Chemical composition and quality of sweet sorghum and maize silages

Skład chemiczny i jakość kiszonek z sorgo cukrowego i kukurydzy

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ABSTRACT

Sweet sorghum (*Sorghum saccharatum)* silage, maize (*Zea mays*) silage, and sorghum and maize (1:1) silage were investigated. The silages were analysed for chemical composition, quality and aerobic stability. Dry matter was the lowest (20.88%) in sorghum silage and the highest (37.45%) in maize silage. In sorghum silage, the concentration of crude ash and crude fibre was higher, and that of crude protein, crude fat and N-free extractives lower compared to maize silage. Neutral detergent fibre and acid detergent fibre were the highest in sorghum silage and the lowest in maize silage.

The silages were dominated by lactic acid, with trace amounts of butyric acid. Maize silage was higher lactic acid and higher total acids than others. All silages were of very good quality according to Flieg-Zimmer scale. Silage pH ranged from 4.20 to 4.31. Sorghum silage was characterized by higher aerobic stability (81h) compared to the other silages from maize (74h) and sorghum and maize 1:1 (69h).

KEYWORDS: silage, *Sorghum saccharatum*, *Zea mays*, quality, chemical composition, aerobic stability

STRESZCZENIE

Przeprowadzono badania nad kiszonkami z sorgo cukrowego (*Sorghum saccharatum)*, kukurydzy (*Zea mays*) i mieszanki sorgo z kukurydzą (1:1). Oznaczono skład chemiczny i jakość oraz stabilność tlenową kiszonek. Kiszonka z sorgo zawierała najmniej (20,88%), a kiszonka z kukurydzy najwięcej (37,45%) suchej masy. W kiszonce z sorgo koncentracja popiołu surowego i włókna surowego była wyższa, a białka ogólnego, tłuszczu surowego i związków bezazotowych wyciągowych niższa niż w kiszonce z kukurydzy. NDF i ADF.

W kiszonkach przeważał kwas mlekowy, przy śladowej ilości kwasu masłowego. Kiszonka z kukurydzy miała więcej kwasu mlekowego i wyższą sumę kwasów niż pozostałe kiszonki. Wszystkie kiszonki uzyskały ocenę bardzo dobrą według skali Fliega-Zimmera. Uzyskane kiszonki wykazywały pH od 4.20 do 4.31. Kiszonka z sorgo odznaczała się wyższą tlenową trwałością (81 h) w porównaniu do kukurydzy (74 h) i mieszanki sorgo z kukurydzą 1:1 (69 h).

SŁOWA KLUCZOWE: kiszonki, sorgo cukrowe, kukurydza, jakość, skład chemiczny, tlenowa trwałość

STRESZCZENIE SZCZEGÓŁOWE

Celem badań było porównanie składu chemicznego, jakości i stabilności kiszonki z sorgo cukrowego i kukurydzy. Doświadczenie przeprowadzono w latach 2004-2006. Do badań wykorzystano sorgo cukrowe (*Sorghum saccharatum*) odmiany Sucrosorgo 506, które porównano kukurydzą (*Zea mays*) odmiany Magister (liczba FAO 270). Kukurydza wysiewana była w ostatniej dekadzie kwietnia, zaś sorgo w drugiej dekadzie maja. Wyodrębniono warianty: sorgo w siewie czystym (obsada 180000 nasion na hektar), sorgo i kukurydza w siewie współrzędowym, (2 rzędy sorgo i 2 rzędy kukurydzy) (90 000 nasion sorga i 45 000 nasion kukurydzy na 1 ha) oraz kukurydza w siewie czystym (90 000 nasion na hektar). Każdy wariant wysiewany był w 8 rzędach, o rozstawie 70 cm. Zbiór przeprowadzano pod koniec września, gdy kukurydza była w fazie dojrzałości woskowej ziarna, wszystkie warianty w jednym terminie. Zielonka przed zakiszaniem pocięto na sieczkę o długości około 1 cm. Kiszonki sporządzono w mikrosilosach (Ø15 cm, wys. 49 cm). W kiszonkach oznaczono skład chemiczny (analiza weendeńska [1] i van Soesta [20]), określono ich jakość [1] i wykonano test na ich stabilność tlenową [8, 9]. Wyniki opracowano statystycznie przy użyciu testu Duncana [17]. Najniższą ilość suchej masy obserwowano w kiszonce z sorgo (20,88%), a najwyższą w kiszonce z kukurydzy (37,45%). Różnice w zawartości suchej masy w kiszonkach były statystycznie istotne ($P \le 0,01$). Koncentracja białka ogólnego i tłuszczu surowego w kiszonce z kukurydzy była wyższa niż w pozostałych kiszonkach (($P \le 0,01$). W naszych warunkach klimatycznych w czasie zbioru sorgo cukrowego dominującą częścią rośliny jest łodyga, dlatego kiszonka z tej rośliny zawierała 36,67% włókna surowego w suchej masie. W przypadku kukurydzy, gdzie organem dominującym w momencie zbioru jest kolba, zawartość włókna surowego wynosiła 21,17% w suchej masie. Różnice w koncentracji włókna surowego w kiszonkach były statystycznie istotne ($P \le 0,01$). Najniższą zawartość związków bezazotowych wyciągowych miała kiszonka z sorgo (44,04% SM), a najwyższą kiszonka z kukurydzy (57,40% SM). Różnice w koncentracji BNW w kiszonkach były statystycznie istotne ($P \le 0,01$). W kiszonce z sorgo było najwięcej, a w kiszonce z kukurydzy najmniej NDF i ADF. Różnice w koncentracji tych składników w kiszonkach były statystycznie istotne ($P \le 0,01$). W kiszonkach przeważał kwas mlekowy, przy śladowej ilości kwasu masłowego. Koncentracja kwasu mlekowego w kiszonce z sorgo była niższa niż kiszonce z kukurydzy ($P \le 0,01$). Suma kwasów w kiszonce z kukurydzy była wyższa niż w pozostałych kiszonkach ($P \le 0,01$). pH kiszonek wahało się od 4,20 do 4,31. Kiszonka z sorgo była najmniej podatna na rozkład tlenowy niż pozostałe badane kiszonki ($P \le 0,01$).

