ACTA SCIENTIARUM POLONORUM *Acta Sci. Pol., Agricultura 6(1) 2007, 13-22*

CHANGES IN THE CHEMICAL COMPOSITION OF MAIZE COBS DEPENDING ON THE CULTIVAR, EFFECTIVE TEMPERATURE SUM AND FARM TYPE

Agnieszka Szyszkowska, Józef Sowiński, Heliodor Wierzbicki
Wrocław University of Environmental and Life Sciences

Summary. The plant material taken for the study was collected from maize fields in Denmark. In total, maize cobs were collected from 58 fields of 15 farms (9 organic and 6 traditional ones). The plant material (97 samples) was divided according to the following criteria: maize cultivars, effective temperature sum (ETS) during growing period, type of farm (traditional and organic farms). The dry matter content of maize cob samples was determined as well as starch, neutral detergent fiber (NDF) and acid detergent fiber (ADF), phosphorus and magnesium content. The dry matter content was negatively correlated with NDF and ADF, but positively correlated with starch. A highly negative correlation of starch content with NDF and ADF was found.

Key words: maize, cobs, organic farms, ETS, cultivars, NDF and ADF content

INTRODUCTION

The acreage under maize production is crucial in many countries due to high dry matter and energy yield per area unit. Maize (grain, silage or green fodder) can be used as feed for all the farm animal species [Fitzgerald and Murphy 1999, Di Marco *et al*. 2002, Filya 2004, Jensen *et al.* 2005]. Diets for high-performance cows and pigs contain also silage made of maize cobs (with or without husks) and moist grain. [Ekinci & Broderick 1997, De Brabander *et al*. 1999, San Emeterio *et al*. 2000, Valadares *et al*. 2000, Schwarz & Preissinger 2000, Broderick *et al*. 2002].

Recently, much attention has been paid to an appropriate selection of maize hybrids allocated mainly for silage fed to dairy cows. As has been observed, maize cultivars differ in yield [Moss *et al*. 2001, Thomas *et al*. 2001], the percentage of corn cobs in the whole plant [Verbič *et al*. 1995, Thomas *et al*. 2001], the rate of the maize cob weight to the weight of grain [Johnson *et al*. 2002]. Many authors report on cultivar-specific differences affecting chemical composition, especially acid detergent fiber (ADF) and

Corresponding author – Adres do korespondencji: dr hab. Agnieszka Szyszkowska, Animal Nutrition and Forage Quality Department of Wrocław University of Environmental and Life Sciences in Wrocław, 38d Chełmońskiego, 51-630 Wrocław, e-mail: szysz@zoo.ar.wroc.pl

neutral-detergent fibre (NDF) contents [Verbič *et al*. 1995, Kuehn *et al*. 1999, Thomas *et al*. 2001, Johnson *et al*. 2002, Schwab *et al*. 2003], starch [Thomas *et al*. 2001, Schwab *et al.* 2003], protein [Kuehn *et al.* 1999, Thomas *et al*. 2001, Johnson *et al*. 2002] and minerals [Thomas *et al*. 2001]. Several hybrids studies identified also the differences in the degree of starch degradation in rumen [Barrière *et al*. 1997, Philippeau & Michalet-Doreau 1997] and *in vitro* digestibility of the organic matter [Philippeau & Michalet-Doreau 1997, Moss *et al*. 2001, Thomas *et al*. 2001].

Since there seems to be no data reported in literature on the chemical composition of maize cobs depending on the cultivar, effective temperature sum (ETS) and the type of farms, the authors of the present study decided to determine to what extent the three factors influence the dry matter, NDF, ADF, crude protein, starch, P, K and Mg content of this part of maize plants.

MATERIAL AND METHODS

The plant material taken for the study was collected from maize fields in Denmark in 2001. In total, maize cobs were collected from 58 fields of 15 farms (9 organic and 6 traditional ones). In total 240 samples were taken. The representative plant material (97 samples) was divided according to the following criteria:

- maize cultivar: Banguy (FAO 230), Buxxil (FAO 200), Crescendo (FAO 190), Manatan (FAO 220), Mixture (three cultivars Manatan, Crescendo, Tassilo), Tassilo (FAO 200),
- ETS during the growing season (1st group 35 samples, 2nd 37 samples and 3rd group 25 samples),
- type of farm (43 samples from traditional and 43 samples from organic farms).

