Evaluation of apple pulp and peanut butter as alternative bunker silo covers

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Savoie, P., Bernier-Roy, M., Pedneault, M.-L. and Amyot, A. 2003. **Evaluation of apple pulp and peanut butter as alternative bunker silo covers**. Canadian Biosystems Engineering/Le génie des biosystèmes au Canada **45**: 2.17 - 2.22. Polyethylene (plastic) film is currently used to cover bunker silos and protect silage against air infiltration, respiration loss, and spoilage. However, used plastic film has become an environmental concern because it is non-degradable and difficult to recycle. Organic covers such as straw, apple pulp or food industry waste have been suggested to replace plastic film, but little information exists on their efficiency as an air barrier. Timothy silage in mini-silos was conserved under six covers: 25 or 50 mm of apple pulp, 2.5 or 5 mm of peanut butter, no cover (negative control), and a practically impermeable seal with a screw cap (positive control). Each silo was formed of six 90 mm high segments separated by a porous screen. Silos were opened after 3, 7, 14, 21, and 42 days. Wet matter, dry matter, fibre content, and pH were measured over time and depth. Results show that organic covers offer some protection against air infiltration up to 21 days, but air infiltrates through the apple pulp and peanut butter covers by 42 days down to 180 mm below the surface where considerable loss and high pH values are observed. It is concluded that these organic covers, within the range of thicknesses used, do not offer adequate protection for bunker silos. **Keywords**: silage, cover, oxidation, loss, organic, polyethylene.

Les films de polyéthylène sont couramment utilisés pour couvrir les silos horizontaux et protéger l'ensilage contre l'oxydation. Toutefois, les films usagés représentent un déchet pratiquement non-dégradable et difficile à recycler. Des matériaux organiques comme la paille, la pulpe de pomme et certains résidus alimentaires ont été proposés pour remplacer le polyéthylène comme couverture de silos, mais leur efficacité est peu connue. Avec de l'ensilage de fléole dans des mini-silos, on a comparé six couvertures: des épaisseurs de 25 ou 50 mm de pulpe de pomme, des épaisseurs de 2,5 ou 5 mm de beurre d'arachide, aucune couverture (témoin négatif) et un couvercle vissé très étanche (témoin positif). Chaque silo était formé de six segments de 90 mm de hauteur, superposés et séparés par un grillage poreux. Les mini-silos étaient ouverts après 3, 7, 14, 21 et 42 jours. La matière humide, la matière sèche, la concentration des fibres et le pH ont été mesurés en fonction du temps et de la profondeur. Les résultats montrent que les couvertures organiques offrent une certaine protection contre l'infiltration d'air jusqu'à 21 jours après la mise en silo. Après 42 jours, les pertes de matières sèches élevées et les pH ammoniacaux indiquent que l'air s'infiltre presque autant à travers les couvertures organiques qu'à travers le témoin négatif sans couverture, jusqu'à une profondeur de 180 mm. En conclusion, la pulpe de pomme et le beurre d'arachide, dans la plage des épaisseurs utilisées, sont inadéquats pour protéger l'ensilage conservé en silos horizontaux. **Mots clefs**: ensilage, couverture, oxydation, perte, organique, polyéthylène.

INTRODUCTION

Polyethylene film is a convenient material to protect silage because it is relatively impermeable, low-cost, and supple. It can easily adhere to various shapes and surfaces such as bunker silos (McLaughlin et al. 1978), large bales (Harrison 1985), and stack silos (Savoie et al. 1986). Plastic film generally provides a good protective cover for silage against air infiltration and spoilage (McDonald et al. 1991).

Over the last decade, some concern has been expressed about handling used plastic film because it is non-degradable and difficult to recycle (Clarke 1993; Negra and Rogers 1997). While landfilling and burning are current disposal options for used plastic film, another alternative is to avoid using plastic altogether. Bolsen (1997) observed that several farmers in Kansas did not cover large bunker silos, thereby eliminating purchase cost of plastic film and labour costs associated with installation and disposal of the cover. However, Bolsen (1997) estimated that the value of lost silage was about four times the cost of purchasing and installing the plastic film (e.g. sealing cost $430 for a 1,000 t bunker and saved $1,644 of silage loss).

