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Moisture Optimization and Energy Saving Effects of Combined Organic Acid and Surfactant Inclusion in Pelleted Feed Production

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ABSTRACT

The purpose of the present study was to determine the effects of inclusion of an organic acid and surfactant (OS) combination on moisture optimization and energy sparing in the production of pelleted compound feeds for dairy and beef cattle. The trial was carried out in two independent private commercial feed factories (factories A and B) producing cattle feed in pellet form. Each factory produced 21 tons of commercial cattle feed (7 batches; 3 tons per batch); factory A, a dairy feed containing 2620 kcal/kg metabolizable energy (ME) with 18.90% crude protein (CP); and factory B, a fattening feed containing 2550 kcal/kg ME with 13.00% CP. Batches for the treatment groups were prepared by adding 0.5, 1.0 and 1.5 kg/ton of OS (Fylax flow) respectively to these basal feeds in the mixer. The moisture retention capacity during pelleting process of all three OS supplemented feeds increased in comparison to the basal feed, whilst moisture content of the finished feeds and energy consumed for production decreased significantly. It was observed that increasing the OS supplementation to 1.5 kg could further increase the moisture retention capacity and moisture content in pellet production compared to the feeds supplemented with 0.5 and 1.0 kg OS, due to the lower power rating of the equipment. It has thus been concluded that adding 0.5, 1.0 and 1.5 kg of OS to commercial compound feeds for dairy resulted in a profitable production with good moisture optimization and energy savings during pelleting.

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Introduction

Pelletizing consists in compacting mash feed into pellets of various sizes according to the animal species to be fed. Pelleted feed has less segregation of ingredients before ingestion by the animal, ensures a higher supply of energy per volume consumed and less energy expenditure for feed prehension. Pelleted feeds are widely used as they enhance animal performance, feed conversion ratio and efficiency (Corzo et al., 2011; Pope et al., 2018). From a feed manufacturing standpoint, the advantages of pelletizing include a reduction in pathogenic microorganism load, as well as a higher starch and protein digestibility thanks to the heat generated in the pellet press. These benefits of pelleted feed depend on the throughput, pelletizing efficiency and economical production while maintaining quality (Basmacıoğlu, 2004). Feed producers strive to produce high quality pellets at lowest possible production costs. Focusing on moisture management in the pelletizing process is one of the foremost factors affecting pellet quality (Abdollahi et al., 2013). Excessive moisture in the feed leads to energy and nutrient loss and toxin formation as it favours mold development. Temperature variation, oxygen and humidity conditions, especially in the storage of cereals, may easily elevate water activity levels (Mannaa and Kim, 2017). On the other hand, too little moisture in the feed has a negative impact on pellet durability. This increases shrinkage and energy consumption in the production process and reduces the efficiency of the pellet press (Moritz et al., 2002). Moisture content in the feeds can exert a positive effect by increasing starch gelatinization and protein denaturation (Moritz et al., 2003). Organic acids and surfactants can be used to optimize the moisture content of the feed and prevent mold contamination along production lines. By virtue of their antibacterial and antifungal properties at low pH, organic acids have been used for years to protect feeds from microbial and fungal deterioration (Canibe et al., 2001; Gül and Tekce, 2017). In addition to their preservative effect in feed by acidifying the feed and preventing feed re-contamination, it has been shown that organic acids can support gut health. They are not just antimicrobial agents for a long time preservation of feedstuffs, but also acidifiers that display their strong antimicrobial effect, supporting the prevention of bacterial infections in the gastrointestinal tract of animals that consume these feedstuffs (Tugnoli et al., 2020). The most commonly used organic acids are formic acid, acetic acid, propionic acid, butyric acid, lactic acid, sorbic acid, citric acid, tartaric acid and malic acid (Gül and Tekce, 2017). Whereas surfactant products, which are mixtures of surface tension reducing substances, play an important role in emulsification, hygiene, moisturizing and solubilization as compounds that reduce interfacial tension in oil-water or solid-water solutions (Rosen and Kungjappu, 2012). It has been reported in some animal feeding studies that addition of surfactants to basal diets beneficially modulates gastrointestinal functions and improves feed conversion (Moritz et al., 2002; Lee et al., 2004; Cong et al., 2009; Yuan et al., 2010). Surfactants can be effective in increasing the ruminal degradability of feedstuffs, modifying volatile fatty acid concentrations in the rumen and increasing ruminal enzyme concentrations (Goto et al., 2003; Lee et al., 2004; Khampa and Wanapat, 2007; Cong et al., 2009). Additives based on combinations of organic acids, such as propionic, and surfactants can be used in feeds to improve microbial control, extend storage period and reducing wastage (Morais et al. 2017; Da Silva Neto et al., 2022).