Immediately after harvest, maize cobs were taken for the dry matter content determination. The results of the studies on maize production technologies, the condition of the plantations before and after harvest and maize yields were reported on in an earlier publication [Sowiński *et al.* 2002, Sowiński & Kristensen 2004]. On organic farms, organic fertilizers were used exclusively and NPK rates were as follows: 147 N, 38 P, 321 K, respectively. On the other hand, NPK rates on traditional farms were: 147 N, 47 P, 185 K, respectively. Planting dates on organic farms were one-week delayed as compared to the traditional ones. Mechanical weed control caused a 17.5% reduction in the number of maize plants before harvest dates. Maize was harvested when the kernels were at milk-dough stage.

The samples immediately after harvest were frozen. The dry matter content of maize cob samples was determined in a laboratory. The frozen material was cut into small pieces and dried in the ventilated oven at the temperature of 70°C for 48 hours at the Danish Institute of Agriculture, Foulum, Denmark. The plant material was prepared for further chemical analyses, which included: crude protein (Kjeldahl method) [AOAC 1990], starch content (enzyme-colorimetric method), NDF and ADF using the method described by Goering & Van Soest [1970] phosphorus and magnesium contents using the colorimetric method, potassium using the flame spectrophotometry method. Chemical analyses were performed at the Wrocław University of Environmental and Life Sciences.

Statistical analyses were made following the GLM procedure (*General Linear Models*) of the SAS system [2000]. The following linear model was used to test the significance of the effects on the variables studied:

$$Y_{ijkl} = \mu + System_i + Farm_j[System]_i + Cultivar_k[Farm_j[System_i]] + error_{ijkl}$$

where:

Y_{ijkl} – observation (dry matter, NDF, ADF, starch, protein, Mg, P),
μ – mean,
$System_i$ – organic vs. conventional, i = 1-2,
$Farm_j$ – farm within each system, j = 1-15,
$Cultivar_k$ – cultivar within each farm, k = 1-6,

The significance of differences between means (computed for respective groups: cultivar, system, ETS) of the analyzed variables was tested with the use of Duncan's Multiple Range Test. Since some cultivar groups were not numerous (a few observations for a given group), the limitation of at least 9 observations per group was imposed; this is how 6 cultivar groups were formed. Furthermore, the differences between groups were tested according to ETS (1st group – low < 2676, 2nd group – medium 2683 – 2777, and 3rd group – high > 2781).

RESULTS

The changes in the dry matter content of maize cobs ranged from 455 to 524 g (Table 1). The lowest dry matter content was found in Buxxil cultivars, while the highest – in the cultivar of Tassilo. The differences between them were significant. Highly significant differences in crude protein content were found between the cultivars of Banguy (76 g) and Crescendo (88 g). The starch content ranged from 536 g (Manatan) to 559 g (Buxxil). ADF content in maize cobs ranged from 87 g (Banguy, Buxxil) to 94 g (Tassilo), while NDF was from 255 to 272 g, depending on the cultivar.

Highly significant differences in the dry matter content, starch and NDF were found between ETS groups. Maize cobs of the cultivars which represented the third ETS group were characterized by significantly higher dry matter content (544 g) and starch content (573 g), while NDF content (248 g) was lower, as compared with the other groups.

Maize cobs collected from traditional farms demonstrated higher dry matter content than on organic farms (526 g and 489 g, respectively). Other components were not affected by the type of farms.

The dry matter content (Fig. 1) was negatively correlated with NDF (r = - 0.441) and ADF (r = -0.326), but positively correlated with starch (r = 0.442). A highly negative correlation of starch with NDF (r = -0.930) and ADF (r = -0.510) was found (Fig. 2-3). An increase in starch content in the maize cob (Fig. 4) was negatively correlated with crude protein (r = -0.362). ETS had a significant effect on the dry matter, starch and NDF content.