Another reason for covering silage is to prevent development of mycotoxins and animal health problems. Gotlieb (1997) observed that “the highest concentrations of toxins were found in horizontal storage methods such as bunker silos and feed piles which were left open to oxygen”. Leaving silos uncovered is not viable as food quality and animal health become more important factors in animal production.

A more attractive alternative to plastic film or no cover is the use of edible biofilms or organic covers. Ideally, a biofilm or organic cover should provide good protection against air infiltration and disintegrate when mixed in silage at the time of feeding. Brusewitz et al. (1991) evaluated a soya-based spray-on biofilm for corn silage. They found that the biofilm did not provide more protection than no cover at all. Other biofilms have been developed to protect food grade produce in controlled environments (Brault et al. 1997; Mezgheni et al. 1998) but they have not been evaluated to protect silage in a natural, rain- and sun-exposed environment.

Holmes (1998) evaluated other covering products which could be mixed when feeding. After 112 days of storage in a 1.2 m tall, 0.20 m diameter cylinder, he reported dry matter losses in chopped alfalfa silage of 9.2% with a plastic cover, 10.2% with a 125 mm thick lime cover, 19.0% with a 125 mm

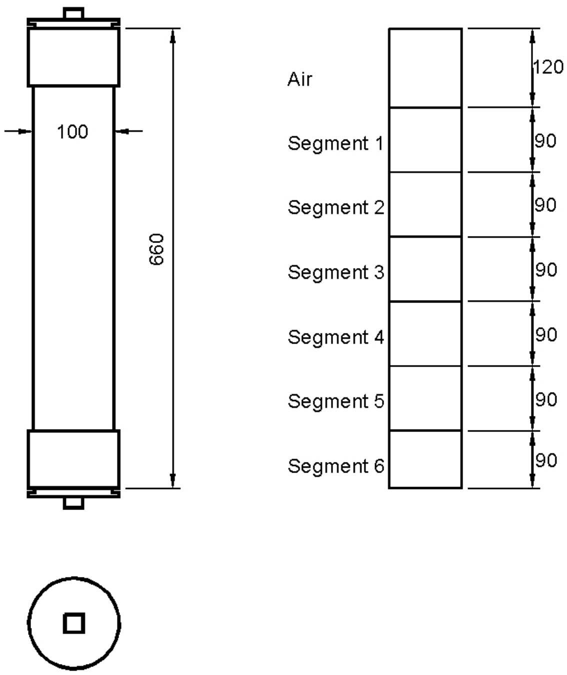

Fig. 1. Schematic view of a cylindrical mini-silo with a screw cap and relative location of the six segments within the silo. All dimensions in millimeters.

thick sawdust cover, 19.0% with an oatseed cover of unspecified thickness, 16.0% with a 12.5 mm thick molasses cover, and 29.9% without a cover. Holmes (1998) concluded that a tightly sealed plastic film remains the preferred method to exclude oxygen and to preserve silage in bunker silos.

Food industry wastes have also been considered to replace plastic film to protect silage. Apple pulp is regularly available in September and October from the apple-juice industry in some areas of eastern Canada. Peanut butter is sometimes downgraded and has been proposed by the food industry as a useful by-product for agriculture. While some of these by-products have been used on a trial basis on commercial farms (notably apple pulp in the Rougemont, Quebec area), little scientific evaluation exists on their efficiency as an air barrier. The objective of this experiment was to assess two organic products, apple pulp and peanut butter, as a covering material to protect silage.

MATERIALS and METHODS

Forage, silos, and covers

Timothy grass was mowed on June 12, 2000 at the boot maturity stage, at the Deschambault Research Farm, Deschambault, Québec. Windrows were left in the field to wilt for 24 h and picked up with a forage harvester set at a theoretical chop length of 9 mm. The chopped forage was brought to the laboratory at Université Laval and used to fill sixty mini-silos like the one illustrated on Fig. 1. Dimensions of a mini-silo were 100 mm inside diameter by 660 mm height (total volume of 0.0052 m^3).

Before filling each mini-silo, a 150-g sample of fresh forage was put aside to determine the initial moisture content by oven drying at 60˚C for 72 h according to standard S358.2 (ASAE 2000). Particle size was measured three times with 0.010 m^3 samples of the freshly chopped crop, before ensiling, according to standard method S424.1 (ASAE 2002).