Besides, moisture optimization can help in reducing energy consumption and costs per unit of production, which are of critical importance for feed mills (Moritz et al., 2003; Manouchehrinejad and Mani, 2018; Özcen and Özgüven, 2021). Some studies show that moisture control in feed production is positively correlated with pellet quality, feed efficiency and economic production (Hott et al., 2008; Nichols et al., 2020). Fairchild and Greer (1999) reported that increasing feed moisture in the mixer by 3% results in a 10% improvement in pellet durability, a decrease in the energy consumption of the pellet press and in grinding costs.

The present study investigated the effects of using a combined feed additive consisting of organic acids and surfactants on moisture optimization and energy savings in commercial pelleted feed production.

Material and Method

This trial was carried out in two independent private commercial feed factories (Factories A and B). Each factory produced 21 tons of commercial cattle feed (7 batches; 3 tons per batch); factory A, a dairy feed containing 2620 kcal/kg metabolizable energy (ME) with 18.90% crude protein (CP); and factory B, a fattening feed containing 2550 kcal/kg ME with 13.00% CP. No additive was supplemented to the batches of feed to be used as control, whereas the test batches were supplemented with organic acid mix and surfactant combination (OS) at incremental dosages of 0.5, 1.0 and 1.5 kg/ton. The OS additive used in this trial was Fylax Flow (Trouw Nutrition TR Gıda Tarım Hayvancılık San. ve Tic. A.Ş., Türkiye). The product was added from the mixer by installing a liquid dosing compressed system. After the additive was dosed and mixed, duplicate samples were taken from four different points: mixer outlet, conditioner outlet, pellet press outlet and cooler outlet. Each sample was analysed for moisture to determine the effectiveness of moisture optimization.

Two samples were collected from each batch of finished feed. The nutrient values of these samples were determined by NIR method, using the equipment in the feed analysis laboratories of Trouw Nutrition TR Gıda Tarım Hayvancılık San. ve Tic. A.Ş. ME values of the feeds were calculated following Turkish Standards Institution (TSI) TS9610 (TSI, 1991) procedure. The OS additive used in the experiment, Fylax Flow, contained 70% organic acid combination (sorbic, formic, acetic, lactic, propionic acids and ammonium propionate) and 30% surfactant (1,2-propanediol). Nutrient compositions of the basal (control) pelleted compound feeds are shown in Table 1.

To measure the energy savings in kw per hour, electricity meter readings were recorded for each batch of control and test feeds at the beginning and end of the production runs.

Applying the then current feed and energy prices to these data, the economic returns that the factories obtained by using this additive were calculated (energy profit per batch).

The effects of OS use on moisture optimization and energy sparing were evaluated separately for the two feed factories. All data were analysed by ANOVA procedure using the Windows IBM SPSS Statistics package version 20.0. The distribution characteristics of the data according to the groups were performed by Shapiro Wilk test. Kruskal Wallis test was used for independent treatment comparisons (control and Flaxy Flow treatments). When independent treatment comparisons were significant for the results obtained from both factories, the level of difference between the treatments was determined by Tukey test. P values below 0.05 were considered to be statistically significant.

Table 1. Nutrient compositions of the basal (control) pelleted compound feeds

Nutrient Composition	Content	
	Factory A	Factory B
Dry matter, %	88.89	88.18
Crude protein, %	18.90	13.00
Crude fibre, %	8.35	6.63
Ether extract, %	4.61	3.29
Ash, %	7.39	9.64
ADF, %	13.60	8.68
NDF, %	27.60	21.88
ADL, %	2.31	2.60
Metabolizable Energy, kcal/kg	2.620	2.550

Table 2. Moisture retention capacities and contents in stages of pellet production, %

Characteristics	Treatments				SEM*	P values
	Control	0.5 kg	1.0 kg	1.5 kg		
Factory A						
Mixer outlet, %	11.5^a	12.85^b	12.6^b	12.7^b	0.018	≤0.05
Conditioner outlet, %	13.3^a	14.0^b	14.1^b	14.2^b	0.122	≤0.05
Pellet press outlet, %	13.0^a	14.1^b	14.0^b	13.9^b	0.076	≤0.05
Cooler outlet, %	10.7^a	11.8^b	11.65^b	11.75^b	0.119	≤0.05
Factory B						
Mixer outlet, %	11.6^a	12.8^{bc}	12.4^b	13.3^c	0.096	≤0.001
Conditioner outlet, %	14.7^a	15.2^b	15.1^b	16.3^c	0.078	≤0.001
Pellet press outlet, %	14.3^a	14.95^b	15.2^b	16.35^c	0.075	≤0.001
Cooler outlet, %	12.2^a	12.9^a	12.85^a	13.6^b	0.198	≤0.05

*Standard error of the mean; ^{a,b} Means with different superscripts in a row differ significantly.