Table 1. Changes in the content of dry matter, crude protein, starch, ADF and NDF in the cobs with husks, g·kg^{-1} dry matter
Tabela 1. Zmiany zawartości suchej masy, białka ogólnego, skrobi, ADF i NDF w kolbach z liśćmi okrywowymi, g·kg^{-1} suchej masy

Specification Wyszczególnienie	Dry matter Sucha masa	Crude protein Białko ogólne	Starch Skrobia	ADF	NDF
	g·kg^{-1} DM – g·kg^{-1} suchej masy				
Cultivar – Odmiana					
Banguy	511A	76B	549A	87A	270A
Buxxil	455B	83AB	559A	87A	255A
Crescendo	510A	88A	543A	90A	272A
Manatan	509A	83AB	536A	89A	272A
Mixture	500A	83AB	547A	92A	270A
Tassilo	524A	79AB	558A	94A	264A
ETS – Suma temperatur efektywnych					
Low – Niska	483C	82A	544B	91A	271A
Medium – Średnia	516B	83A	541B	88A	272A
High – Wysoka	544A	81A	573A	93A	248B
Farm type – Typ gospodarstwa					
Traditional Konwencjonalne	526A	82A	550A	88A	267A
Organic Ekologiczne	489B	80A	553A	93A	265A

A, B, C – values in the columns with different letters differ significantly ($P \leq 0.01$) – A, B, C – wartości w kolumnach oznaczone różnymi literami różnią się statystycznie istotnie ($P \leq 0,01$)
* ETS during vegetation period: low < 2676, medium 2683-2777, high > 2781 – Suma temperatur efektywnych w okresie wegetacji: niskie < 2676, średnie 2683-2777, wysokie > 2781

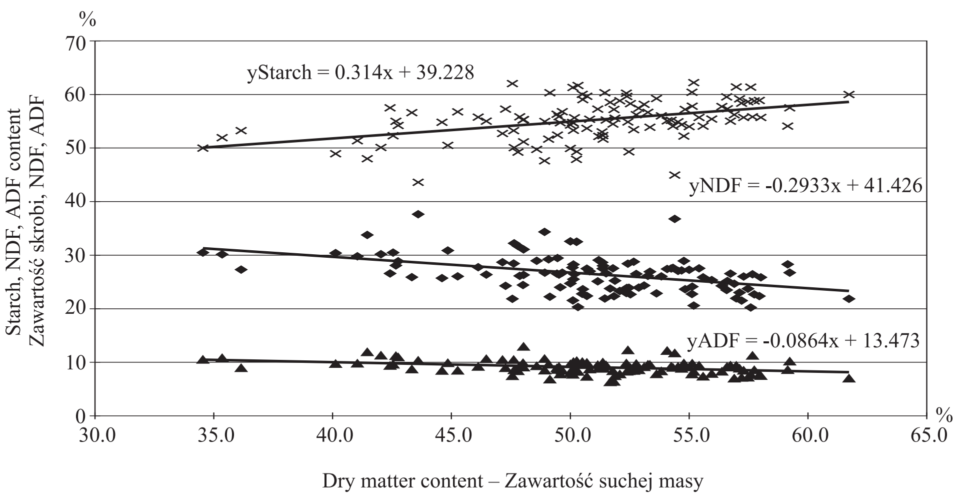

Fig. 1. Relationships between the dry matter content and NDF, ADF and starch content in the cobs
Rys. 1. Stosunek pomiędzy zawartością suchej masy, NDF, ADF a zawartością skrobi w kolbach

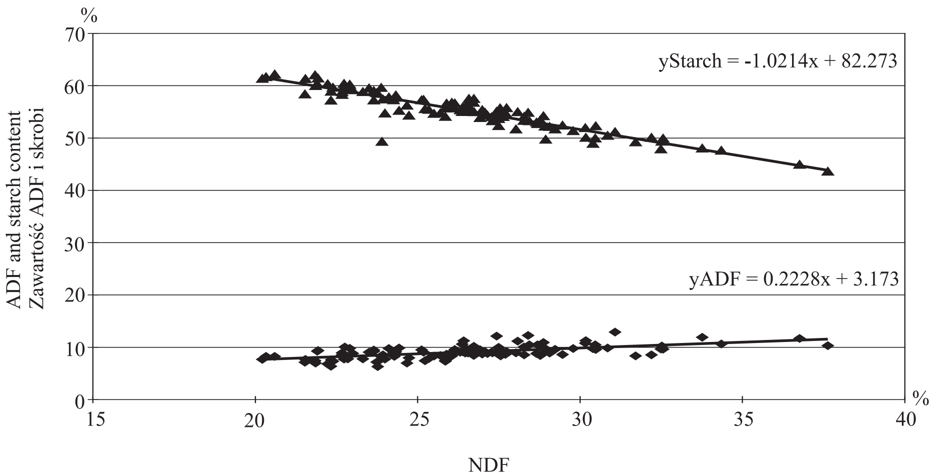

Fig. 2. Relationships between NDF and ADF, starch content in the cobs
Rys. 2. Stosunek pomiędzy NDF i ADF a zawartością skrobi w kolbach