INTODUCTION

Increasing summer drought in some regions of Poland reduces the yield of maize, which is the main crop used to feed dairy cows. For this reason, some cattle breeders are inclined to grow sorghum to stock up on roughages [18].

The high content of water soluble carbohydrates (WSC) and low buffer capacity make sorghum easy to ensile [2, 15]. This plant is also resistant to water shortages due to the extensive root system, which facilitates the extraction of water from deeper soil layers [6]. During periods of long drought, plants go dormant and stop growing, but when soil moisture increases they resume growth [3]. In addition, leaf blades are covered with a wax layer, which protects them against water loss [19]. The high yield of sorghum green mass is also an important consideration [7].

Good results can be obtained by growing plants together: sorghum and maize are planted in alternating rows and a mixture of both is harvested in the autumn. This enables the yielding potential of sorghum and the high energy value of maize to be fully used [13].

The aim of the study was to compare sweet sorghum and maize silages for chemical composition, quality and stability.

MATERIAL AND METHODS

This study was conducted in 2004-2006 in south-western Wielkopolska region of Poland (51°48¢N, 16°18¢E, 65 m above sea level).

Sweet sorghum (*Sorghum saccharatum*) cv. Sucrosorgo 506 was compared with maize (*Zea mays*) cv. Magister (FAO 270). Seeds were provided by Syngenta Seeds. Maize was planted in late April and sorghum in mid May. Weather conditions during plant growth are given in Table 1.

The following variants were tested:

– a pure stand of sorghum. Seeding rate was 180 000 seeds per hectare, and seeds per row were planted 7 cm apart.

– a mixed stand of sorghum and maize. Planting pattern consisted of two rows of sorghum alternating with two rows of maize. Seeding rate per hectare was 90 000 sorghum seeds and 45 000 maize seeds.

– a pure stand of maize. Seeding rate was 90 000 seeds per hectare, and seeds per row were planted 15 cm apart.

Each variant was planted in 8 rows spaced 70 cm apart.

Table 1. Mean daily temperature (°C), rainfall (mm) and number of days with rainfall during the plant growth period
Tabela 1 Średnie temperatury dobowe (°C), ilość opadów (mm) i liczba dni z deszczem podczas wzrostu roślin

Year of the study		April	May	June	July	August	September
	A	9.5	12.7	16.1	17.9	19.8	14.1
2004	B	18.3	49.9	55.1	49.3	57.0	23.2
	C	9	12	18	15	17	12
	A	9.2	13.7	16.7	20.1	17.3	16.1
2005	B	19.1	65.2	18.6	76.7	54.0	42.9
	C	7	14	7	14	12	9
	A	9.1	13.8	18.5	24.0	17.7	17.0
2006	B	50.9	49.2	40.3	13.4	119.2	20.4
	C	12	13	8	4	22	6
1981-2007	A	8.6	14.1	16.6	18.8	18.3	13.7
	B	28.9	46.8	57.9	72.1	59.7	41.8
	C	8.9	10.0	11.9	12.2	11.0	10.1

A – temperature, °C; B – rainfall, mm; C – days with rainfall

Plants were harvested in late September (all variants in the same day), when maize was at the dough stage of maturity. Prior to ensiling, forage was chopped to about 1 cm length.