Each mini-silo was filled in six successive segments of 90 mm high by 100 mm inside diameter. The mass within each segment was constant (425 g fresh) to correspond to a density of 600 kg wet mass/m^3. A manual-driven piston and weights were used to compress the forage to the specified height and density. Between each segment, a round vinyl screen was placed to facilitate segment separation after the conservation period.

The uppermost segment (called segment #1) was covered with one of the following six treatments: 1) an air-tight screw cap, the positive control, which included a 120-mm head-space of air initially present at the time of sealing; 2) no cover at all; 3) a thickness of 25 mm of apple pulp spread evenly with a spatula; 4) a thickness of 50 mm apple pulp; 5) a thickness of 2.5 mm of peanut butter; and 6) a thickness of 5 mm of peanut butter.

The apple pulp was obtained with a juice extractor (Jr Pro model, Juiceman Ltd., Mount Prospect, IL). Fresh apples were pressed to extract the juice. The remaining pulp was used to cover the designated mini-silos. The pulp had a density of 1070 kg/m^3 so a mass of 210 or 420 g was spread to obtain a thickness of 25 or 50 mm over the 100 mm diameter mini-silos. The pulp had an initial moisture of 80.8% on a wet basis (standard deviation, SD, of 0.53% based on four oven-dried samples).

The peanut butter was a food grade product (Creamy Plus, Briska Inc., Montréal, QC) with a density of 1325 kg/m^3. A mass of 26 or 52 g was spread to obtain a thickness of 2.5 or 5.0 mm. The chosen peanut butter thicknesses were 1/10 the thicknesses of the apple pulp on the basis of roughly equal costs for either organic cover, and on the assumption that the oily nature of peanut butter would provide a considerably more efficient air barrier than apple pulp. The peanut butter had an initial moisture content of 0.14% on a wet basis (SD of 0.18%, n = 4).

Sampling and analysis of silage

A total of 60 mini-silos was filled as described above, with ten mini-silos per cover treatment. Two silos (replications) from each treatment were opened and emptied at five time intervals: after 3, 7, 14, 21, and 42 days of storage. Each silage segment was handled separately. The total wet mass was measured, a 50 g sample was frozen for pH measurement and the remainder (about 375 g) was oven dried for moisture determination at 60˚C for 72 h (ASAE 2000). At the last opening, after 42 days of storage, a larger sample of 200 g was frozen for pH, acid detergent fibre (ADF), and neutral detergent fibre (NDF) determination. For the pH measurement, 20 g of silage was mixed into 200 mL of water for 20 min, and the electrode inserted in the liquid mixture (pH meter model 407 A/L, Orion Research, Cambridge, MA). ADF and NDF were measured with an ANKOM^{200} fibre analyzer (ANKOM Technology, Fairport, NY).

To evaluate cover efficiency, the total wet mass and the dry matter loss were compared over time for each segment. The wet mass and the dry matter loss were expressed in relative terms with respect to their initial values. The dry matter loss was estimated within each silo segment as:

$$L = 100 - \frac{m_f\left(100 - M_f\right)}{m_o\left(100 - M_o\right)} \quad (1)$$

where:

L = relative dry matter loss (% of initial dry matter),
m_o = initial wet mass in a segment,
m_f = final wet mass in a segment,
M_o = initial moisture content (%, wet basis). and
M_f = final moisture content (%, wet basis).

