FERMENTATION PROCESS CHARACTERISTICS OF DIFFERENT MAIZE SILAGE HYBRIDS

CHARAKTERISTIKA FERMENTAČNÉHO PROCESU RÔZNYCH SILÁŽNYCH HYBRIDOV KUKURICE

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ABSTRACT

The aim of this study was to detect the fermentation process differences in different hybrid maize silage. We conserved in laboratory conditions hybrids of whole maize plants with different length of the vegetative period (FAO number). Maize hybrids for silage were harvested in the vegetation stage of the milk-wax maturity of corn and the content of dry matter was from 377.7 to 422.8 $g.kg^{-1}$. The highest content of dry matter was typical for silages made from the hybrids with FAO number 310 (400.0 $g.kg^{-1}$) and FAO 300a (400.4 $g.kg^{-1}$). The content of desirable lactic acid ranged from 23.7 $g.kg^{-1}$ of dry matter (FAO 350) to 58.9 $g.kg^{-1}$ of dry matter (FAO 420). We detected the occurrence of undesirable butyric acid in silages from hybrids FAO 250, 300b, 310 and 380. The highest content of total alcohols we found in silages made from hybrid with FAO number 240 (25.2 $g.kg^{-1}$ of dry matter). Ammonia contents were in tested silages from 0.153 (FAO 270) to 0.223 $g.kg^{-1}$ of dry matter (FAO 240). The lowest value of silage titration acidity we analyzed in silage made from hybrid FAO 420 (3.66).

We observed in maize silages with different length of plant maturity tested in the experiment differences in content of lactic acid, total alcohols, titration acidity, pH and content of fermentation products.

Key words: maize, FAO number, silage, fermentation process

ABSTRACT IN SLOVAK LANGUAGE

Cieľom experimentu bolo analyzovanie rozdielov vo výsledku fermentačného procesu kukuričných siláží vyrobených z rozdielnych hybridov. V laboratórnych podmienkach sme silážovali celé rastliny kukurice, ktorých hybridy sa vzájomne odlišovali dĺžkou vegetačného obdobia (číslo FAO). Zber rastlín bol realizovaný vo vegetačnom štádiu mliečno-voskovej zrelosti zrna a obsahu sušiny od 377.7 do 422.8 $g.kg^{-1}$. Najvyšším obsahom sušiny sa vyznačovali siláže vyrobené z hybridov s číslom FAO 310 (400.0 $g.kg^{-1}$) a FAO 300a (400.4 $g.kg^{-1}$). Obsah žiaducej kyseliny mliečnej kolísal medzi 23.7 $g.kg^{-1}$ sušiny (FAO 350) a 58.9 $g.kg^{-1}$ sušiny (FAO 420). Výskyt nežiadúcej kyseliny maslovej sme detekovali v silážach hybridov FAO 250, 300b, 310 a 380. Najvyšší obsah celkových alkoholov sme zistili v silážach vyrobených z hybridu FAO 240 (25.2 $g.kg^{-1}$ sušiny). Obsah amoniaku bol v analyzovaných silážach od 0.153 (FAO 270) do 0.223 $g.kg^{-1}$ sušiny (FAO 240). Najnižšou hodnotou aktívnej kyslosti výluhov siláží sa vyznačovali siláže vyrobené z hybridu s číslom FAO 420 (3.66).

Testované silážne kukuričné hybridy s rôznou dĺžkou dozrievania rastliny sa vyznačovali značnými rozdielmi v obsahu kyseliny mliečnej, celkových alkoholov, kyslosti vodných výluhov, pH a obsahu fermentačných produktov.