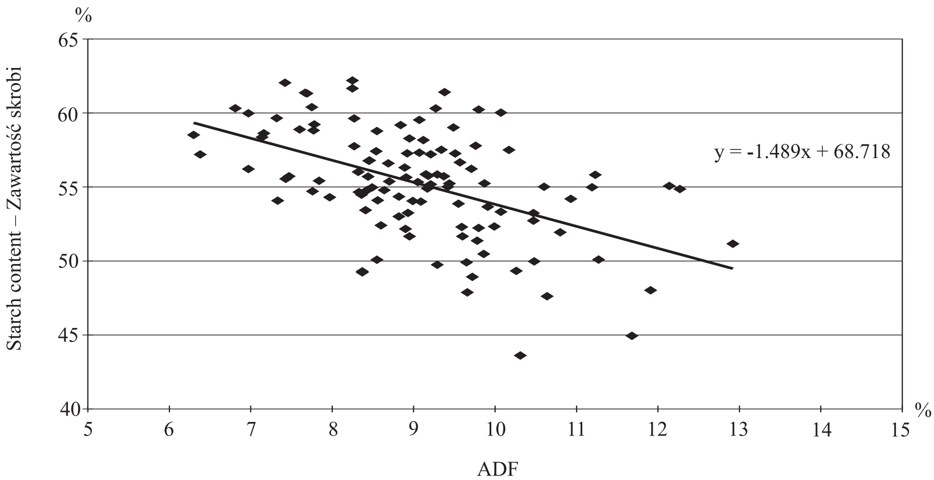

Fig. 3. Relationships between ADF and starch content in the cobs
Rys. 3. Stosunek pomiędzy ADF a zawartością skrobi w kolbach

Phosphorus, potassium and magnesium content in maize cobs depended on the maize cultivar (Table 2). The highest phosphorus content was found in Buxxil (2.6 g), while the lowest – in Crescendo (2.2 g), Banguy, Manatan (2.3 g) cultivars. Buxxil demonstrated a significantly higher potassium content (4.2 g) than other maize cultivars. Significant differences in magnesium content were found between Tassilo, Buxxil (1.7 g), Crescendo (1.8 g) and Banguy cultivars (2.3 g).

ETS affects the changes in mineral compounds content of maize cobs. Magnesium and potassium content of maize cobs varied, depending on the type of farm.

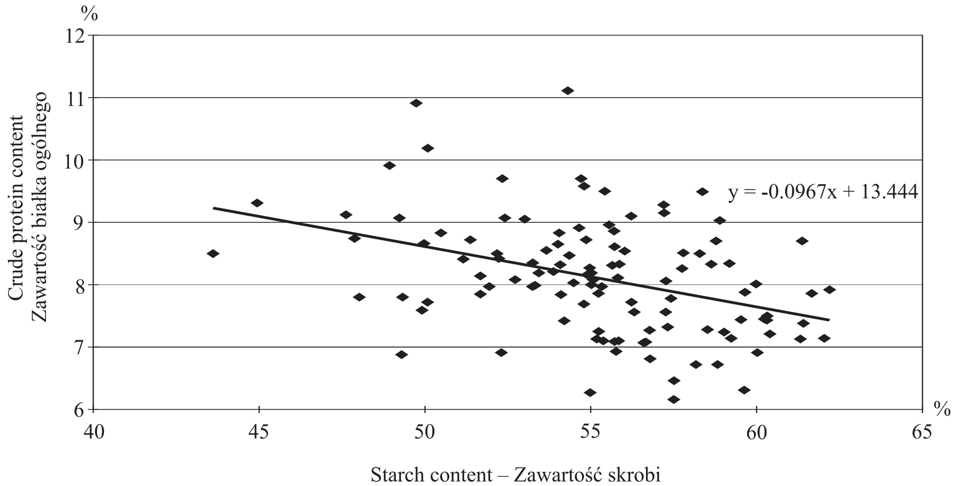

Fig. 4. Relationships between starch and crude protein content in the cobs
Rys. 4. Stosunek pomiędzy zawartością skrobi i białka ogólnego w kolbach

