Abstract: Costs of covering green forage bales by various methods. There are presented costs of covering partially dried green forage bales designed for silage; the cost structure include machine, labour, fuel and foil costs. In covering cylindrical bales the highest cost was found for storing bales in the foil bags CW (68.0 PLN·t⁻¹ d.m.), while the least cost for application of in-line wrapping machine CSz (30.90 PLN·t⁻¹ d.m.). In covering rectangular bales the most expensive was wrapping of single bales PP (59.80 PLN·t⁻¹ d.m.), while the least expensive was application of in-line wrapping machine PSz (30.40 PLN·t⁻¹ d.m.). In the cost structure the highest share was found for the foil cost, while the remaining cost components were small.

Key words: green forage, bale covering, specific costs.

INTRODUCTION

In references one can find papers aimed at determination of inputs (energy, labour and costs) on the harvest and conservation of low green forage for silage [Nazarow 2001; Gach 2003; Gach et al. 2007]. The results and analyses of carried out investigations on these inputs showed that in their structure (especially costs) a substantial share is taken by operations connected to storing and protection of plant material silage against the access of air [Gach 2003; Gach et al. 2007]. The papers on investigations of wrapping machines can be found also [Bulinski et al. 1994; Waszkiewicz 1994]. However, there is the lack of investigations and analyses on operations connected with covering of bales with consideration to all possible methods hitherto used in practice [Skonieczny 2009]. This work aimed at learning of costs involved in this particular operation at various forms of covering bales.

MATERIAL AND METHODS

In order to determine exploitation indices of the outfits and machines and their fuel consumption the investigations were carried out under production conditions during making silage in the foil covered bales, with the use of Standards:
PN-90/R-55003, BN-77/9195-02 and BN-76/9195-01. Fuel consumption was determined by the full-tank method.

The material-economic inputs on particular technologies of silage production of meadow grass were determined according to valid methodology and methods elaborated in IBMER; they were adapted and expanded with the elements based on own theoretical analyses [Muzalewski and Olszewski 2000; Muzalewski 2008; Skonieczny 2009; Gach and Skonieczny 2010].

The costs were calculated with the use of developed computer program and basing on the presented methodology; the foil consumption was determined with the use of theoretical dependences.

In calculations there were also used the values of parameters and technical and exploitation indices of applied outfits and machines as well as other parameters and indices connected with plant materials and auxiliary materials, mainly for wrapping bales.

In the analysis there were considered all practically used methods for wrapping bales with application of the following outfits or machines:
- **CP** – wrapping of single cylindrical bales with wrapping machine Z 274 Sipma SA in Lublin with tractor Ursus 335,
- **PP** – wrapping of single or double rectangular bales with tractor trailed wrapping machine McHalle 998 with tractor John Deere 6210,
- **CSz** – wrapping of cylindrical bales with in-line wrapping machine Stretch-O-Matic with own internal combustion engine,
- **PSz** – wrapping of rectangular bales with in-line wrapping machine Stretch-O-Matic,
- **CW** – covering of cylindrical bales in foil bags with the use of loader AG BAG BALLERINA with own internal combustion engine,
- **PW** – covering of rectangular bales in foil bags with the use of loader AG BAG SOARE BALE BAGGER with own internal combustion engine.

The technical and exploitation parameters of used machines are listed in Table 1.

The price and mass of foil used in bale covering are presented in Table 2.

Additional information on the values of parameters and indices taken to calculations are presented in Table 3.

Additional values taken in calculations include the cost of man-hour 12 PLN·h–1 and the cost of fuel 4.38 PLN·dm–3. The yield of green forage partially dried to relative moisture content of 60% was assumed as 9 t·ha–1, and recalculated to dry matter mass to 3.6 t·ha–1.

### COST ANALYSIS OF COVERING BALES

Figure 1 presents the costs of bale covering related to dry matter mass unit of green forage in bales, with consideration to cost structure (cost of machine, labour, fuel and foil). The following assumptions were made: cylindrical bales of diameter 1.5 m and width 1.2 m, rectangular bales of identical cross section 1.2 m × 0.7 m and various length. Six layers of foil was taken in all wrapping methods. Besides, different density of bales was introduced: 0.18 t·d.m.·m–3 for cylindrical bales, and 0.21 t·d.m.·m–3 for rectangular bales.

Considering the total cost values one can find the highest cost (68.0 PLN·t–1
The similar cost was found for wrapping of single cylindrical bales CP (60.80 PLN·t⁻¹ d.m.) and rectangular bales PP (59.70 PLN·t⁻¹ d.m.), as well as for in-line wrapping of cylindrical bales CSz (30.90 PLN·t⁻¹ d.m.) and rectangular bales PSz (30.40 PLN·t⁻¹ d.m.). The least cost was found for storing cylindrical bales in foil bags (43.30 PLN·t⁻¹ d.m.). The foil cost dominates the input structure; the highest values

