to prepare and distribute fermented or hydrated feed than dry feed. This is because the feed manager must add water to the barrels containing feed and stir the feed, both as it is being prepared and as it is being distributed. These extra steps result in an estimated 50 minutes of daily work to prepare and distribute fermented or hydrated feed, versus 30 minutes daily for a dry diet. Labor hours in Table 6 represent the total hours summed for the entire experiment duration (3 Mar – 9 Oct, 220 days).
    ii) The farm wage is assumed to be $15/hr, typical for farm workers in Washington State in 2019.
    iii) Feed consumption data are based on observed values in this experiment.
    iv) The feed price of $1,000/ton is the 2019 price of Scratch and Peck Naturally Free organic layer mash.
2) Watering
    i) Labor. The Dry diet requires some extra labor for water distribution. Because hens do not like to drink warm water, their water vessels need to be refilled with cool water two to four times a day during periods of hot weather (70°F or warmer) to keep them drinking enough to stay hydrated. Furthermore, hens on a dry diet require more drinking water because they do not take in any water with their food as they do with a wet diet. For the economic analysis, it was assumed that a once-daily water refill

performed as part of the feeding routine was sufficient in spring and fall seasons, but that two additional water refills (15 minutes each) were performed daily during the summer (8 Jun – 5 Sep) for the dry treatment only.

ii) It is assumed that the farm is on a well and there are no unit-costs for water.

3) Egg revenues. Numbers of eggs produced in each diet system are based on observed values in this experiment. The value per dozen-pack of $8 represents the price set by Foothills at Farmers' Markets, its primary retail channel.

We note that net revenue estimates include only variables affected by the diet system, not infrastructure or overhead costs, and therefore do not represent overall profitability of a pastured-flock egg enterprise.

Results of the analysis (Table 6) indicate that the most profitable system was a Fermented-diet system, with net revenues of $5,124, compared to $4,717 in a Dry-diet system and $3,524 in a Hydrated-diet system. Total feed costs were only slightly less in the Fermented-diet system ($3,245) than in the Dry-diet system ($3,293), and overall labor costs, including both feed and watering, were greater in the Fermented system ($2,725) than the Dry-diet system ($1,635+$668 = $2,302); but the Fermented-diet system yielded 109 dozen-packs of eggs more than the Dry-diet system and thereby outperformed it.

Table 6. Economic performance of a 100-bird laying flock based on three diet systems evaluated over 220 days (3 Mar – 9 Oct)

	Dry	Hydrated	Fermented
		Costs	
Feeding			
Labor hours	109	182	182
Labor cost per hour	$ 15	$ 15	$ 15
Feeding labor cost	$ 1,635	$ 2,725	$ 2,725
Feed quantity, lbs	6,585	6,345	6,489
Feed cost $/lb	$ 0.50	$ 0.50	$ 0.50
Total feed cost	$ 3,293	$ 3,173	$ 3,245
Watering			
Labor hours	44.5	0	0
Labor cost per hour	$ 15	$ 15	$ 15
Watering labor cost	$ 668	$ -	$ -
		Revenues	
Number of eggs	15,478	13,734	16,786
Dozen-packs	1,289	1,144	1,398
Price per dozen	$ 8	$ 8	$ 8
Value of eggs	$10,312	$ 9,152	$11,184
Net revenue	**$ 4,717**	**$ 3,254**	**$ 5,214**

4.6 Hen behavior and mortalities

During their daily visits to the experimental flock, trial managers took notes on the hens' behavior. Certain behaviors were observed multiple times, reported in Table 7. These notes were informal (hens were not observed systematically or for long periods each day) but we report them for the sake of completeness.

Egg-breaking was most frequently observed in the Fermented feed houses, whereas aggression and digging behaviors were more common in the Dry feed houses. It was observed that more birds died in the Dry feed treatment (9) than in the Fermented (2) or Hydrated (0) treatments.

Table 7. Hen behavior observations; number of observations by diet

	Dry	Hydrated	Fermented
Breaking and/or eating eggs		1	4
Digging holes	2		
Aggressive	2		
Burying eggs	3		
Total mortalities	9	0	2

5. Discussion

In this experiment, feed preparation method had economically relevant effects on the performance of pasture-raised laying flocks. A wet fermented diet was associated with greater egg production than a dry mash diet and similar feed consumption levels, resulting in lower feed-per-egg values. Greater egg revenues from the Fermented-diet system offset its extra labor requirements and made it more profitable than a Dry-diet system. Conversely, offering a wet feed soaked just prior to feeding was associated with an economic disadvantage relative to dry or fermented feed, arising from lower rates of egg production than the Dry-feed diet, while labor requirements were similar to those of the Fermented-diet system.