Kľúčové slová: kukurica, číslo FAO, siláž, fermentačný proces

DETAILED ABSTRACT IN NATIVE LANGUAGE

Cieľom experimentu bolo analyzovanie rozdielov vo výsledku fermentačného procesu kukuričných siláží vyrobených z rozdielnych hybridov. V laboratórnych podmienkach sme testovali výsledok fermentačného procesu kukuričných siláží vyrobených z hybridov vzájomne sa odlišujúcich dĺžkou vegetačného obdobia (číslo FAO). Zber celých rastlín bol realizovaný vo vegetačnom štádiu mliečno-voskovej zrelosti zrna pri obsahu sušiny od 377.7 g.kg^{-1} (FAO 250) do 422.8 g.kg^{-1} (FAO 300b) a výške strniska 15 cm. Celé rastliny boli mechanicky spracované na priemernú dĺžku rezanky 20 mm. Silážnu hmotu sme zakonzervovali do laboratórnych síl s objemom 4 dm^3 bez prídavku konzervačných aditív. Po 8 týždňoch fermentácie sme v priemerných vzorkách siláží stanovili obsah sušiny a ukazovatele fermentačného procesu. Najvyšším obsahom sušiny sa vyznačovali siláže vyrobené z hybridov s číslom FAO 310 (400.0 g.kg^{-1}) a FAO 300a (400.4 g.kg^{-1}). Obsah žiaducej kyseliny mliečnej kolísal medzi 23.7 g.kg^{-1} sušiny (FAO 350) a 58.9 g.kg^{-1} sušiny (FAO 420). V obsahu kyseliny octovej splnili siláže všetkých testovaných hybridov podmienku pre zaradenie do 1. akostnej triedy (obsah < 20 g.kg^{-1} sušiny). Výskyt nežiadúcej kyseliny maslovej sme detekovali v silážach hybridov FAO 250, 300b, 310 a 380. Vo všetkých prípadoch bola prekročené limitujúca hranica 1. akostnej triedy (2.5 g.kg^{-1} sušiny). Najvyšší obsah celkových alkoholov sme zistili v silážach vyrobených zo skorého hybridu FAO 240 (25.2 g.kg^{-1} sušiny), ktoré sa súčasne vyznačovali najvyšším obsahom fermentačných produktov a druhou najnižšou hodnotou pH (3.9). Obsah amoniaku bol v analyzovaných silážach od 0.153 (FAO 270) do 0.223 g.kg^{-1} sušiny (FAO 240). Najnižšou hodnotou aktívnej kyslosti výluhov siláží sa vyznačovali siláže vyrobené z hybridu s číslom FAO 420 (3.66).

Testované silážne kukuričné hybridy s rôznou dĺžkou dozrievania rastliny sa vyznačovali preukaznými rozdielmi v obsahu fermentačných kyselín, celkových alkoholov, kyslosti vodných výluhov, pH a obsahu fermentačných produktov.

INTRODUCTION

Already in Old Testament was mentioned the technology of ensiling as method of forage conservation for ruminants. But only during last 40 years began detail description of the silage conservation process, in which is desirable the production of lactic acid. Primary is achieved the process of conservation by decrease of pH what is result of lactic acid bacteria fermentation [11].

Forages are major component in the feeding rations for ruminants, especially for dairy. Forage quality can vary depending on variety [4, 5], stage of maturity at harvest [1], crop management and hybrid [2].

From the point of global importance maize represents in all forms elementary and important feed for farm animals. Feed produced from maize is characterized by high content of energetic nutriments and relatively low content of nitrogenous compounds with low biological value [6]. In conditions of Slovakia Bíro [3] consider the plant of maize from aspect of utilizable energy as the most important crop for feeding. Its plasticity for different technology of harvest and storage provides wide scale of feed with different dietetic and energetic features. Exactly the energy involved in feeding ration for ruminants is the limited nutrient [7].

