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Productivity, milk composition and milk quality of cows fed maize silage covered with oxobiodegradable film

Wydajność, skład i jakość mleka krów żywionych kiszonką z kukurydzy okrytą folią oksybiodegradowalną

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Abstract

The aim of the study was to determine if oxobiodegradable film can be used as an alternative to standard film for silage making in agricultural practice. Whole-crop maize silage covered with oxobiodegradable film was fed as a component of partly mixed ration (PMR) for dairy cows. The oxobiodegradable coating used to cover the silage heap ensured that the fermentation process was normal, as evidenced by the quality parameters (pH 3.8, 72 hours of aerobic stability) and chemical composition of the silages. Fodder covered with biodegradable material contained less ammonium nitrogen than silage with standard foil (55.3 vs. 66.63 $g \cdot kg^{-1}$ N total, respectively). The concentration of lactic acid was also lower (77.75 vs. 89.65 $g \cdot kg^{-1}$ dry matter). Feeding whole-crop maize silage covered with oxobiodegradable film had no adverse effect on productivity (daily 30.65 vs. 31.17 kg fat corrected milk – FCM respectively), composition (protein – 3.33 in the experimental group vs. 3.3% in the control group, fat – 3.89 vs. 3.79%) and some technological suitability of milk.

Keywords: aerobic stability, biodegradable film, milk quality, milk yield, silage

Streszczenie

Celem badań było ustalenie, czy można w praktyce rolniczej zastosować do produkcji kiszonek folię oksybiodegradowalną jako alternatywę folii standardowej. Kiszonkę z całych roślin kukurydzy okrytą folią oksybiodegradowalną podawano jako komponent dawki częściowo wymieszanej (PMR) dla krów mlecznych. Folia oksybiodegradowalna użyta do okrycia stosu kiszonkowego gwarantowała prawidłowy przebieg procesów fermentacji, o czym świadczą parametry jakościowe kiszonek (pH 3,8, 72 godziny stabilności tlenowej) i ich skład chemiczny. Pasza okryta materiałem biodegradowalnym zawierała mniej azotu amoniakalnego niż kiszonka okryta folią standardową (odpowiednio 55,30 vs. 66,63 g·kg^{-1} N ogólnego). Koncentracja kwasu mlekowego również była niższa (77,75 vs. 89,65 g·kg^{-1} suchej masy). Skarmianie kiszonek z całych roślin kukurydzy okrytej folią biodegradowalną nie wpłynęło ujemnie na wydajność (odpowiednio 30,65 vs. 31,17 kg mleka dziennie o skorygowanej zawartości tłuszczu – FCM) i skład mleka (białko – 3,33 u krów z grupy doświadczalnej vs. 3,3% w grupie kontrolnej; tłuszcz – 3,89 vs. 3,79%) oraz wybrane parametry jego przydatności technologicznej.

Słowa kluczowe: folia biodegradowalna, jakość mleka, kiszonka, stabilność tlenowa, wydajność mleka

Introduction

Silage is the basic feed source for beef and dairy cattle production. One of the prerequisites for making silages that are safe for animals is to protect the preserved silage from oxygen. Improper covering of silage will increase infiltration of air into the silage, leading to dry matter loss, deterioration in quality parameters, and reduction in feed nutritive value and aerobic stability at feeding. It is common practice and economically justified to ensile feeds in clamp silos covered with low-density film from pure polyethylene. Polyethylene foil is the standard material used to prevent silage spoilage due to relatively low price, low oxygen permeability, good plasticity and easy availability. However, the management of worn-out polyethylene films is a problem. Alarmingly, worn-out silage wrap is going to illegal dumping sites, being buried or burned, while the released components of polymer plastics are a serious environmental threat (Rymarz and Klecan, 2001; Majdiuk, 2002; Rutkowska et al., 2002; Denoncourt et al., 2004a, 2004b; Świątkowski and Walczak, 2004; Borreani and Tabacco, 2005; Laffin et al., 2005; Denoncourt et al., 2006, 2007; Borreani et al., 2014; Borreani and Tabacco, 2015). One alternative to standard coating is biodegradable film produced on the basis of natural origin polymers (chitosan, cellulose, starch, soy or whey protein, and others) or synthetic macromolecular compounds that provide food for microorganisms. The use of biodegradable materials for silage making is conditional on efficient protection of ensiled material from oxygen and on maintaining the high nutritive value of the feeds at feeding (Świątkowski and Walczak, 2004; Denoncourt et al., 2004a, 2004b, 2006, 2007).

The aim of the study was to determine if oxobiodegradable foil made from modified low-density polyethylene (PE), used in agricultural practice as an alternative to standard film for covering whole-crop maize silage heaps, makes it possible to produce valuable feed that is safe for dairy cows.

