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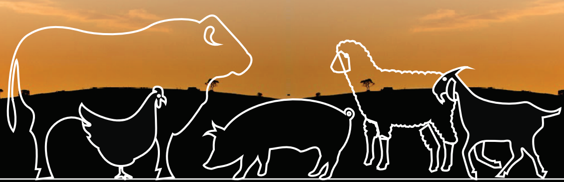

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QUALITY OF WHOLE-PLANT CORN SILAGE ON FAMILY FARMS

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Abstract: Whole-plant corn silage is a starting point for economical and modern animal husbandry. It is a quality green feed replacement and the most important cattle feed. The quality of whole-plant corn silage is of great importance in milk production. Continuous monitoring of silage quality is an important part of feeding programmes. The aim of this study was to use chemical and microbiological analyses to determine the quality of whole-plant corn silage produced on family farms. The analysed samples contained, on average, 66.37% moisture (58.79-72.01%), 33.63% dry matter (27.99-41.21%), 2.07% crude protein (1.07-3.06%), 1.26% crude fat (0.72 -1.84%) and 8.09% crude cellulose (5.72-9.98%). The average pH value, taken as an indicator of the quality of fermentation, was 3.90 (3.50-4.16). Total volatile fatty acid comprised 1.87% (0.67-2.47%) lactic acid, 0.68% acetic acid (12.20-1.52%) and 0.02% (0-0.27%) butyric acid. The average proportions of lactic, acetic and butyric acids in the silage were 72.80% (33.3-88.81%), 26.45% (9.35-66.67%) and 0.75% (0-10.16%). The authors determined silage quality using the Flieg score. The samples from 12 farms were graded as very good, while the silage from the other farms was evaluated as good (4 farms) and satisfactory (2 farms). The analysis of microbiological quality showed that the samples on average contained 405,556 (10,000-3,000,000) of silage bacteria and 7,000 (0-80,000) of mould. Sulphate-reducing Clostridia and Salmonella were not identified. The samples matched quality requirements prescribed by the rulebook.

Key words: silage, analysis, quality, family farms

Introduction

Silage is a starting point for economical and modern animal husbandry. It is a quality green feed replacement and the most important cattle feed. Modern technologies of ensiling whole corn plants aim at obtaining high quality silage with as higher nutrient level as possible, by using methods that enable maximum preservation and a high level of utilization of nutritive values (*Johnson et al., 1999*). Whole-plant corn silage is one of the most important nutrients in the diet of dairy cows (*Đorđević et al., 2011*).

Corn gives high yields of green biomass. Its dry matter contains relatively high energy levels it is well-consumed by cows. In countries with intensive cattle breeding, conserved bulk feed is used throughout the year, combined with concentrates. Silage is one of the main forms of conserved bulk feed. An essential characteristic of whole-plant corn silage is digestibility, which affects the utilisation of nutrients. An important factor that determines the digestibility is the maturity of silage corn (*Ferraretto and Shaver, 2012*; *Akins and Shaver, 2014*).

Whole-plant corn silage can be used during winter, or throughout the year (*Der Bedrosian et al, 2012*). It is characterized by good taste and it is an important nutrient for preparing totally mixed rations (*Neylon and Kung, 2003*). The quality of silage depends on the botanical classification of plants, stage if plant development, growing cycle, ensiling conditions, silo facilities, ensiling techniques, organization of work, subsequent fermentation, future use and organization of feeding (*Johnson et al., 2003; Stojanović et al., 2010*).

The aim of modern technologies of ensiling whole-plant corn is to obtain starting material with the highest nutritional value possible, to apply appropriate procedures and use some supplements that will enable better conservation and utilisation of silage (*Đorđević et al., 2011*).

The quality of whole-plant corn silage is very important in milk production on family farms. Hence, quality control is a significant part of feeding programmes (*Seglar, 2003*). Quite often, poor quality silage leads to serious metabolic disorders (*Stojkovic et al., 2012; Krnjaja et al., 2013*). Silage samples should arrive at a laboratory as soon as possible to avoid subsequent changes that can occur in quality indicators (*Solórzano et al., 2012*). Controlling silage quality with appropriate laboratory analyses is part of good agricultural practices required in the diet of all cattle categories (*Fulgueira et al., 2007*).

The aim of this study was to use chemical and microbiological analyses in order to determine the quality of whole-plant corn silage produced on family farms.

Material and Methods

The study was conducted on 18 family farms from 17 places and 9 regions of the Republic of Serbia, in the period from 1st October 2010 to 31st November 2011 (Table 1). Depending on their production (milk, milk and meat), these family farms had Simmental and/or Holstein-Friesian cattle.