MATERIALS AND METHODS

We ensiled in experimental conditions 10 different hybrids of maize (Zea Mays L.) without additives. According to length of the vegetative period were the hybrids early (FAO 240, 250, 270, 300a, 300b), middle early (FAO 310, 350, 380) and middle late (FAO 420 and 450). Tested hybrids were grown in identically agro climatic conditions. We obtained the biological material from University agricultural farm SPU in Kolíňany. Whole plants of maize were harvested in vegetation stage of the milk-wax maturity of corn with content of dry matter from 377,7 g.kg^{-1} (FAO 250) to 422,8 g.kg^{-1} (FAO 300b) and the length of stubble was 15 cm. The whole plants were cut to average 20 mm length of cut and ensiled in laboratory silos with volume 4 dm^3 and sealed.

We opened the silos after 8 months of fermentation by temperature 18-20 °C and in average samples determined content of dry matter and indices of fermentation process. We used standard analytical methods (Regulation of the Slovak Ministry of Agriculture no. 2136/2004-101 about sampling of feeds and about laboratory testing and evaluating of feeds). Content of dry matter we determined gravimetric by drying of sample to constant weight by temperature 103±2 ^{0}C (before drying by t 60 °C). Silage extracts we prepared from 200 g of sample and overflowed by 2000 ml of distilled water, after 20 hours strained. Contents of fermentation acids (lactic, acetic, butyric) we detected on analyzer EA 100 (Villa Labeco) by electroforetic method. Content of ammonia (NH_3) and alcohols we determined by microdifusive method, acidity of aqua extract by alkalimetric titration to pH 8,5 and active acidity by electrometric method.

We statistical tested determined differences by single-factor analyze of variance (ANOVA) with software STATGRAPHICS 5.1.

Table 1 Result of fermentation process of maize silage made from early hybrids
Tabuľka 1 Výsledok fermentačného procesu kukuričných siláží vyrobených zo skorých hybridov

n = 3		DM	LA	AA	BA	Alc.	NH_3	TA	pH	FP
			$g.kg^{-1}$		$g.kg^{-1}$ of dry matter			mg KOH		
FAO 240	$\overline{x}$	361.1	42.6^{abd}	5.0^{a}	0	25.2^{a}	0.223^{a}	1074.2^{abd}	3.9^{ad}	78.2^{abd}
	s	2.71	1.9	1.4	-	0.49	0.02	68.7	0.04	2.4
FAO 250	$\overline{x}$	367.9	32.3^{b}	5.4^{b}	7.0	19.8^{a}	0.221^{b}	964.4^{b}	4.1^{b}	64.5^{ab}
	s	11.66	2.72	0.4	0.09	1.34	0.01	43.9	0.01	1.66
FAO 270	$\overline{x}$	389.6	28.9^{ac}	4.0^{bcd}	0	8.7^{a}	0.153^{abd}	911.0^{abc}	4.03^{ac}	41.6^{bd}
	s	3.11	1.78	0.12	-	2.12	0.02	12.78	0.006	2.54
FAO 300a	$\overline{x}$	400.4	28.3^{d}	6.5^{bcd}	0	8.1^{a}	0.210^{d}	900.2^{bd}	4.21^{d}	42.8^{bd}
	s	4.01	1.05	0.55	-	1.75	0.01	18.99	0.05	3.3
FAO 300b	$\overline{x}$	381.8	36.2^{cd}	8.9^{ab}	3.4	12.08^{a}	0.180	1142.5^{bcd}	3.95^{bcd}	60.5^{abd}
	s	3.67	4.02	1.75	2.94	1.68	0.03	45.71	0.04	3.0

* DM- dry matter, LA- lactic acid, AA- acetic acid, BA- butyric acid, Alc.- alcohols, NH_3- ammonia, TA- titration acidity, pH- active acidity,
FP – fermentation products, $\overline{x}$ arithmetic mean, s – standard deviation
The values with identical superscript are significantly different at P<0.05