The advantage of the Fermented diet was greatest in the fall, when hens in this group reduced their feed intake while sustaining high rates of egg production relative to the Dry-diet group, resulting in greater feed efficiency (Fig. 4). Feed-per-egg values in the Fermented-diet groups relative to the Dry-diet groups were 11 percent less in summer and 20 percent less in fall. Although formal data collection was suspended in October owing to labor constraints, informal indications were that the Fermented-feed groups continued to perform best into the winter. Egg counts from four dates in Nov and Dec yielded average eggs per hen-day^{-1} values of 0.56 in the Dry-diet groups, 0.61 in the Hydrated and 0.71 in the Fermented. Therefore, we anticipate that the relative advantage of a Fermented-feed system would be greater than that presented here in a flock that was studied year-round.

Fermentation is thought to improve feed functionality by breaking down complex storage compounds, degrading mycotoxins and improving digestibility and nutrient availability (Shi et al. 2017; Jakobsen et al. 2015; Assohoun et al. 2013). Results from this study offers evidence supporting a nutritional advantage from fermented feed.

Although overall performance suggests the nutritional status of the Fermented-diet birds was generally better than that of the Dry-diet birds in this study, they were slower to attain full production (Table 1). This could be explained by a period of adjustment when the experimental diets were introduced at 16 weeks. Engberg et al. (2009) reported that broilers introduced to fermented feed at 16 weeks initially appeared to find it less palatable or were less able to digest it. This effect may have constrained the productivity of Fermented-diet birds in our study relative to their full potential during the early part of the experiment, underestimating egg production in a Fermented-diet system where fermented feed is introduced earlier to the pullets.

Birds in the Hydrated feed treatment laid fewer, heavier eggs than birds on Dry or Fermented feeds in this study. Nutritional status of the hen is known to influence egg production, and sub-optimal nutrition can delay onset of lay (Bain et al. 2016; Bouvarel et al. 2011), leading to heavier eggs throughout the laying cycle (Rajendran 2011). Over the experimental period, birds on the Hydrated diet consumed less feed than other groups. In combination with their laying pattern, this suggests their nutritional status was less good than that of hens on Dry and Fermented diets. One possible explanation is swelling of the grains. The mash used for this experiment was whole-grain and contained wheat, barley and pea grains which swell up in water. While the Fermented feed was soaked for long enough to soften and break down the largest particles in the feed, the Hydrated feed may simply have become so bulky that the birds were unable to consume enough. It is probable that previous research demonstrating nutritional advantages associated with wet feed (Forbes 2003) used cracked or ground feeds with smaller particle size.

Fermented and hydrated feed consumption values were likely inflated in this study by evaporation of water between feed distribution and collection, and possibly also through spillage from the feed troughs. Nonetheless, this type of wastage would probably also occur in a typical commercial flock – one reason why it is so important to carry out an experiment such as this in a setting representative of typical farm practices. It is of note that fermented feed performed well economically despite the likely over-estimation of raw consumption and feed-per-egg values.

During the experiment, trial staff noticed that the birds on dry feed behaved more aggressively towards each other than birds on hydrated or fermented feed, with more feather-pecking. We hypothesize that this is explained by more intense competition in the Dry-diet groups owing to selective feeding from the mash, which drives the birds to establish a pecking order (hens lower in the pecking order have less access to the most desirable components). The calmer behavior of fermented-diet birds is a significant advantage in the context of a large commercial flock; it makes them easier to manage and may be an additional reason for farmers to choose fermented feed, although this particular advantage might also be gained from using pelleted feed.

Pastured poultry can be husbanded with very limited labor inputs. Larger commercial producers (e.g., over 1,500 birds) typically use feed-on-demand systems wherein a large quantity of pelleted feed is placed in the field for the birds to eat over the course of several days. Fermented feed can be prepared and transported efficiently but does require daily hands-on time by farm staff and specialized infrastructure to transport the slurry (around twice as heavy as the dry feed alone). While fermented feed may outperform dry feed economically in the context of a daily-feed system, it is unlikely to offer an economic advantage when compared with large-scale feed-on-demand.

For a mid-scale producer such as Foothills Farm, however, fermenting the poultry feed represents a 'value-add' which is meaningful to the farm's customers. Foothills sells at farmers' markets and local grocery stores and is closely connected with its customer base. Its customers are interested in the welfare of the animals and health properties of the eggs and will pay more for eggs they believe represent quality in these respects. Distinctive eggs help the farm draw attention to its other product offerings. In a context such as this, fermenting feed is a question not just of the economics of the pasturing system, but also the farm's characterization and relationship to the community.