Table 2. Phosphorus, potassium and magnesium content in maize cobs with husks, g in kg DM (mean for cultivars, ETS and farm type)
Tabela 2. Zawartość fosforu, potasu i magnezu w kolbach kukurydzy z liśćmi okrywowymi, g w kg suchej masy (średnie wartości dla odmian, sumy temperatur efektywnych i typu gospodarstwa)

Specification Wyszczególnienie	Phosphorus – Fosfor	Potassium – Potas	Magnesium – Magnez
	$g \cdot kg^{-1}$ DM		
Cultivar – Odmiana			
Banguy	2.3B	2.5B	2.3A
Buxxil	2.6A	4.2A	1.7B
Crescendo	2.2B	3.0B	1.8B
Manatan	2.3B	3.2B	2.0AB
Mixture	2.4AB	3.1B	2.2A
Tassilo	2.4B	3.2B	1.7B
ETS* – Suma temperatur efektywnych			
Low – Niskie	2.4AB	3.5B	2.0A
Medium – Średnie	2.3B	2.9A	2.1A
High – Wysokie	2.5A	3.2AB	1.6B
Farm type – Typ gospodarstwa			
Traditional Konwencjonalne	2.3A	2.9B	2.0A
Organic Ekologiczne	2.4A	3.5A	1.7B

oznaczenia jak w tabeli 1 – for explanations, see Table 1

DISCUSSION

In many European countries most animal feed is made of maize, alfalfa, grasses and mixtures of legumes with grasses. The percentage of NDF ranged from 375 to 561 g, from 368 to 552 g, from 410 to 673 g, from 476 to 516 g and and of ADF – from 242 to 360 g, from 323 to 480 g, from 274 to 673 g, from 310 to 331 g, respectively, when converted into the dry matter of silage made of maize, alfalfa, grass and a grass-clover mixture silage [Bosch *et. al.* 1992, De Boever *et. al*. 1993, Fitzgerald and Murphy 1999, San Emeterio *et al.* 2000, Di Marco *et. al.* 2002, Beauchemin *et. al*. 2003]. According to NRC [1983] and Nocek [1997], the dry matter content in dairy cattle diets should contain from 250 to 300 g of NDF, from 190 to 240 g of ADF and from 300 to 400 g of starch, which should undergo decomposition in the rumen at a rate of 50-70 %. As compared with the total crop maize silage, CCM contained more DM, starch, but less fiber, NDF and ADF [De Brabander *et al.* 1999]. The results of the study show that cobs of maize cultivars under investigation varied in dry matter (455-524 g), NDF (255-272 g), ADF (87-94 g), starch (536-559 g), magnesium (1.7-2.3 g), phosphorus (2.2-2.6 g) content. The feeding value of maize cultivars is related to grain to stover ratio [Barrière *et al.* 1997]. The optimal grain content should be about 46% and starch about 30%. Most cereal grains show a low content of ADF and NDF, for example, in barley the content of ADF ranged from 55 to 80 g and the content of NDF – from 252 to 308 g [Ovenell & Nelson 1992, Ramsey *et al.* 2001, Beauchemin *et. al.* 2003]. Silage made from moist maize cobs used for cow feeding provide not only a high starch amounts as well as fiber fractions which help defining the diet recommended by Nocek [1997]. Present study shows a high negative correlation of starch with NDF (r = -0.930) and ADF (r = -0.510). Starch degradation also depends on cultivar, grain maturity (dry matter content) and processing technologies [San Ematerio *et al*. 2000, Kurtz *et al*. 2003].

The nutritional value of whole maize plants and the maize cob alone used for silage depends not only on the chemical composition typical for a given cultivar but also on the location of maize plantations, weather conditions (ETS), fertilization, maturity at harvest and mechanical processes used for grinding before silage-making [Ekinci *et al*. 1997, Thomas *et al*. 2001, Johnson *et al*. 2002, Jensen *et al*. 2005]. ADF content decreased with increased fertilization. ADF and NDF contents were negatively correlated with the grain yield as well as the cob content (Moss *et al.* 2001). The results obtained in the present study show the effect of ETS on the dry matter content, NDF and starch in maize cobs. Maize cobs collected from two different types of farms (traditional versus organic ones) varied in dry matter (526 versus 489 g), and chemical composition ADF (88 versus 93 g), magnesium (2.0 versus 1.7 g). Barrière *et al*. [1997] reported on the fertilizer use also affecting maize yields and, consequently, the total protein content of whole maize cobs.