Table 3. Energy consumption values during pelleted feed production

Characteristics	Treatments				SEM*	P values
	Control	0.5 kg	1.0 kg	1.5 kg		
Factory A						
Power rating (start-up), kW	526	526	526	526	-	-
Energy consumption**, kW	70^a	66^b	64^c	68^d	1.030	≤0.001
Factory B						
Power rating (start-up), kW	346.5	346.5	346.6	346.6	-	-
Energy consumption, kW	43^a	35^b	35^b	31^c	0.786	≤0.001

*Standard error of the mean; ^{a,b} Means with different superscripts in a row differ significantly.

Results and Discussion

The results pertaining to the moisture retention capacity of the feeds during pelletizing process are shown in Table 2. Moisture retention capacities of compound feed pellets after mixer, conditioner, pellet press and cooler in plant A increased (P≤0.05) in batches supplemented with 0.5, 1.0 and 1.5 kg/ton OS compared to basal feed (control). Whereas in factory B, the moisture retention increase observed in the feed samples with 0.5 and 1.0 kg OS supplementation taken at the mixer, conditioner and pellet press outlets was statistically significant compared to the control, while the highest moisture retention capacity at these production stages was obtained with 1.5 kg OS (P≤0.001) supplementation. Similarly, the post-cooler moisture retention capacity of the feed with 1.5 kg OS supplementation from factory B reached to the highest value compared all others (P≤0.001). According to the average data obtained from the two factories, the moisture contents of all supplemented feeds increased significantly compared to the basal feed (P≤0.001). Although there were no significant differences between the commercial compound feeds supplemented with 0.5 and 1.0 kg/ton of OS during the pelletizing process in both factories, the moisture retention capacities of these two treatments increased compared to the control group without supplementation. Moisture retention value was significantly higher compared to all other treatments when the OS dosage was increased to 1.5 kg/ton in Factory B. This result can be attributed to the relatively lower power rating and energy consumption of the pellet press in plant B. However, it might be attributed also to the high organic acid content of Fylax Flow. According to Hott et al. (2008), the addition of moisture-mold inhibitor mixture in the pelletizing process can improve pellet efficiency due to increased exposure to organic acids in the additive's composition. The researchers also suggested that the addition of moisture-mold inhibitor mixture in the pilot-scale mill extended the shelf life and moisture percentage of the feed without diluting its nutrient profile. On the other hand, the surface-active agent (surfactant) content of the OS used in this study may have contributed to enhanced moisture control. Moritz et al. (2002) reported that surfactant addition can increase the water/starch ratio prior to pelleting and significantly improve starch gelatinization, which may help in producing a more durable pellet with better moisture optimization. Furthermore, they also reported that the use of surfactants facilitated the absorption of water by the grain, thereby increasing the moisture content of the feed, and that broilers fed such diets performed better in terms of live weight gain.

The increased moisture retention capacity provided by surfactants is also related to both hydrophilic and hydrophobic groups in their structure (Goto et al., 2003). The surface-active agents they contain accumulate at the interfaces of different substances (air-water and oil-water), reducing the repelling forces between the phases insoluble in one another, thus allowing them to mix (Sperling and Parak, 2010). Hence, it is stated that bacterial enzyme secretion can be increased by interacting with the lipid parts of cell membranes (Singh et al., 2007). When supplemented to ruminant feeds, surfactants increase the ruminal enzyme secretion and nutrient digestibility, and manipulate the concentration of volatile fatty acids in the rumen (Lee et al., 2004; Cong et al., 2009; Yuan et al., 2010; Liu et al., 2013).

The fact that the moisture content throughout the stages of pelletizing process (after mixer, conditioner, pellet press and cooler) was higher in the supplemented feeds than in the control, indicates that the water added in the mixer did not evaporate and retained by the effect of OS during the pelletizing process. This means that the addition of 0.5, 1.0 and 1.5 kg/ton of OS at the mixer is beneficial and quite important for feed mills.

At the end of pelletizing, the moisture content of all OS supplemented feeds decreased significantly compared to the basal (control) feed in both factories, regardless of the level of supplementation. This circumstance indicates that OS supplementation may extend the shelf life of feeds. It has been suggested that unless the moisture content of compound feeds is above 12%, the addition of organic acid (2.5/ton calcium propionate) will ensure that they can be stored for one month without deterioration (Gül and Tekce, 2017). In this study, the increase observed in the moisture content of the 1.5 kg OS supplemented feeds produced in Factory B versus 0.5 and 1.0 kg supplemented ones, may be related to its higher moisture retention capacity at all stages of pellet production.