Silage was made in microsilos (Ø15 cm, height 49 cm) sealed with rubber bungs, which contained fermentation tubes with glycerol to remove fermentation gases.

Chemical composition of silages was determined using the Weende [1] and van Soest methods [20]. Acid content and pH [1] as well as silage quality were determined [1]. The aerobic stability of silages was tested according to a method described by Honig [8, 9]. Silages were tested over 7 days in a controlled environment facility in ambient temperature of 20°C ± 1°C. Changes in silage temperature under aerobic conditions were measured with a Squirrel 2000 logger, which recorded temperature every hour as a mean of two measurements taken at half-hour intervals.

The results were analyzed statistically using Duncan’s test [17], the experimental factor were variants of the experiment (sorghum, maize and mix of sorghum and maize).

RESULTS AND DISCUSSION

Sorghum silage contained only 20.88% dry matter (Table 2). Other authors [2, 7] reported higher levels of dry matter for this silage. When silage is made from material of such high moisture, many nutrients are lost through seepage of silage juices, which pollutes the environment [4]. In the feeding of high-yielding cows, surplus water in silage is an unnecessary burden that limits the intake of ration dry matter [12]. Maize silage had the highest dry matter content. Differences in the dry matter content of silages were statistically significant (P≤0.01).

Crude protein content of maize silage was higher than that of other silages (P≤0.01). Similar findings were reported by Gul et al. [7]. Meanwhile, Avasi et al. [2] reported that sorghum silage contained more protein compared to maize silage. Pyś et al. [16] did not find any difference in crude protein concentration between sorghum silage and maize silage, but observed lower amounts of true protein in sorghum silage compared to maize silage (P≤0.05).

Under Polish climatic conditions, stem is the dominant component of sweet sorghum during harvest [10], as a result of which sorghum silage contained 36.67% crude fibre in dry matter. In maize, where cob is the dominant component at harvest, crude fibre content was 21.17% in dry matter. Podkówka and Podkówka [14] report that good quality silage should contain about 19% crude fibre in dry matter. The difference in the concentration of crude fibre between silage variants was statistically significant (P≤0.01).

The dry matter of sorghum silage contained 64.73% neutral detergent fibre (NDF) and 41.03% acid detergent fibre (ADF) (Table 3). Gul et al. [7] found similar NDF and higher ADF amounts in sorghum silage. Podkówka and Podkówka [14] reported that in maize silage, NDF and ADF content should not exceed 45% and 25% in dry matter, respectively. In our study, the content of these fibre fractions was lower. Gul et al. [7] obtained higher NDF and ADF levels in maize silage compared to our study. Differences in the NDF and ADF content of the analysed silages were significant (P≤0.01). Meanwhile, Gul et al. [7] did not find statistically significant differences in NDF and ADF content between sorghum and maize silages. Lema et al. [11] indicated that the content of the NDF in the sweet sorghum silage depends on the variety.

The silages were dominated by lactic acid, with trace amounts of butyric acid (Table 4). When material with a low dry matter content and high WSC content was ensiled, the fermentation process was very intensive and the silage contained much lactic acid [4]. However, this is not supported by the present study, because lactic acid concentration in the analysed silages was similar. Likewise, Pyś et al. [16] did not find any significant differences in the amount of lactic acid between sorghum silage and maize silage. Pyś et al. [16] reported that maize silage has higher total acids than sorghum silage (P≤0.05). In our study, we found no statistically significant differences in total acids between silages. The pH of silages ranged from 4.20 to 4.31. Other authors [2, 7] reported lower pH levels for sorghum and maize silages.

Table 2. Chemical composition of silages (%)
Tabela 2 Skład chemiczny kiszonek (%)