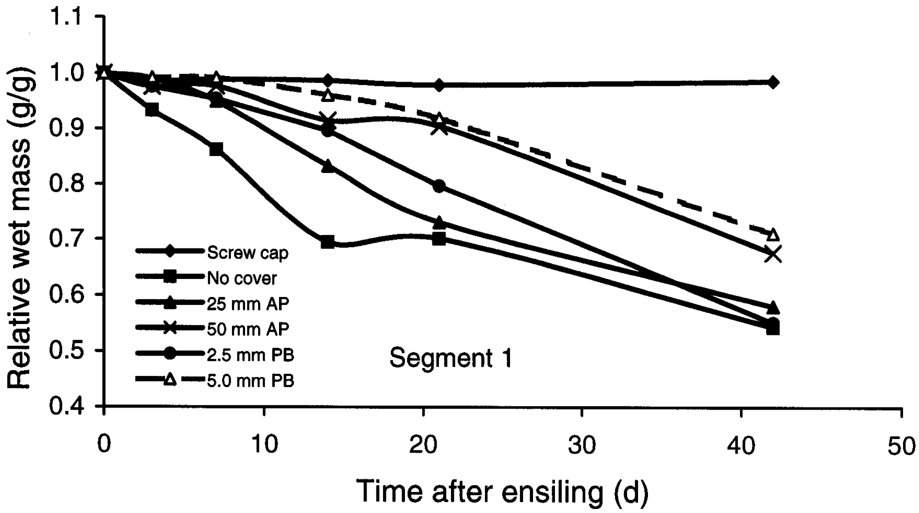

Fig. 2. Relative wet matter in uppermost segment (0 to 90 mm from surface) as a function of time and type of cover (AP = apple pulp, PB = peanut butter).

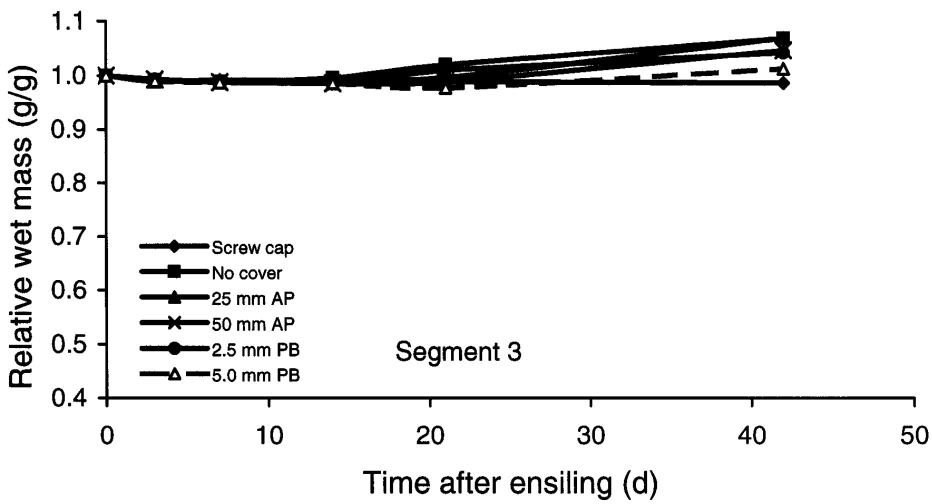

Fig. 3. Relative wet matter in the third segment (180 to 270 mm from surface) as a function of time and type of cover (AP = apple pulp, PB = peanut butter).

Statistical analyses were carried out with Excel software (MicroSoft) to compare treatments. The analysis of variance (ANOVA) was used to determine significant differences between treatments. If the ANOVA was significant at the 0.05 level, then the least significant difference (LSD) method was used to rank results.

RESULTS and DISCUSSION

The initial moisture content averaged 75.53% (wet basis) and was relatively uniform (SD of 0.34%, n = 60). The geometric mean particle length of the chopped forage was 8.22 mm with a geometric SD of 2.29 mm (n = 3).

Changes in wet mass

Figure 2 shows changes of wet mass in segment #1 (0 to 90 mm from the surface) for the six cover treatments during the 42-day experiment. Values are an average of two replications. Under the positive control screw cap cover, the relative mass remained very stable, decreasing by 1% after three days and by 2% after 42 days. Under the negative control without a cover, the relative wet mass decreased by 7% after 3 days and by 46% after 42 days. The decline of the relative wet mass with organic covers was between these two extremes. Thinner covers lost more mass in segment #1: 42% under 25 mm apple pulp and 45% under 2.5 mm peanut butter after 42 days. Mass declines were 32% under 50 mm apple pulp and 29% under 5 mm peanut butter after 42 days.

Figure 3 shows changes in wet mass in segment #3 located 180 to 270 mm below the surface. Wet mass declined by only 1% after 14 days under all covers. Differences between covers appeared later, with some #3 segments actually increasing in mass after 42 days. Segments #3 in silos without a cover and silos with 25 mm apple pulp both had an increase of 7% of wet mass after 42 days. Such an increase can be explained by water production during oxidation of the upper segments and downward migration of the water. Some segments in the negative control silos had relative moisture content increases as high as 12%.