Energy consumption values during pelletizing of commercial compound dairy feeds produced in Factory A are given in Table 3, whereby a decreasing energy consumption was observed in the batches supplemented in the mixer with 0.5 kg, 1.0 kg and 1.5 kg OS compared to the control feed ($P \leq 0.001$). On the other hand, energy consumption during pelletizing was significantly reduced in the 1.0 kg OS supplemented feed, compared to the feeds with 0.5 kg and 1.5 kg OS addition ($P \leq 0.001$). In Factory B, where fattening feed was produced, the amount of energy consumption did not change between the supplementation of 0.5 kg and 1.0 kg OS in the mixer ($P \geq 0.05$). However, energy consumption of these two feeds was lower compared to the control ($P \leq 0.001$). In factory B, the addition of 1.5 kg OS in the mixer significantly reduced ($P<0.001$) the energy consumption during pelletizing compared to the other feeds. Energy consumption during pelleting process was significantly reduced in the feeds with 1.0 kg/ton OS supplementation in Factory A and 1.5 kg/ton in Factory B compared to the other treatments. In Factory A, this may be due to other factors affecting the pelleting quality since the moisture retention capacities of the OS supplemented feeds throughout all pelleting stages and their final moisture contents were similar (Yalçın et al., 2017; Yalçın et al., 2018). This may also be attributed to the fact that the moisture retention capacity of the 1.5 kg/ton OS supplemented feed in factory B was higher during the pelleting stages. On the other hand, in both factories a lower energy consumption was observed in all feeds with OS supplementation compared to the controls. This is a very important finding for the feed mills. The diets prepared for this trial were not of low energy density, but there are also studies suggesting that low-energy diets may have an effect on the energy consumption during production (Moritz et al., 2003). In the same study it was also emphasized that energy sparing effects may be due to improved pellet quality and that the decrease in the electrical energy required for pelletizing may be related to moisture addition to low energy diets (Moritz et al., 2003).

At the end of the experiment, the economic results obtained with supplementation of 0.5, 1.0 and 1.5 kg/ton of OS to pelleted commercial dairy feeds produced in factory A are given in Figure 1. The OS costs per batch of supplemented feed were calculated at 3.93, 7.85 and 11.78 € for the three treatments, yielding profits of 18.63, 12.33 and 10.25 € respectively.

The economic results obtained with supplementation of 0.5, 1.0 and 1.5 kg/ton of OS to pelleted commercial fattening feeds produced in Factory B are given in Figure 2. The OS costs per batch of supplemented feed were calculated at 2.36, 4.71 and 7.07 € for the three treatments, yielding profits of 4.54, 1.31 and 5.45 € respectively.

In both factories, OS supplemented feeds ensured a profit per batch. In factory A, a numerically increasing profit rate was calculated in parallel with incremental OS addition in the mixer. The relatively higher per batch profit rate observed in the 1.5 kg/ton OS supplemented feed produced in factory B can be attributed to the fact that this feed group had the lowest energy consumption during production. According to Hott et al. (2008), increasing moisture-mold inhibitor mixture addition (1% and 2%) reduces the cost of pellet production, as this practice decreases the relative electrical energy use.