Table 1. Number of farmers, cattle breeds, districts and places included in the study

Number of farmers	Number of cattle breeds	Number of districts	Number of places
18	2	9	17

In the study period, the farms had on average 1,276 heads of all categories of Simmental and Holstein-Friesian cattle, comprising 615 cows, 197 calves, 317 heifers and 147 beef cattle.

The samples of whole-plant corn silage were taken from each farm and delivered in plastic bags to accredited laboratories for chemical and microbiological testing within the Institute for Animal Husbandry in Belgrade. Standard quantitative laboratory methods (based on a gravimetric, volumetric and potentiometric titration), identified the following indicators of silage quality: total moisture, crude protein, crude fat, crude fibre and pH value. Organic acid levels were determined and a quality assessment was carried out (the Flieg score). Microbiological analysis showed the characteristics of the silage in terms of total bacterial count, total mould count, sulphate-reducing Clostridia, isolation and identification of Salmonella and type of mould and yeast. The quality of the sample was determined adhering to the provisions from the "Rulebook on the quality of animal feed" (Official Gazette of the Republic of Serbia, No. 4, 2010, Article 101 and 102).

The experimental results were statistically analysed using STATISTICA v6. StatSoft, Inc. (2003).

Results and Discussion

Quality control of the whole-plant corn silage on family farms is necessary for optimizing the diet of all cattle categories on a farm.

Table 2. Chemical composition and pH value of whole-plant corn silage

Farm	Total moisture (%)	Crude protein (%)	Crude fat (%)	Crude cellulose (%)	pH
1	62.94	2.49	1.12	9.05	3.88
2	63.01	2.39	1.21	7.91	4.09
3	64.56	2.00	0.87	9.19	4.09
4	68.04	1.73	0.90	6.81	4.16
5	65.50	1.08	1.39	8.33	3.78
6	71.41	1.17	1.17	5.72	3.95
7	63.18	1.96	1.23	8.66	4.06
8	59.11	3.06	1.50	9.98	4.05
9	72.01	1.07	0.72	7.63	4.08
10	64.21	2.05	1.01	8.56	4.08
11	65.63	2.13	1.11	8.97	3.91
12	70.21	1.46	0.90	8.72	3.88
13	71.20	2.44	1.38	7.76	3.74
14	70.57	2.14	1.84	7.40	3.50
15	68.53	2.13	1.67	8.14	3.73
16	66.41	2.62	1.74	8.38	3.80
17	69.43	1.81	1.26	6.95	3.58
18	58.79	2.65	1.66	7.52	3.93
Average	66.37	2.07	1.26	8.09	3.90
SD	4.08	0.56	0.33	1.01	0.19
CV	6.14	27.14	25.85	12.46	4.81
Min	58.79	1.07	0.72	5.72	3.50
Max	72.01	3.06	1.84	9.98	4.16

The average moisture in the analysed samples was 66.37% (58.79-72.01%), while the dry matter was on average 33.63% (27.99-41.21%) (Table 2). The variation in dry matter can result in changes in levels of nutrients and energy. Adequate silage moisture is crucially important for the level of compression and the quality of fermentation (*Seglar, 2003*). Most recommendations indicate that the optimal moisture should be 65-70%, and dry matter content 30-35%. Crude protein averaged 2.07 (1.07-3.06%), crude fat 1.26% (0.72-1.84%) and crude cellulose 8.09 (5.72-9.98%). The average pH value taken as an indicator of fermentation quality was 3.90 (3.50-4.16). *Kung and Shaver (2001)* reported that the optimum pH value of corn silage ranged 3.7-4.2.

Table 3. Volatile fatty acids in whole-plant corn silage

Farm	Lactic acid (%)	Acetic acid (%)	Butyric acid (%)
1	2.10	0.98	0
2	1.35	0.64	0
3	1.59	0.78	0.08
4	0.81	0.47	0
5	2.36	0.39	0
6	2.32	1.52	0.01
7	1.63	0.34	0
8	2.10	0.24	0.27
9	0.67	1.33	0
10	2.47	1.18	0
11	1.64	0.89	0
12	1.83	0.50	0
13	2.27	0.78	0
14	2.47	0.49	0
15	2.07	0.47	0
16	2.32	0.58	0
17	2.01	0.37	0
18	1.75	0.20	0
Average	1.87	0.68	0.02
Min	0.67	0.20	0
Max	2.47	1.52	0.27

Chemical analysis showed the level of volatile fatty acids in the silage. Lactic acid was 1.87% (0.67-2.47%), acetic acid 0.68% (0.20- 1.52%) and butyric acid 0.02% (0-0.27%) (Table 3). The results show that the main product of sugar fermentation in the silage is lactic acid, which exhibits pronounced bactericidal but poor fungicidal effect. The silage also contained acetic and a less amount of butyric acid. In addition to propionic acid, they have very fungicidal properties so only fewer amounts of these acids are acceptable (*Đorđević et al., 2011*).