When the six covers were compared statistically, the positive control (screw cap) preserved a higher level of wet mass than the five other covers (p = 0.05) in segment #1 after 42 days of storage. The positive control became superior to the negative control (no cover) after 3 days, to the 25 mm apple pulp after 7 days, to the 2.5 mm peanut butter after 21 days and to the two other organic covers (50 mm apple pulp, 5 mm peanut butter) after 42 days. Thicker organic covers delayed air infiltration but did not prevent it.

Changes in dry mass

Changes in dry mass were estimated by Eq. 1 based on changes in wet mass and moisture content. Table 1 presents the DM (dry

Table 1. Estimated dry matter loss (%) after 42 days of storage in mini-silos.

Segment	Screw cap	No cover	25 mm apple pulp	50 mm apple pulp	2.5 mm peanut butter	5.0 mm peanut butter
1	1.22	37.61	N/A*	N/A*	70.60	71.83
2	0.52	45.62	47.00	17.77	30.45	16.82
3	0.05	1.87	0.63	-0.88	3.26	1.47
4	0.37	-1.02	3.97	8.36	-1.48	2.86
5	3.21	0.31	3.92	-5.31	2.17	1.51
6	0.50	12.36	0.39	0.35	-4.25	-1.30
Average**	0.98	16.33	17.15	6.34	16.79	15.53

* Dry matter loss estimate is not available in the first segment with an apple pulp cover because of mixing and the inability to obtain an accurate estimate of forage moisture content.

**Average dry matter loss for 6 segments (540 mm height). Loss for apple pulp covers estimated by assuming loss in segment 1 equal to loss in segment 2.

matter) loss estimates after 42 days of storage. There were a few negative values which can be explained either as experimental error due to overestimation of the final dry matter (i.e. underestimation of the final moisture content) or due to migration of dry matter from one segment to another by leaching of soluble nutrients.

The DM loss in each of the six segments and for each of the five measurement periods (3, 7, 14, 21, and 42 days after ensiling) was compared between the six cover treatments by analysis of variance. The positive control (screw cap) had lower DM loss than the five other covers in 116 comparisons out of 150 (the positive control compared to the 5 other covers x 5 periods x 6 segments); 24 of theses differences were statistically significant at $p = 0.05$. Compared to the screw cap cover, the treatment without a cover had significantly higher DM losses most often (7 times) followed by the thin peanut butter cover (6 times), the thin apple pulp cover (5 times) and the thicker peanut butter and apple pulp covers (4 times each).

In the positive control silo, the DM loss ranged from 0.1 to 3.2% in the six segments and averaged 1.0%. In the negative control silo without a cover, the DM loss ranged from 0% in the lower segments to 45.4% in the top segment and averaged 16.3%. Precise loss could not be estimated in segment #1 with apple pulp (either 25 or 50 mm thickness) because there was some mixing of the silage and the cover at the time of emptying the silo. In silos covered with 25 mm thick apple pulp, losses ranged from 0 to 47% in segments #2 to 6; the average loss over six segments was estimated as 17.2% by assuming that DM loss of segment #1 was the same as DM loss in segment #2, which is probably an underestimation of total loss. Therefore, the 25 mm thick apple pulp had as much DM loss as no cover at all. In the silos covered with 50 mm apple pulp, the DM loss ranged from 0 to 18% in segments #2 to 6; the average loss over six segments was estimated as 6.3%. The thicker apple pulp cover provided a greater protection from air infiltration and oxidation than no cover at all. The two peanut butter covers provided a poor protection of silage, with very high losses above 70% in the first segment. The thicker peanut butter reduced slightly DM loss compared to the thinner peanut butter cover (15.5% vs 16.8%), but both practically provided no more protection than no cover at all (16.3% DM loss).