RESULTS AND DISCUSSION

After termination of fermentation process we detected in silages from tested hybrids content of dry matter from 361.1 to 400.4 $g.kg^{-1}$. We determined the lowest content of dry matter in silages from hybrid with FAO number 240 and the highest content in silage from hybrid FAO 300a. The critical indicators of fermentation process are content of fermentation carboxyl acids, and active acidity (pH). Content of desirable lactic acid we found from 23.7 $g.kg^{-1}$ of dry matter (FAO 350) to 58.9 $g.kg^{-1}$ of dry matter (FAO 420). In content of lactic acid we detected higher values like present Stekar et al. [10], 11.0-16.9 $g.kg^{-1}$ of dry matter. The highest content of acetic acid (16.1 $g.kg^{-1}$ of dry matter), which is in most cases the inherent sign of conservation fermentation, we detected in silages from late maize hybrid with FAO number 450. Silages of all tested hybrids fulfilled condition of acetic acid content to classification as 1st quality class (content of acetic acid < 20 $g.kg^{-1}$ of dry matter). From point of negative influence to animal health and quality and nutritive value of silages is undesirable content of butyric acid. In tested silages we determined the butyric acid in hybrids with FAO number 250, 300b, 310 and 380. The limit for 1st quality class (2.5 $g.kg^{-1}$ of dry matter) exceeded hybrids with FAO number 250 (7 $g.kg^{-1}$ of dry matter), 310 (5.2 $g.kg^{-1}$ of dry matter), 380 (4.6 $g.kg^{-1}$ of dry matter) and 300b (3.4 $g.kg^{-1}$ of dry matter). Content of total alcohols in silages widely fluctuated, from 5.0 (FAO 420) to 25.2 $g.kg^{-1}$ of dry matter (FAO 240). The highest contents of alcohols were in silages from early hybrids. Content of ammonia, which represents destruction of nitrogenous compounds, varied from 0.153 (FAO 270) to 0.223 $g.kg^{-1}$ of dry matter (FAO 240). Greatly higher content of ammonia in maize silages (0.640 $g.kg^{-1}$ of dry matter) reported Cherney et al. [8]. Stekar et al. [10] reported the average content of ammonia in maize silage between 0.200 and 0.300 $g.kg^{-1}$ of dry matter. Titration acidity of silage extracts (TA) ranged from 772.7 mg KOH/100 g of silage to 1362.7 mg KOH/ 100g. The highest TA was in silage from hybrid with FAO number 420, in which titration acidity we detected also the lowest pH (3.66) and the lowest content of alcohols. Active acidity (pH) determined in our experiments correspond with results of Cherney et al. [8], they state pH of silages from different hybrids 3.9±0.08. Similar pH (4.03-4.1) determined also Forouzmand et al. [9]. Content of fermentation products was different, from 38.5 to 42.9 $g.kg^{-1}$ of dry matter in hybrids with FAO number 270, 300a, 310 and 350, in other silages was higher than 60 $g.kg^{-1}$ of dry matter. Statistical significance of differences among early, middle early and middle late hybrids we mention in tables 1 and 2.

Table 2 Result of fermentation process of maize silage made from middle early and middle late hybrids
Tabuľka 2 Výsledok fermentačného procesu kukuričných siláží vyrobených zo stredne skorých a stredne neskorých hybridov

n = 3		DM	LA	AA	BA	Alc.	NH_3	TA	pH	FP
			g.kg^{-1}			g.kg^{-1} of dry matter		mg KOH		
FAO 310	$\overline{x}$	400.0	25.95^{a}	3.4^{a}	5.2	8.3^{a}	0.160^{a}	1014.2^{a}	4.14^{a}	42.9^{a}
	s	8.78	1.59	0.99	0.82	1.46	0.005	74.07	0.05	1.12
FAO 350	$\overline{x}$	388.2	23.7^{b}	7.6^{ab}	0	7.13^{b}	0.210^{ab}	832.5^{ab}	4.29^{ab}	38.5^{ab}
	s	6.41	0.64	0.67	-	0.5	0.02	27.44	0.02	1.07
FAO 380	$\overline{x}$	391.4	45.9^{abc}	7.7^{ac}	4.6	10.7^{bc}	0.170^{bc}	772.7^{ac}	4.24^{ac}	68.8^{ab}
	s	1.1	4.32	1.33	1.63	1.13	0.01	46.0	46.0	4.38
FAO 420	$\overline{x}$	386.6	58.9^{abcd}	3.4^{bcd}	0	5.0^{abc}	0.200^{acd}	1362.7^{abcd}	3.66^{abcd}	66.2^{abd}
	s	2.25	2.94	0.45	-	0.86	0.003	14.72	0.02	4.51
FAO 450	$\overline{x}$	381.1	52.1^{abd}	16.1^{abcd}	0	5.8^{c}	0.160^{bd}	916.5^{abcd}	4.04^{bcd}	75.6^{abd}
	s	7.97	2.11	5.84	-	0.88	0.02	30.47	0.04	2.68