Materials and methods

Whole maize plants were harvested at a dry matter content of 348.8 g·kg^{-1}. Ground forage was ensiled with a microbiological additive in a covered clamp silo with 800

Mg of capacity. The raw material was compacted with a wheeled tractor. One half of the silo was covered with standard low-density film from pure polyethylene (control silage) and the other half with a oxobiodegradable film from modified low-density polyethylene, produced from starch (experimental silage). The silage clamp was weighed down with tyres. After 4 months of preservation, the silages were used in a 100-day feeding trial with dairy cows. Cows were divided into two feeding groups with eight animals per group. Polish Holstein-Friesian black-white cows with an average body weight of 650 kg were similar in terms of age (4 to 5 years old) and lactation (middle stage of third lactation). Animals were fed according to the PMR system. PMR contained maize silage (64.3%), mixed legume-grass silage (18.4%), fresh brewers' grains (9.2%), rapeseed cake (1.8%), rapeseed meal (1.8%), ensiled triticale grain (4%), mineral mixture (0.3%), and ground limestone (0.2%). The basal diet was formulated to support 25 kg of milk production. Higher yielding cows additionally received 1 kg of concentrate per 1-2 litres of milk produced. In the control group (I), PMR contained maize silage covered with standard film. Treatment in group II was maize silage covered with biodegradable film. PMR was fed twice daily *ad libitum*. Animals were given free access to water. Diets were formulated based on new feed evaluation systems (Strzetelski et al., 2009). The herd was milk recorded by the Polish Federation of Cattle Breeders and Dairy Farmers. Test milking's were carried out once a month together with sampling of milk and feeds for analysis.

Feed samples were analysed for nutrient content including acid (ADF) and neutral detergent fibre (NDF), in accordance with standard procedures (AOAC International, 1990). Fresh samples of maize silage were analysed for pH and level of organic acids (lactic, acetic, butyric) and ammonia nitrogen (AOAC International, 1990). The samples were additionally tested for stability based on temperature test in an air-conditioned room, the ambient temperature of which was kept at 20 °C (±1 °C) (Honig, 1990). Alongside silage samples, biodegradable film samples were also collected to determine the average decrease in elastoplastic properties compared to the initial parameters of biodegradable film, based on relative elongation at break along and across the length of extrusion (PN-EN 13206, 2003; PN-EN 13207, 2003). Milk was analysed for the content of solids, total protein, total fat and urea using a MilkoScan 4200 apparatus. Technological suitability of milk for processing was evaluated based on pH value and fermentation and fermentation-rennet tests (Budsławski, 1973).

Nutritive value of the silages was determined based on their chemical composition according to the INRA system (Institut National de la Recherche Agronomique). Tabular values of digestibility coefficients, r and sjp values were taken into account when calculating the energy and protein value of the feeds (Strzetelski et al., 2009). All results were analysed statistically using Statistica software. Student's t-test was used to analyse differences between two means.

Results and discussion

These studies showed that chemical composition and nutritive value of maize silage covered with biodegradable coating was generally comparable with those of silage covered with standard film, with small differences in some parameters analysed (crude fibre, ADF, PDIE – protein digested in the small intestine when rumen-fermentable energy is limiting) (Table 1).

Table 1. Chemical composition and nutritive value of whole-crop maize silages during 4 to 7 months of storage (n=12)

Item	Silage covering method	
	Standard film	Oxobiodegradable film
Dry matter (%)	32.48±1.5	32.22±1.22
Crude ash (%)	4±0.35	4.25±0.37
Crude protein (%)	9.99±0.49	9.9±0.34
Crude fat (%)	4.61±1.21	4.51±0.51
Crude fibre (%)	19.01*±0.76	18.07*±0.91
ADF (%)	19.5*±0.89	18.92*±0.59
NDF (%)	34.11±1.28	33.98±1.42
UFL	0.98±0.02	0.98±0.01
PDIN (g)	61.15±3.22	60.8±2.11
PDIE (g)	66.58**±1.35	67.78**±0.9
LFU	1.27±0	1.27±0

*P≤0.05, **P≤0.01, ADF – acid detergent fibre, NDF – neutral detergent fibre, UFL – feed unit for lactation, PDIN – protein digested in the small intestine when rumen-fermentable nitrogen is limiting, PDIE – protein digested in the small intestine when rumen-fermentable energy is limiting, LFU – lactation fill unit.

Similar relationships were reported by Denoncourt et al. (2006), who covered ensiled maize with biodegradable film based on soy protein, calcium caseinate, carboxymethylcellulose, zein and palmitic acid.