### TABLE 1. Technical and exploitation parameters of used machines

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Tractor U 3512</td>
<td>34.6</td>
<td>–</td>
<td>–</td>
<td>79 910</td>
<td>URSUS</td>
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<tr>
<td>Tractor John Deere 6210</td>
<td>61</td>
<td>–</td>
<td>–</td>
<td>220 000</td>
<td>John Deere</td>
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<tr>
<td>Wrapping machine Z-274</td>
<td>–</td>
<td>diameter 1.2–1.5</td>
<td>470</td>
<td>9 150</td>
<td>Sipma SA Lublin</td>
</tr>
<tr>
<td>Wrapping machine McHale 998</td>
<td>–</td>
<td>width 1.2 height 1.4 length 1.8</td>
<td>3800</td>
<td>198 000</td>
<td>McHale</td>
</tr>
<tr>
<td>In-line general-purpose wrapping machine Stretch-O-Matic – cylindrical bales – rectangular bales</td>
<td>9.6</td>
<td>diam. &lt; 1.52 1.68 × 1.25</td>
<td>1250</td>
<td>70 272</td>
<td>SaMasz Białystok</td>
</tr>
<tr>
<td>Loader for cylindrical bales AG BAG BALLERINA</td>
<td>6.6</td>
<td>bags: diameter 1.2 or 1.5</td>
<td>2650</td>
<td>122 000</td>
<td>AG BAG</td>
</tr>
<tr>
<td>Loader for rectangular bales AG BAG SQUARE BALE BAGGER</td>
<td>6.6</td>
<td>bags: diameter 2.4 or 2.7</td>
<td>2800</td>
<td>164 500</td>
<td>AG BAG</td>
</tr>
</tbody>
</table>

Source: Gromadzki 2008, information of manufacturers or importers.

### TABLE 2. Specification of foil for covering green forage bales

<table>
<thead>
<tr>
<th>Item</th>
<th>Mass [kg]</th>
<th>Purchase price [PLN]</th>
<th>Manufacturer Importer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foil in roll (width 0.5 m, length 1800 m)</td>
<td>21.5</td>
<td>220</td>
<td>Silotitte</td>
</tr>
<tr>
<td>Foil in roll (width 0.75 m, length 1500 m)</td>
<td>26.9</td>
<td>275</td>
<td>Silotitte</td>
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<tr>
<td>Bag TDF 415 (diam. – 1.2 m, length – 45 m)</td>
<td>21</td>
<td>640</td>
<td>AG BAG</td>
</tr>
<tr>
<td>Bag TDF 515 (diam. – 1.5 m, length – 45 m)</td>
<td>25</td>
<td>800</td>
<td>AG BAG</td>
</tr>
<tr>
<td>Bag TDF 815 (diam. – 2.4 m, length – 45 m)</td>
<td>64</td>
<td>1200</td>
<td>AG BAG</td>
</tr>
<tr>
<td>Bag TDF 915 (diam. – 2.7 m, length – 45 m)</td>
<td>71</td>
<td>1350</td>
<td>AG BAG</td>
</tr>
</tbody>
</table>

Source: Information materials of manufacturers or importers.
TABLE 3. Exploitation indices of applied machines

<table>
<thead>
<tr>
<th>Machine</th>
<th>Exploitation period $T_b$ [hour]</th>
<th>Exploitation period $T_{lat}$ [year]</th>
<th>Covering output $W_{07}$ [bale·h$^{-1}$]</th>
<th>Fuel consumption $[\text{dm}^3\cdot\text{h}^{-1}]$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractor U 3512</td>
<td>10 000</td>
<td>20</td>
<td>–</td>
<td>–</td>
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<tr>
<td>Tractor JD 6210</td>
<td>12 000</td>
<td>20</td>
<td>–</td>
<td>2.9</td>
</tr>
<tr>
<td>Wrapping machine Z-274</td>
<td>2 000</td>
<td>10</td>
<td>18</td>
<td>10.8</td>
</tr>
<tr>
<td>Wrapping machine McHale 998</td>
<td>3 500</td>
<td>15</td>
<td>32</td>
<td>26.8</td>
</tr>
<tr>
<td>In-line wrapping machine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stretch-O-Matic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>– cylindrical bales</td>
<td>3 500</td>
<td>15</td>
<td>30</td>
<td>16.2</td>
</tr>
<tr>
<td>– rectangular bales</td>
<td>3 500</td>
<td>15</td>
<td>46</td>
<td>27</td>
</tr>
<tr>
<td>Loader AG BAG BALLERINA</td>
<td>3 500</td>
<td>15</td>
<td>30</td>
<td>16.2</td>
</tr>
<tr>
<td>Loader AG BAG SQUARE BALE BAGGER</td>
<td>3 500</td>
<td>15</td>
<td>38</td>
<td>35.2</td>
</tr>
</tbody>
</table>

Source: Muzalewski 2008, information of own investigations and analyses.