6. References

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7. Figures

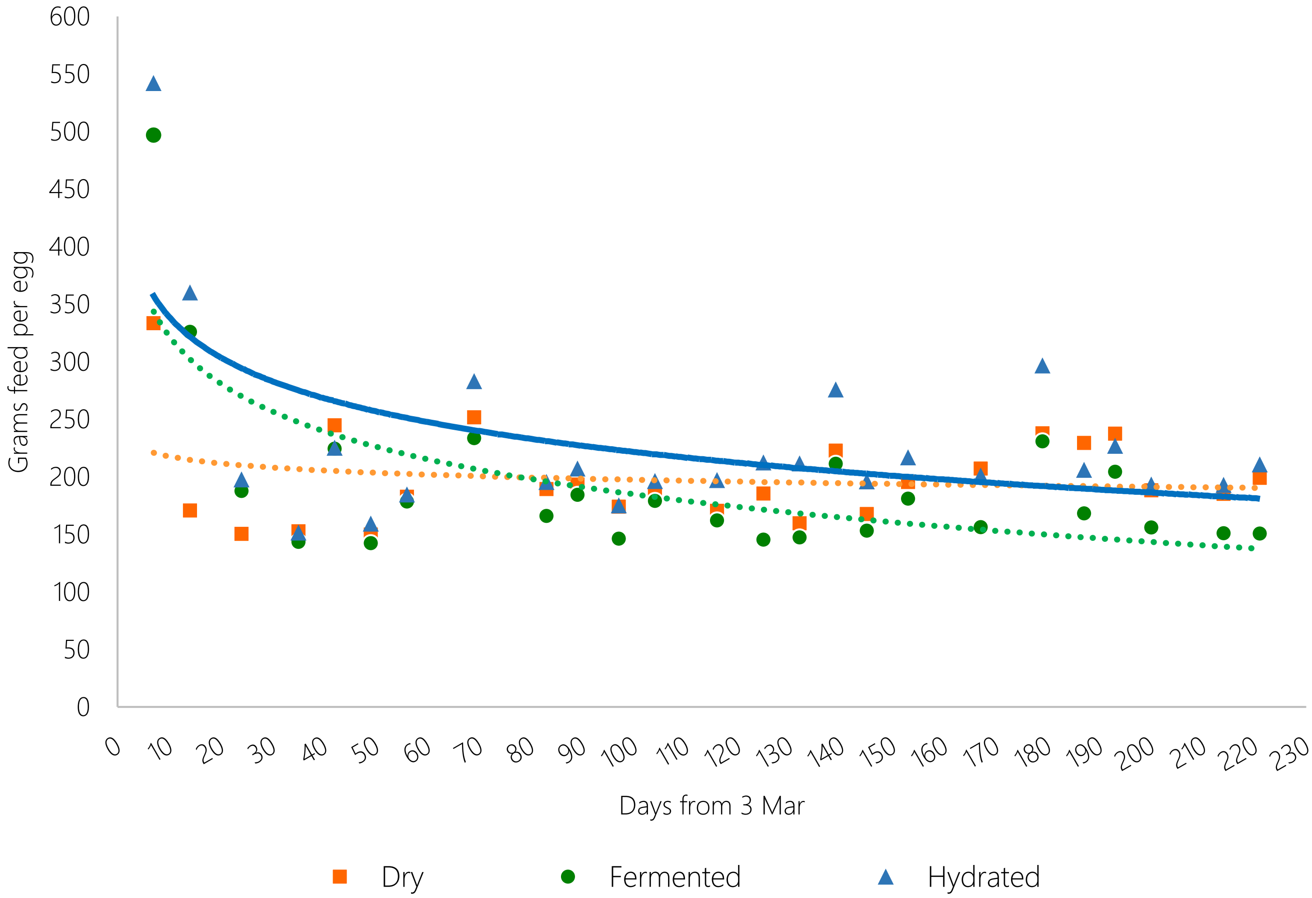
Figure 1. Diagram of the pasture house layout.

House 1 Fermented	House 2 Dry	House 3 Hydrated
House 4 Hydrated	House 5 Fermented	House 6 Dry
House 7 Dry	House 8 Hydrated	House 9 Fermented

Figure 2. The pasture houses in the field, February 2019. This photo is taken from the south, so the house in the foreground is number 9.

Figure 3. Fermented feed

Figure 4. Feed efficiency (grams feed per egg), 3 Mar – 9 Oct*†



*Trendlines are logarithmic.

†All eggs graded USDA Extra-Large.

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