The quality parameters of silages studied here show that fermentation processes were normal regardless of the covering method (Table 2).

Table 2. Quality of whole-crop maize silages and changes in biodegradable film properties

Item	Silage covering method	
	Standard film	Oxobiodegradable film
pH	3.77±0.07	3.8±0.08
$N\text{-}NH_3$ ($g\cdot kg^{-1}\cdot N$ total)	66.63**±7.1	55.3**±9.1
Lactic acid ($g\cdot kg^{-1}$ DM)	89.65*±5.9	77.75*±3.98
Acetic acid ($g\cdot kg^{-1}$ DM)	17.4±0.22	16.78±1.06
Butyric acid ($g\cdot kg^{-1}$ DM)	0.5±0.02	0.49±0.03
Aerobic stability (hours)	72	72
Initial value of relative elongation at break for (%)	426	426
Relative elongation at break after 7 month of storage (% of initial value)	-	36.42

$^{*}P\leq 0.05$, $^{**}P\leq 0.01$, $N\text{-}NH_3$ - ammonia nitrogen, DM – dry matter.

Different results were obtained for grass silage covered with hydrophobic biodegradable film based on whey protein concentrate, calcium caseinate, carboxymethylcellulose, zein and fatty acids (Denoncourt et al., 2004a). At 135 days of storage, the pH of silages covered with biodegradable film was 9.09. Similar results were obtained for maize silage covered with film based on soy protein, calcium caseinate, carboxymethylcellulose, zein and palmitic acid (Denoncourt et al., 2006). After 8 weeks of storage, the pH of silages covered with biodegradable film was higher than that of silage covered with standard coating. According to the authors quoted above, the high pH value of silages is evidence that these films failed to protect the silages from oxygen during fermentation. In this study, analysis of the other quality parameters of silages showed that the concentration of lactic acid and the ammoniacal nitrogen content of the experimental silage were significantly lower compared to the control silage. The proportion of acetic and butyric acids in dry matter of the silages covered using different films was comparable. Denoncourt et al. (2006) demonstrated that after 8 weeks of storage, maize silage covered with biodegradable foil based on soy protein, calcium caseinate, carboxymethylcellulose, zein and palmitic acid had a similar content of lactic acid but a higher content of acetic acid compared to the control silage. The relationships found for ammonia were similar to those obtained in this study. For grass silage covered with biodegradable film based on whey protein concentrate, zein and fat components. Denoncourt et al. (2007) showed that after 70 days of preservation the amount of lactic acid was higher for silages covered with biodegradable film compared to control silages. The concentration of acetic acid was comparable for silages covered with biodegradable film and for control silages, as was the case in this study. It should be noted that the study cited above was conducted on a laboratory scale and this study was carried out on a production scale.

The principal measure of silage spoilage is an increase in silage temperature in aerobic condition (Denoncourt et al., 2007). In these studies, biodegradable film prevented maize silage from becoming unstable to the same degree as standard coating (Table 2). Similar results were obtained in studies of Borreani et al., 2010. Other experiments (Borreani et al., 2012; Borreani and Tabacco, 2015) showed better stability of maize silage covered with biodegradable film than silage covered with standard film. Denoncourt et al. (2006) showed that the temperature of maize silages covered with biodegradable film based on soy protein with different hydrophobic barriers was significantly higher compared to the control silage. Self-heating of silages in silos may suggest that the biodegradable layer failed to protect the silages from spoilage when they were exposed to atmospheric influences.

Denoncourt et al. (2004b) reported that production of good silage using biodegradable film is dependent on plastic components. In fact, a number of components characterized by different mechanical and physical properties give specific functional properties to the film. In practice, the components used may act antagonistically. By way of example, plasticizers (glycerol, sorbitol) improve tear resistance but may make the film more susceptible to water penetration due to the hydrophilic nature of these materials. The addition of fatty acids to the plastic mass significantly improved properties of the water evaporation barrier, but inclusion of polysaccharides and proteins may allow air to infiltrate the silage. These researches showed (Table 2) that at the end of the feeding trial, oxobiodegradable foil lost around 63.58% of its elastoplastic properties compared to the initial value, which is evidence that oxobiodegradation had already occurred. According to the manufacturer, the fact that biodegradable composite lost ≥80% of its properties is indicative of complete biodegradation to environmentally safe products.