FIGURE 1. Costs of bale covering by various methods related to dry matter mass unit with consideration to cost structure (cost of machine, labour, fuel and foil): CP – D = 1.5 m; L = 1.2 m; i = 6; PP – B = 1.2 m; H = 0.7 m; L = 2.0 m; n$$_s$$ = 2; i = 6; CSz – D = 1.5 m; L = 1.2 m; n = 36; i = 6; PSz – B = 1.2 m; H = 0.7 m; L = 1.4 m; n$$_s$$ = 2; n = 64; i = 6; CW – d = 1.5; l = 45; D = 1.2 m; L = 1.2 m; n = 35; PW – d = 2.7 m; B = 1.2 m; H = 0.7 m; L = 2.2 m; n$$_s$$ = 3; n = 101; $${\gamma}_c$$ = 0.18 t·d.m.·m$^{-3}$; $${\gamma}_p$$ = 0.21 t·d.m.·m$^{-3}$.
occur in putting of cylindrical bales in foil bags CW (almost 59.00 PLN·t⁻¹ d.m.) that stands for 86.2% of total costs.

The lower foil costs were found for wrapping of single cylindrical bales CP (53.40 PLN·t⁻¹ d.m.) (87.8%), then PP (39.20 PLN·t⁻¹ d.m.) (66.1%) and PW (34.30 PLN·t⁻¹ d.m.) (78.3%). The least identical level of foil cost (about 25 PLN·t⁻¹ d.m.) was found for in-line wrapping machines CSz and PSz (over 80% of total costs).

The second place was taken by machine costs. The highest values were found for covering single rectangular bales PP (about 16 PLN·t⁻¹ d.m. – 26.8% of total costs), the least costs for CP method (3.50 PLN·t⁻¹ d.m. – 5.8% of total costs). In the remaining covering methods the single machines were used: in-line wrapping machine and the bale loaders. They were imported and their purchase prices were high; this influenced the specific costs: CSz and PSz – 4.50 PLN·t⁻¹ d.m. (about 14.5%), CW – 7.80 PLN·t⁻¹ d.m. (11.5%) and PW – 8.20 PLN·t⁻¹ d.m. (18.8%) of total costs.

The labour costs was determined assuming one operator of the outfit or machine. The highest labour costs were found for wrapping cylindrical bales CP (3.45 PLN·t⁻¹ d.m. – 5.7%), while the least for PW (0.83 PLN·t⁻¹ d.m. – 2.0%). The costs of the remaining methods were similar (about 1.05 PLN·t⁻¹ d.m.).

The highest fuel costs were found for wrapping the single rectangular bales with foil PP (3.35 PLN·t⁻¹ d.m. – 5.9%) and then CP (2.23 PLN·t⁻¹ d.m. – 3.7%).

CONCLUSIONS

1. In wrapping of cylindrical bales the highest costs occurred in bale storing in foil bags CW (68.0 PLN·t⁻¹ d.m.), the medium costs in wrapping of single cylindrical bales CP (60.80 PLN·t⁻¹ d.m.) and the least costs in application of in-line wrapping machine CSz (30.90 PLN·t⁻¹ d.m.).
2. In covering rectangular bales the most expensive was wrapping of single bales PP, where the cost of wrapping double bales with six layers of foil amounted to 59.80 PLN·t⁻¹ d.m., then covering cylindrical bales in the foil bags PW (43.30 PLN·t⁻¹ d.m.), and the least expensive was application of in-line wrapping machine PSz (30.40 PLN·t⁻¹ d.m.).
3. In the specific cost structure, with dominating share of foil costs and sometimes machine costs, the share of remaining cost components was minimal. The highest labour costs were found for wrapping cylindrical bales CP (3.45 PLN·t⁻¹ d.m. – 5.2%), and the least costs for PW (0.83 PLN·t⁻¹ d.m. – 2.0%). The costs of remaining methods were identical (about 1.05 PLN·t⁻¹ d.m.). The highest costs of fuel consumption were found for oil wrapping of double rectangular bales PP (3.55 PLN·t⁻¹ d.m. – 9.0%), and then for CP (2.20 PLN·t⁻¹ d.m. – 6.8%).
4. The least costs of covering both the cylindrical and rectangular bales with application of in-line wrapping machine encourage to carry out inve-
stigations and analyses, including determination of quality of the obtained fodder, aimed at explaining of the lack of wider practical interest in this method for wrapping bales.

REFERENCES


STRESZCZENIE: Koszty ponoszone przy różnych sposobach osłaniania bel. Celem pracy było określenie kosztów ponoszonych przy różnych sposobach osłaniania bel. Do obliczeń wykorzystywano wartości parametrów i wskaźników techniczno-eksploatacyjnych stosowanych agregatów i maszyn oraz innych parametrów i wskaźników dotyczących materiału roślinnego, jak również folii do osłaniania bel. Obraczenia kosztów dokonano z wykorzystaniem opracowanego programu komputerowego na podstawie przedstawionej metodyki. Określono koszty osłaniania bel dla wszystkich analizowanych sposobów w odniesieniu do jednostki masy suchej substancji zielonki w belach, z podaniem ich struktury, uwzględniającej: koszty maszyn, robocizny, paliwa i folii. Koszty określono dla różnych średnic bel, jak również zróżnicowanego zagęszczenia bel cylindrycznych (0,18 t s.m·m–3) i prostopadłościennych (0,21 t s.m·m–3).

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