* DM- dry matter, LA- lactic acid, AA- acetic acid, BA- butyric acid, Alc.- alcohols, NH_3- ammonia, TA- titration acidity, pH- active acidity,
FP – fermentation products, $\overline{x}$ arithmetic mean, s – standard deviation
The values with identical superscript are significantly different at $P<0.05$

CONCLUSION

According to testing fermentation we can state that the silages made from maize hybrids with different FAO numbers were different. From tested early, medium early and medium late hybrids we found the best parameters of fermentation process in silages of medium late hybrid with FAO number 420. For silages of this hybrid were typical the highest lactic acid concentration, and the lowest content of acetic acid what positively influenced the value of pH.

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REFERENCES

[1] Coors J.G., Albrecht K.A., Bures E.J., Ear-fill effects on yield and quality of silage corn, Crop Sci., (1997) 37:243-247.

[2] Bíro D., Galik B., Juráček M., Šimko M., Nutritive value and digestibility characteristics of different maize silage hybrids, Acta fytotech. et zootech., (2007), 10: 17-19.

[3] Bíro D., Nutričné a technologické faktory ovplyvňujúce kvalitu a výživnú hodnotu siláži, In: 5. dni výživy a veterinárnej dietetiky. Bratislava: ŠVPS, 2002: 51-56.

[4] Jung H.G., Scheaffer C.C., Barnes D.K., Halgerson J.L., Forage quality variation in the U.S. alfalfa core collection, Crop. Sci., (1997) 37: 1361-1366.

[5] Jung H.G., Mertens D.R., Buxton, D.R., Forage quality variation among maize inbreds: in vitro digestion kinetics and predictions with NIRS, Crop. Sci., (1998) 38: 205-210.

[6] Summers J.D. 2001. Maize, Factors Affecting its digestibility and variability in its feeding value. In: Bedford, M.R. and Partridge, G.G.: Enzymes in farm animal nutritionWallingford: CABI Publishing, 2001: 109-124

[7] DePeters E.J., Cant J.P., Nutritional factors influencing the nitrogen composition of bovine milk: a rewiew, J. Dairy Sci, (1992) 75: 2027-2032.

[8] Cherney D.J.R., Cherney J.H., Cox W.J., Fermentation characteristics of corn hybrids ensiled in mini-silos, J. Anim. Sci., (2004) 87: 4238-4246.

[9] Forouzmand M.A., Ghorbani G.R., Alikhani M., Influence of hybrid and maturity on the nutritional value of corn silage for lactating dairy cows 1: Intake, milk production and component yield, Pakistan J. Nutr., (2005) 4: 435-441.

[10] Stekar J.M.A, Stibilj V., Golob A., Kodra M., Quality and nutritive value of maize silage prepared from different hybrids, Options Méditerr., (1991) 16: 137-139.

[11] Woolford M.K., Silage inoculants and their coming of age. In: Expanding horizonts: Alltech's 18th European, middle and east and African lecture. 2004.

[12] Regulation of the Slovak Ministry of Agriculture No. 2145/2004-100.

[13] Regulation of the Slovak Ministry of Agriculture No. 39/1/2002-100.