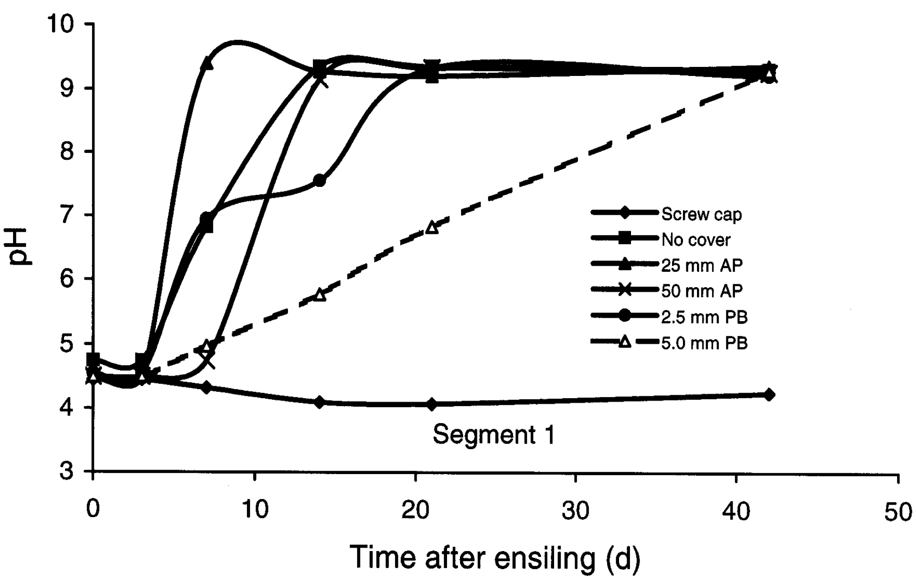

Fig. 4. Silage pH in the uppermost segment (0 to 90 mm from surface) as a function of time and type of cover (AP = apple pulp, PB = peanut butter).

Changes in silage pH and fibre content

Figure 4 illustrates changes of silage pH in segment #1 over time for the six cover treatments. With the screw cap positive control cover, the silage fermented and stabilized quickly at a pH of 4.1. This is a typical pH level for a well-sealed, homolactic fermentation of grass silage with a moisture content of 75% (McDonald et al. 1991). With the negative control, i.e. without a cover, silage pH rose above 9.0 by day 14. This increased pH is a result of aerobic deterioration of amino acids and the production of ammonia (McDonald et al. 1991). An even more rapid rise of pH was observed by day 7 in mini-silos covered with 25 mm of apple pulp. When mini-silos were covered with 50 mm of apple pulp,

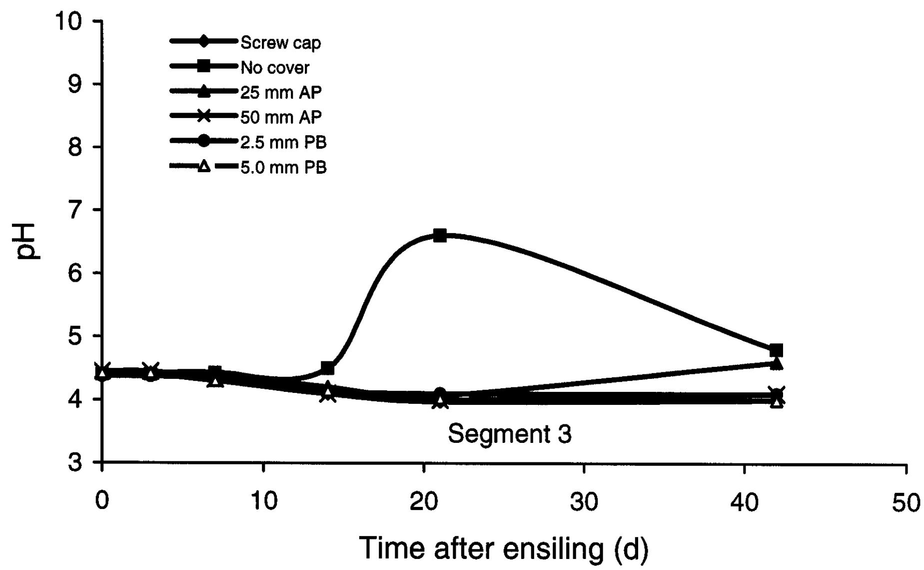

Fig. 5. Silage pH in the third segment (180 to 270 mm from surface) as a function of time and type of cover (AP = apple pulp, PB = peanut butter).

more time elapsed before a similar pH rise was observed. With peanut butter covers, the pH rise was further delayed but after 42 days, pH in segment #1 had reached a level above 9.0 indicating deamination and the production of ammonia.

Figure 5 shows changes in pH for segment #3. There are fewer signs of deterioration after 42 days at this level (180 to 270 mm below the surface) than there were in the upper segment #1. However, the negative control (no cover) and 25 mm apple pulp cover start showing signs of deterioration even at this silage depth with pH slowly rising after 42 days. One would expect further deterioration for exposure times beyond 42 days.