CONCLUSIONS

1. Forage made of maize cobs with husk showed the NDF content meeting the dairy cattle diets requirements, whereas the content of ADF was too low and the content of starch exceeded the required values.

2. The content of dry matter in cobs was positively correlated with the content of starch, and negatively – with the content of NDF and ADF fractions.

3. The cultivars tested did not differ in ADF, NDF and starch content in cobs. ETS increased the starch content and decreased the content of NDF fraction.

4. The mineral composition depended on the cultivar, ETS and the farm type.

REFERENCES

AOAC, 1990. Official Methods of Analysis, Association of Official Analytical Chemists 15th Edition. Washington, DC

Barrière Y., Argillier O., Michalet-Doreau B., Hebert Y., Guingo E., Gianffret C., Émile J.C., 1997. Relevant traits, genetic variation and breeding strategies in early silage maize. Agronomie 17, 395-411.

Beauchemin K.A., Yang W.Z., Rode L.M., 2003. Effects of particle size of alfalfa-based dairy cow diets on chewing activity, ruminal fermentation, and milk production. J. Dairy. Sci. 86, 630-643.

Bosch M.W., Lammers-Wienhoven S.C.W., Bangma G.A., Boer H., van Adrichem P.W.M., 1992. Influence of stage of maturity of grass silages on digestion processes in dairy cows. 2. Rumen contents, passage rates, distribution of rumen and faecal particles and mastication activity. Livest. Prod. Sci. 32, 265-281.

Broderick G.A., Mertens D.R., Simons R., 2002. Efficacy of carbohydrate sources for milk production by cows fed diets based on alfalfa silage. J. Dairy Sci. 85, 1767-1776.

De Brabander D.L., De Boever J.L., De Smet A.M., Vanacker J.M., Boucque C.V., 1999. Evaluation of the physical structure of fodder beets, potatoes, pressed beet pulp, brewers grains and corn cob silage. J. Dairy Sci. 82, 110-121.

De Boever J.L., De Smet A., De Brabander D.L., Boucque C.V., 1993. Evaluation of physical structure. 1. Grass silage. J. Dairy Sci. 76, 140-153.

Di Marco O.N., Aello M.S., Nomdeden M., Van Houtte S., 2002. Effect of maize crop maturity on silage chemical composition and digestibility [*in vivo*, *in situ and in vitro*]. Anim. Feed Sci. Technol. 99, 37-43.

Ekinci C., Broderick G.A., 1997. Effect of processing high moisture ear corn on ruminal fermentation and milk yield. J. Dairy Sci. 80, 3298-3307.

Filya I., 2004. Nutritive value and aerobic stability of whole crop maize silage harvested at four stages of maturity. Anim. Feed Sci. Technol. 116, 141-150.

Fitzgerald J.J., Murphy J.J., 1999. A comparison of low starch maize silage and grass silage and the effect of concentrate supplementation of the forages or inclusion of maize grain with the maize silage on milk production by dairy cows. Livest. Prod. Sci. 57, 95-111.

Goering J.K., Van Soest P.J., 1970. Forage fibre analysis [apparatus, reagents, procedures, and some applications]. Agric. Handbook No. 379. ARS-USDA, Washington, DC.

Jensen C., Weisbjerg M.R., Nørgaard P., Hvelplund T., 2005. Effect of maize silage maturity on site of starch and NDF digestion in lactating dairy cows. Anim. Feed Sci. Technol. 118, 279-294.

Johnson L.M., Harrison J.H., Davidson D., Robutti J.L., Swift M., Mahanna W.C., Shinners K., 2002. Corn silage management. I. Effects of hybrid, maturity and mechanical processing on chemical and physical characteristic. J. Dairy Sci. 85(4), 833-853.

Kuehn C.S., Linn J.G., Johnson D.G., Jung H.G., Endres M.I., 1999. Effect of feeding silages from corn hybrids selected of leafiness or grain to lactating dairy cattle. J. Dairy Sci. 82, 2746-2755.