Table 4. Proportion of volatile fatty acids (Flieg score) in whole-plant corn silage

Farm	Lactic acid (%)	Acetic acid (%)	Butyric acid (%)	Flieg score
1	68.16	31.84	0	Very good
2	67.94	32.06	0	Very good
3	64.91	31.94	3.15	Good
4	63.40	36.60	0	Good
5	85.77	14.23	0	Very good
6	60.31	39.50	0.19	Good
7	82.55	17.45	0	Very good
8	80.49	9.35	10.16	Satisfactory
9	33.33	66.67	0	Satisfactory
10	67.54	32.46	0	Very good
11	64.78	35.22	0	Good
12	78.34	21.66	0	Very good
13	74.50	25.50	0	Very good
14	83.57	16.43	0	Very good
15	81.64	18.36	0	Very good
16	79.91	20.09	0	Very good
17	84.43	15.57	0	Very good
18	88.81	11.19	0	Very good
Average	72.80	26.45	0.75	Very good
Min	33.33	9.35	0	Satisfactory
Max	88.81	66.67	10.16	Very good

An important indicator of optimum fermentation is the level and proportion of lactic, acetic and butyric acid (Table 4). Increased production of lactic acid reduces pH value, which prevents the growth of undesirable microorganisms. Good whole-plant corn silage should contain minimum 65 to 70% total acid (*Kung and Shaver, 2001*). The average proportion of lactic acid in the analysed silage was 72.80% (33.33-88.81%), acetic acid 26.45% (9.35-66.67%) and butyric acid 0.75% (0-10.16%). Quality rating was conducting by using the Flieg score. The samples from 12 farms was graded as very good, while the silage from the other farms was evaluated as good (4 farms) and satisfactory (2 farms).

Table 5. Microbiological analysis of whole-plant corn silage

Farm	Total bacterial count (in 1 g)	Total Mould count (in 1 g)	Sulphate-reducing Clostridia (in 50 g)	Isolation and identification of Salmonella (in 50 g)
1	80,000	Not isolated	Not isolated	Not isolated
2	90,000	20,000	Not isolated	Not isolated
3	100,000	80,000	Not isolated	Not isolated
4	80,000	Not isolated	Not isolated	Not isolated
5	10,000	Not isolated	Not isolated	Not isolated
6	20,000	Not isolated	Not isolated	Not isolated
7	20,000	Not isolated	Not isolated	Not isolated
8	60,000	5,000	Not isolated	Not isolated
9	10,000	10,000	Not isolated	Not isolated
10	30,000	5,000	Not isolated	Not isolated
11	3,000,000	1,000	Not isolated	Not isolated
12	60,000	Not isolated	Not isolated	Not isolated
13	200,000	1,000	Not isolated	Not isolated
14	20,000	1,000	Not isolated	Not isolated
15	1,900,000	Not isolated	Not isolated	Not isolated
16	1,400,000	2,000	Not isolated	Not isolated
17	20,000	1,000	Not isolated	Not isolated
18	200,000	Not isolated	Not isolated	Not isolated

The analysis of microbiological quality of the samples showed, on average, 405,556 bacteria (10,000-3,000,000), compared to 12,000,000, what is the allowed bacterial count that can be found in silage (Table 5). The sample contained on average 7,000 moulds (0-80,000), compared to the allowed 200,000. Sulphate-reducing Clostridia were not identified. Neither were Salmonella.