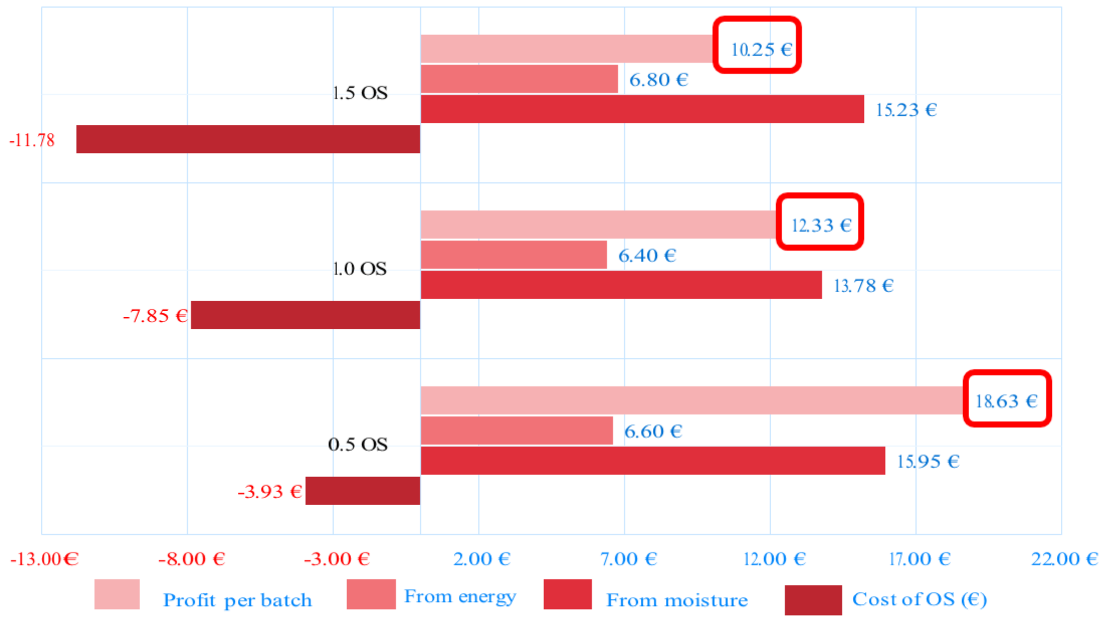

Figure 1. Economic results obtained with supplementation of OS in Factory A

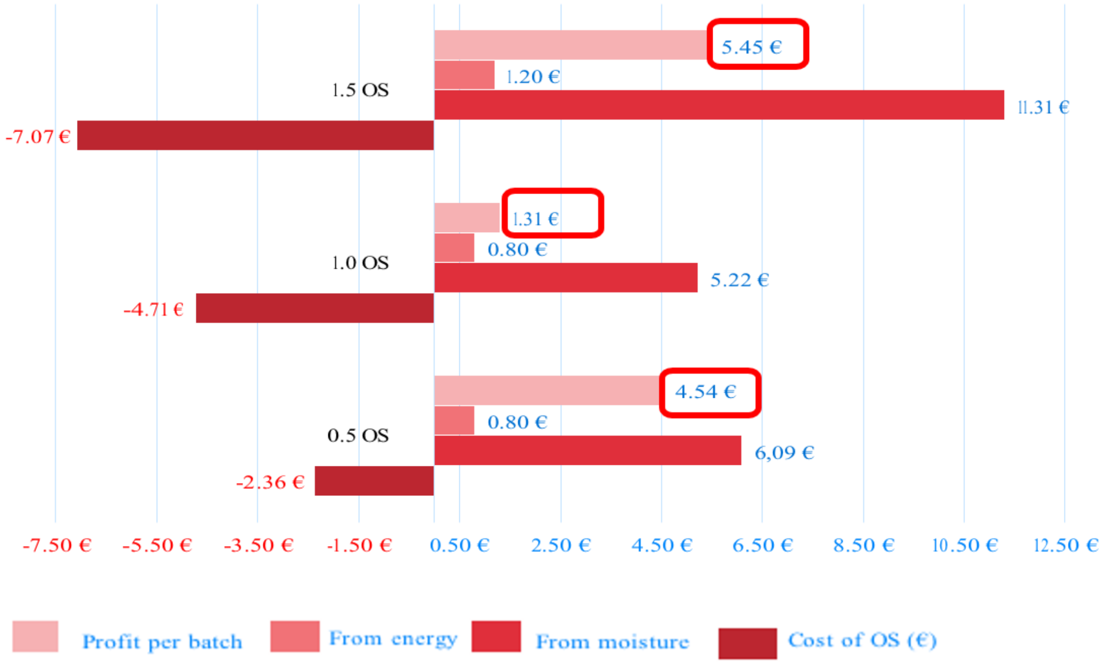

Figure 2. Economic results obtained with supplementation of OS in Factory B

Conclusion

In conclusion, the addition of 0.5, 1.0 and 1.5 kg/ton of organic acid and surfactant combination to commercial compound feeds for dairy and beef cattle increased the moisture retention capacity during pelleting and the moisture content of the final pellets, whilst reducing the electrical energy consumption of the production process. In Factory B, which had lower power rated equipment, increasing the dosage of OS supplementation to 1.5 kg/ton further enhanced the moisture holding capacity, resulting in pellets with higher final moisture content than other feeds with 0.5 and 1.0 kg/ton OS addition. The results of this study indicate that supplementation of an organic acid and surfactant combination may help profitable pelleted feed production by providing moisture optimization and reducing energy consumption.

The studies on energy use in the feed manufacturing industry and pellet lines in compound feed factories are quite limited. More extensive research is needed on how the ingredients behave and interact to improve pellet quality and maximize energy savings, and thereby profits, for commercial feed manufacturers.

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