Kurtz H., Ettle T., Schwarz F.J., 2003. Ruminale Abbaubarkeit von Maisstärke – Einfluss von Kornreife und Konservierungsform. Mais. 2, 72-74.
Moss B.R., Reeves D.W., Lin J.C., Torbert H.A., McElhenney W.H., Mask P., Kezar W., 2001. Yield and quality of three corn hybrids as affected by broiler litter fertilization and crop maturity. Anim. Feed Sci. Technol. 94, 43-56.
NRC, 1983. Nutrient Requirements of Dairy Cattle. 6th ed., National Academy Press Washington DC.
Nocek J.E., 1997. Bovine acidosis: implications on laminitis. J. Dairy Sci. 80, 1005-1028.
Ovenell K.H., Nelson M.L., 1992. Feedlot performance, carcass characteristics of steers, and digestibility of diets containing different barley cultivars. Proc. West. Sect. Am. Soc. Anim. Sci. 43, 35-46.
Philippeau C., Michalet-Doreau B., 1997. Influence of genotype and stage of maturity of maize on rate of ruminal starch degradation. Anim. Feed Sci. Technol. 68, 25-35.
Ramsey P.B., Mathison G.W., Goonewardene L.A., 2001. Relationships between ruminal dry matter and starch disappearance and apparent digestibility of barley grain. Anim. Feed Sci. Technol. 94, 155-170.
SAS User's Guide, 2000. Version 8.0 Edition. SAS Institute Inc. Cary, NC.
San Emeterio F., Reis R.B., Campos W.E., Satter L.D., 2000. Effect of coarse or fine grinding on utilization of dry or ensiled corn by lactating dairy cows. J. Dairy Sci. 83, 2839-2848.
Schwab E.C., Shaver R.D., Lauer J.G., Coors J.G., 2003. Estimating silage energy value and milk yield to rank corn hybrids. Anim. Feed Sci. Technol. 109, 1-18.
Schwarz F.J., Preissinger W., 2000. CCM und LKS in Milchviehrationen. Mais. 1, 12-15.
Sowiński J., Kristensen I.S., E Hermansen J., 2002. A field study of maize yield on mixed organic and conventional dairy farms in Denmark in 2001. Proceeding of Scientific Aspects of Organic Farming. Jelgava, 114-120.
Sowiński J., Kristensen I., 2004. Efektywność zwalczania chwastów w kukurydzy na konwencjonalnych i ekologicznych farmach duńskich [Effectiveness of weed control in maize on traditional and organic Danish farms]. Post. Ochr. Rośl. 44(1), 406-413 [in Polish].
Thomas E.D., Mandebvu P., Ballard C.S., Sniffen C.J., Carter M.P., Beck J. 2001. Comparison of corn silage hybrids for yield, nutrient composition, in vitro digestibility, and milk yield by dairy cows. J. Dairy Sci. 84, 2217-2226.
Valadares Filho S.C., Broderick G.A. Valadares R.F.D., Clayton M.K., 2000. Effect of replacing alfalfa silage with high moisture corn on nutrient utilization and milk production. J. Dairy Sci. 83, 106-114.
Verbič J., Stekar J.M., Resnik-Čepon M., 1995. Rumen degradation characteristics and fibre composition of various morphological parts of different maize hybrids and possible consequences for breeding. Anim. Feed Sci. Technol. 54, 133-148.

ZMIANY SKŁADU CHEMICZNEGO KOLB KUKURYDZY W ZALEŻNOŚCI OD ODMIANY, SUMY TEMPERATUR EFEKTYWNYCH I TYPU GOSPODARSTWA

Streszczenie. Badania przeprowadzono w oparciu o kolby kukurydzy pobrane z pól rolników duńskich w roku 2001. Łącznie pobrano 97 prób, z 58 pól z 15 gospodarstw (9 ekologicznych i 6 tradycyjnych). Uzyskane wyniki przeanalizowano w zależności zróżnicowania odmianowego, sumy temperatur efektywnych oraz typu gospodarstwa.

Zawartość suchej masy w kolbach w głównej mierze decydowała o zawartości skrobi, NDF, ADF, a także zawartości fosforu i magnezu. Zawartość suchej masy była ujemnie skorelowana z zawartością NDF i ADF, natomiast dodatnio z zawartością skrobi. Wysoka zawartość NDF i ADF w kolbach kukurydzy była ujemnie skorelowana z udziałem skrobi.

Słowa kluczowe: kukurydza, kolby, gospodarstwa ekologiczne, sumy temperatur efektywnych, odmiany, NDF, ADF

Zaakceptowano do druku – Accepted for print: 14.05.2007