Table 6. Determination of microorganisms (mould, yeasts) and sample quality

Farm	These analyses are determined		Sample quality
	Moulds	Yeasts	
1	Not determined	Saccharomyces cerevisiae	Corresponds
2	Mucor	Not determined	Corresponds
3	Mucor, Aspergillus flavus, Penicilium	Not determined	Corresponds
4	Not determined	Saccharomyces cerevisiae	Corresponds
5	Not determined	Not determined	Corresponds
6	Not determined	Not determined	Corresponds
7	Not determined	Saccharomyces cerevisiae	Corresponds
8	Penicilium	Saccharomyces cerevisiae	Corresponds
9	Mucor, Penicilium	Not determined	Corresponds
10	Penicilium	Not determined	Corresponds
11	Mucor, Rhisopus, Aspergillus flavus, A. ochraceus, A.fumigatus, A.niger, Penicilium, Fusarium, Alternaria	Not determined	Corresponds
12	Not determined	Not determined	Corresponds
13	Mucor, Aspergillus flavus	Not determined	Corresponds
14	Penicilium	Not determined	Corresponds
15	Not determined	Saccharomyces cerevisiae	Corresponds
16	Mucor	Not determined	Corresponds
17	Fusarium	Saccharomyces cerevisiae	Corresponds
18	Not determined	Saccharomyces cerevisiae	Corresponds

One should expect quality whole-plant corn silage should contain high levels of nutrients and energy, and be microbiologically stable over a long storage period. The study showed the presence of certain types of microorganisms (mould, yeasts) in the silage from 10 farms, and the presence of yeast on the silage from 7 farms (Table 6). The samples were entirely in line with the provisions in the "Rulebook on the quality of animal feed" (Official Gazette of the Republic of Serbia, No. 4, 2010).

Conclusions

The analysed samples of whole-plant corn silage contained on average 66.37% moisture (58.79-72.01%), 33.63% dry matter (27.99-41.21%), 2.07% crude protein (1.07-3.06%), 1.26% crude fat (0.72-1.84%) and 8.09% crude cellulose (5.72-9.98%). The average pH value, taken as an indicator of fermentation quality was 3.90 (3.50-4.16). When it comes to volatile fatty acids, lactic acid was 1.87% (0.67-2.47%), acetic acid 0.68% (12.20 to 1.52%) and

butyric acid 0.02% (0-0.27%). The average proportion of lactic acid in the silage was 72.80% (33.33-88.81%), acetic acid 26.45% (9.35-66.67%) and butyric acid 0.75% (0-10.16%). Quality rating of the silage was conducted by using the Flieg score. The samples from 12 farms were graded as very good, while the silage from the other farms was evaluated as good (4 farms) and satisfactory (2 farms). The analysis of microbiological quality showed that the silage on average contained 405,556 bacteria (10,000-3,000,000). The quality of the samples matched the requirements prescribed by the rulebook.

Kvalitet silaže cele biljke kukuruza na porodičnim govedarskim farmama

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Rezime

Savremene tehnologija siliranja cele biljke kukuruza imaju za cilj dobijanje kvalitetne silažne mase što veće hranljive vrednosti uz primenu postupaka koji će omogućiti maksimalno očuvanje i visok nivo iskoristivosti hranljive vrednosti. Stalno praćenje kvaliteta važan je deo programa ishrane svih kategorija goveda. Cilj ovoga istraživanja bio je utvrđivanje kvaliteta silaže cele biljke kukuruza proizvedene na porodičnim govedarskim farmama primenom hemijske i mikrobiološke analize. U analiziranim uzorcima silaže cele biljke kukuruza prosečan sadržaj vlage iznosio je 66,37 % (58,79-72,01%), sadržaj suve materije 33,63 % (27,99-41,21%), sirovog proteina 2,07% (1,07-3,06%), sirove masti 1,26% (0,72-1,84%) i sirove celuloze 8,09 (5,72-9,98%). Prosečna pH vrednost iznosila je 3,90 (3,50-4,16). Sadržaj isparljivih masnih kiselina za mlečnu kiselinu iznosio je 1,87% (0,67-2,47%), sirćetnu kiselinu 0,68% (0,20-1,52%) i buternu kiselinu 0,02% (0-0,27%). Prosečna proporcija mlečne kiseline u analiziranoj silaži iznosila je 72,80% (33,33-88,81%), sirćetne kiseline 26,45% (9,35-66,67%) i buterne kiseline 0,75% (0-10,16%). Ocena kvaliteta silaže po Flieg-u je pokazala da su uzorci sa 12 govedarskih farmi dobili ocenu vrlo dobar, dok je na ostalim farmama silaža ocenjena kao dobra (4 farme) i zadovoljavajuća (2 farme). Analizom mikrobiološkog kvaliteta utvrđeno je da se u uzorcim silaže nalazilo prosečno 405.556 (10.000-3.000.000) bakterija i 7.000 (0-80.000) plesni. Sulforedukujuće klostridije i salmonele nisu identifikovane. Uzorci su odgovarali uslovima kvaliteta koje propisuje pravilnik.

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