NDF and ADF were measured on silage samples after 42 days of storage, and results are reported in Tables 2 and 3. The overall average values for the six segments and six covers were 56.3% NDF and 40.6% ADF. In the case of NDF, there was no significant difference between covers in segments #1, 3, 4, 5, and 6. Only segment #2 showed a significant difference in NDF between covers: the two treatments with apple pulp cover (25 and 50 mm thicknesses), along with the screw cap cover, had a lower NDF than the three other treatments (no cover, peanut butter at two thicknesses). The forage crop is mainly composed of carbohydrates: sugar, starch, pectin, hemicellulose, cellulose, and lignin (McDonald et al 1991). The NDF includes hemicellulose, cellulose, and lignin whereas the ADF includes cellulose and lignin. When important oxidation losses occur, the non-fibre carbohydrates (sugar, starch, pectin) are usually the

Table 2. Neutral detergent fibre (NDF, %) after 42 days of storage in mini-silos.

Segment	Screw cap	No cover	25 mm apple pulp	50 mm apple pulp	2.5 mm peanut butter	5.0 mm peanut butter
1	56.85	55.59	53.19	52.52	54.49	56.17
2	56.18 [a]*	58.64 [b]	54.16 [a]	56.02 [a]	58.85 [b]	58.50 [b]
3	56.25	58.89	57.63	56.90	57.10	58.40
4	55.00	56.78	56.98	56.98	55.96	56.33
5	56.08	55.84	55.91	55.49	55.68	56.35
6	56.51	56.47	56.68	55.83	55.81	56.37

* Treatments on the same horizontal line (single segment) with the same letter are not statistically different (p=0.05) by the least significance difference (LSD) test.

Table 3. Acid detergent fibre (ADF, %) after 42 days of storage in mini-silos.

Segment	Screw cap	No cover	25 mm apple pulp	50 mm apple pulp	2.5 mm peanut butter	5.0 mm peanut butter
1	36.34 [a]*	44.24 [d]	41.79 [cd]	40.18 [bc]	40.69 [bc]	38.49 [ab]
2	35.89 [a]	44.11 [d]	41.16 [bc]	41.09 [bc]	43.67 [cd]	39.53 [b]
3	36.66	38.82	37.70	35.89	36.02	36.29
4	35.61	35.73	36.52	35.85	35.29	36.82
5	36.36	36.34	35.85	35.79	35.57	36.43
6	36.30	39.14	35.98	36.26	35.49	37.03

* Treatments on the same horizontal line (single segment) with the same letter are not statistically different (p=0.05) by the least significance difference (LSD) test.

first to be consumed, followed by hemicellulose. This can explain partly why the concentration of ADF might increase while the concentration of NDF might decrease.

In the case of ADF, there were significant differences in the first two segments (Table 3). The fibre content remained lowest in the well protected silage under the screw cap (36.1%). ADF reached the highest level (44.2%) in the uncovered silo as a result of important oxidation and loss of soluble nutrients. Intermediate levels of ADF were found in the first two segments of other mini-silos as follows: 39.0% with the 5 mm peanut butter cover, 40.6% with the 50 mm apple pulp cover, 41.5% with the 25 mm apple pulp cover, and 42.2% with the 2.5 mm peanut butter cover. Fibre content, especially ADF, increased in the first two segments for all cover treatments except the screw cap. The organic covers used in this experiment did not prevent air infiltration, oxidation, and deterioration of the silages. Considerably thicker organic covers than the 50 mm for apple pulp used here might delay air infiltration long enough to minimize storage losses under certain circumstances. The use of thicker covers and longer storage periods could be the object of further investigation.

CONCLUSIONS

Organic covers composed of apple pulp (thicknesses of 25 and 50 mm) and peanut butter (thicknesses of 2.5 and 5 mm) were not efficient in protecting grass silage against air infiltration and dry matter (DM) loss. These covers delayed the air infiltration by a week or two, as compared to a silo without any cover. DM loss was quite important with organic covers, sometimes as much as 70% within 42 days in the first segment which corresponded to the top 90 mm layer. Layers below 180 mm were affected very little by air infiltration and DM loss during the 42-day experimental period with or without a cover. Organic covers composed of apple pulp or peanut butter, with thicknesses in the given experimental range, cannot be recommended to protect silage because of considerable air infiltration and oxidation losses.

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