Item	Year	Sorghum		Maize		Sorghum:maize 1:1	
		mean	Sx	mean	Sx	mean	Sx
Dry matter (%) Sucha masa (%)	2004	19.79A	0.35	24.48Ba	1.47	23.38Bb	1.09
	2005	23.83A	1.52	47.98B	6.33	31.50C	2.12
	2006	21.81A	1.84	36.23Ba	1.53	27.39b	1.97
	average	20.88A	2.14	37.45B	7.73	25.17C	4.74
Crude ash (% DM) Popiół surowy (% SM)	2004	6.11	0.13	5.92	2.02	5.24	0.66
	2005	5.54	0.90	3.36	1.23	4.67	0.71
	2006	5.78	0.58	4.22	1.80	4.89	0.97
	average	6.04a	0.45	5.08b	1.52	5.43ab	0.89
Crude protein (% DM) Białko ogólne (%SM)	2004	9.40	2.00	10.17	1.63	9.36	2.01
	2005	8.31	1.82	9.05	2.42	8.54	1.64
	2006	8.80	1.31	9.41	2.06	8.87	1.65
	average	9.70A	1.64	11.45B	2.67	10.04A	1.92
Crude fat (% DM) Tłuszcz surowy (%SM)	2004	3.18Aa	0.38	4.29Ba	0.66	3.78b	0.88
	2005	2.14	0.58	3.48	0.53	2.54	0.42
	2006	2.61A	2.08	3.75Ba	2.16	3.07b	0.13
	average	3.25A	1.77	4.91B	1.52	3.47A	0.90
Crude fibre (% DM) Włókno surowe (%SM)	2004	38.45A	3.06	23.45B	1.56	28.14C	0.16
	2005	38.02A	1.45	16.92B	2.53	27.97C	1.89
	2006	38.19A	1.36	19.13B	2.54	28.04C	0.55
	average	36.67A	2.33	21.17B	3.06	28.24C	0.84
N-free extractives (% DM) BNW (%SM)	2004	42.86A	0.34	56.17B	5.03	53.48C	3.01
	2005	45.99A	2.89	67.19B	5.71	56.28C	3.91
	2006	44.62A	0.82	63.49B	3.13	55.13C	2.14
	average	44.04A	1.90	57.40B	7.63	52.82C	3.65

ab - p≤0.05; AB - p≤0.01

Silages scored 87.3 to 95.6 points on the Flieg-Zimmer scale (non-significant difference) and were of very good quality. Likewise, Gul et al. [7] found no quality differences between sorghum and maize silages.

Table 3. Structural carbohydrate fractions of silages (% dry matter)
Tabela 3 Frakcje węglowodanów strukturalnych w kiszonkach (% suchej masy)

Item	Year	Sorghum		Maize		Sorghum:maize 1:1	
		mean	Sx	mean	Sx	mean	Sx
NDF (% DM)	2004	65.74A	3.01	41.71B	3.62	48.93C	2.12
	2005	66.60A	1.85	32.10B	2.35	49.40C	2.88
	2006	66.21A	1.14	35.33B	3.30	49.18C	1.16
	average	64.73A	2.29	39.54B	5.46	52.20C	3.69
ADF (% DM)	2004	44.21A	0.69	27.53B	1.39	32.47C	3.34
	2005	41.75A	3.57	16.30B	2.59	30.03C	2.87
	2006	42.87A	2.69	20.09B	2.07	31.07C	0.99
	average	41.03A	3.10	23.11B	4.93	32.41C	2.38

AB - p≤0.01

Table 4. Quality and aerobic stability of silages
Tabela 4 Jakość i stabilność tlenowa kiszonek

Item		Sorghum		Maize		Sorghum:maize 1:1	
		mean	Sx	mean	Sx	mean	Sx
pH		4.20	0.28	4.31	0.17	4.23	0.33
Lactic acid (% DM)		9.61	1.21	9.40	2.72	8.87	2.12
Acetic acid (% DM)		2.62	0.62	2.31	0.40	2.39	0.39
Butyric acid (% DM)		0.13	0.29	0.20	0.26	0.02	0.02
Total acids (% DM)		12.36	1.24	11.91	2.93	11.28	2.37
Lactic acid in total acids (%)		77.7	3.97	77.9	3.97	78.0	3.67
Silage quality on Flieg-Zimmer scale	points	92.3	11.0	87.3	13.4	95.6	3.77
	score	very good		very good		very good	
Aerobic stability (hours)		81A	3.3	74B	3.8	69B	2.6

AB - p≤0.01

Sorghum silage showed lower susceptibility to aerobic deterioration compared to the other silages studied (P≤0.01). Pyś et al. [16] and Filya et al. [5] found no differences in aerobic stability between sorghum and maize silages. Avasi et al. [2] reported that sorghum silage is more susceptible to aerobic deterioration compared to maize silage.

CONCLUSIONS

Sweet sorghum silage contained less dry matter and more crude fibre compared to maize silage. The silages were dominated by lactic acid, with trace amounts of butyric acid. The silages were of very good quality. Sorghum silage was less susceptible to aerobic spoilage compared to the other silages. To increase the level of dry matter and lower levels of fibre in silage prepared from sorghum, use it with corn mixture (1:1).

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