In these studies, the supplementation of PMR diet with maize silage covered with biodegradable film had no significant effect on differences in cow performance and milk composition (Table 3). Considering the protein and urea content of the analysed milk, it can be said that the ration was well balanced for protein and energy content (Nagle, 1994). The somatic cell content did not exceed the limit set by EU countries

(Jurczak, 2005). In these studies, cow's milk composition was within the range of milk components typical of European dairy breeds. According to Jurczak (2005), the solids, protein and fat content of milk from European cows averages 12.3, 3.2 and 3.8%, respectively. Fluctuations in milk composition represent a normal physiological event and are not indicative of mammary gland dysfunction provided that they fall within a certain range. Chemical composition of milk is dependent primarily on genetic factors and nutrition, and to a certain extent on physiological factors (Barłowska et al., 2005). Milk composition determines the level of physicochemical traits, which are indicative of its technological suitability. It is also thought that some breeds of cows are better suited to market milk production and others are more suited to produce milk for processing (Barłowska et al., 2005; Jurczak, 2005). Active acidity of 6.5-6.7 is considered to be normal pH of milk. Higher values most often suggest mastitis and passage of blood serum (pH 8.2) into milk. pH values of <6.5 may be indicative of colostral milk, development of milk microflora with production of lactic acid, faulty feeding practices or metabolic disorders (Jurczak, 2005). In these studies, the active acidity of milk from cows fed a diet with silage covered with biodegradable film was characteristic of normal fresh milk (pH 6.74) whereas the pH of milk from control cows (6.82) was slightly above the upper limit of active acidity for fresh milk.

Budsławski (1973) and Jurczak (2005) reported that the suitability of raw milk for cheese making can be determined based on fermentation test, which is an indirect method used in the microbiological evaluation of milk. In these studies (Table 3), regardless of the feeding method, the highest proportion was represented by milk samples with clot type PŁ (49% in the control group, 40% in the experimental group). Under test conditions, PŁ type is characteristic of liquid milk and indicates that there is no clot. Milk that shows no other faults may be approved for processing. Type PŁ clot may be indicative of the presence of antibiotics or inhibitors. Gelatinous clot type GL, the most preferred by cheese makers, is indicative of large amounts of proper lactic fermentation bacteria. GL milk is suitable for processing into all types of dairy products. If milk contains many lactic fermentation bacteria, rapid souring is expected to take place. In this study, the greatest proportion of milk samples (31%) with the most preferred clot by cheese makers was observed in the group fed a diet containing silage covered with biodegradable film. Inverse relationships were found for type S milk. Type S milk can be used for processing and the occurrence of this clot type is indicative of the low content of lactic fermentation bacteria and the presence of rennet enzyme bacteria. Type S_3 milk is not suitable for cheese making (Budsławski, 1973; Jurczak, 2005).

The fermentation-rennet test enables the suitability of milk for cheese making to be determined more accurately (Jurczak, 2005). In the experimental group, 41% of milk samples were classified as clot type I (healthy milk, pure lactic fermentation, suitable for cheese making) and 59% as clot type II (faulty milk, conditionally suitable for processing). In the control group, the proportion of pure fermented milk samples (clot type I) was lower (25%) compared to the proportion of milk samples conditionally suitable for processing (75%) (clot type II).

Table 3. Yield, composition and quality of cows' milk

Item	Feeding groups: Control n=8	Feeding groups: Experimental n=8
Daily milk yield (kg)	33.62±6.25	31.05±3.78
Daily FCM yield (kg)	31.17±4.67	30.65±5.66
Daily ECM yield (kg)	32.25±4.14	30.47±5.1
Solids (%)	12.58±0.87	12.59±1.54
Protein (%)	3.3±0.29	3.33±0.31
Fat (%)	3.79±0.71	3.89±0.59
Urea ($mmol \cdot l^{-1}$)	4.3±0.29	4.16±0.72
Active acidity (pH)	6.74±0.06	6.82±0.37
SCC ($1{,}000 \cdot dm^{-3}$)	240^{*}±21.6	199^{*}±80.05
Some traits of technological suitability (proportion of samples in %):		
Fermentation test		
PŁ - without clot, liquid milk	49	40
GL - gelatinous clot	18	31
S - cheese clot	33	29
Fermentation-rennet test		
I - healthy milk, pure milk fermentation	25	41
II - faulty milk	75	59

*P≤0.05, FCM – fat corrected milk, ECM – energy corrected milk, SCC – somatic cell count.

Conclusions

The oxobiodegradable film used to cover the silage heap in a covered clamp silo ensured that the fermentation process was normal, as evidenced by quality parameters and chemical composition of the silages.

Feeding whole-crop maize silage covered with oxobiodegradable film as a component of PMR for dairy cows had no adverse effect on productivity, composition and technological suitability of milk.

Oxobiodegradable film made from modified low-density polyethylene could be used in agricultural practice as an alternative to standard film for production in covered clamp silos of good quality silages.

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