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Comparative study of white cabbage, traditional variety and hybrid intended for biological fermentation

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Summary

Traditional Serbian variety of white cabbage, cultivar "*Futoški*" (33 samples) and hybrid "*Bravo*" (10 samples) were investigated in this study for their applicability to biological fermentation. Different chemical, physical, texture and sensory characteristics of raw cabbage heads were investigated. Obtained experimental results were analyzed using descriptive statistics, while correlation analysis showed the relations between different assays. Also, Principal Component Analysis (PCA) has been applied to classify and discriminate between different cultivars cabbage heads. Furthermore, standard score has been introduced to enable more comprehensive comparison between the investigated samples, in order to find the optimum sample, regarding observed chemical, physical, texture and sensory properties. PCA analysis showed that the best sample for cabbage cultivar "*Futoški*" was sample 9, while sample 34 was the best for hybrid "*Bravo*", regarding their chemical, morphological and sensory characteristics.

Introduction

Cabbage (*Brassica oleracea var capitata*) is a widely used vegetable in Serbia. Farmers cultivate hybrids because of their higher yield, compacted head, uniform quality and resistance to diseases, but traditional varieties are still highly prized because of their taste, tradition and suitability for fermentation. Traditional varieties are characterized by loose heads suitable for spontaneous fermentation, since brine diffuses easier into the loose heads (CVETKOVIĆ et al., 2008). White cabbage "*Futoški*" is a traditionally grown and fermented variety in Serbia, but it is also recognized in the EU. One of the most important commercial products obtained from *Brassica* vegetables is sauerkraut, which results from the lactic acid fermentation of shredded and salted white cabbage. Proper cabbage fermentation depends on cabbage variety (DOBRIČEVIĆ et al., 2004; STAMER et al., 1969). Fermented cabbage is traditionally produced in the Balkans using whole heads of cabbage instead of shredded cabbage (JOHANNINGSMEIER et al., 2007; WIANDER and PALVA, 2008; LU et al., 2003). Fermentation time lasts 1-1.5 months (NIKSIC et al., 2005). For proper whole cabbage head fermentation important quality requirements are minimum 3 % sugar content (MALINOWSKA-PAN'CZYK, 2012; NIKETIĆ, 1988) and gentle cabbage leaves with less expressed venation. Moreover, compact head is not a desirable attribute because it retards the progress of fermentation process by lowering the rate of the salt diffusion into the cabbage tissue (CVETKOVIĆ et al., 2012).
In this paper, cultivar "*Futoški*" and hybrid "*Bravo*" were analyzed as a raw vegetable, with their morphological, chemical and sensory characteristics in the purpose of their suitability for whole cabbage head fermentation. Experimental results have been subjected to analysis of variance (ANOVA) to show relations between applied assays (physical, chemical and sensory). In order to enable more comprehensive comparison between the investigated samples, standard score (SS) has been introduced. Principal component analysis (PCA) has been applied to classify and discriminate between the analysed samples and different cultivars.

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Materials and methods

Plant material

Cabbage heads, cultivar "*Futoški*", were harvested from 33 parcels while cabbage heads, hybrid "*Bravo*", were collected from 10 parcels in Futog district, northern Serbia (Province of Vojvodina). They are late fall varieties. Cabbages were harvested in fall 2012. Both types of cabbage were treated with appropriate agro-ecological measures. Soil preparation included deep plowing at 30 cm depth performed in autumn 2011. Also, NPK formulation 8:16:24 in the amount of 800 kg ha^{-1} and manure was added in amount of 30-40 t ha^{-1}. Seedlings were transplanted in mid-July 2012. Cabbage crops were irrigated in 8-12 day intervals with 30-40 mm of water. Young plants were treated with Actarom 25 WG. Further treatment was with Dihtane-M24 and Rodomil gold. Against weeds, herbicide Treflan was used. Harvesting of cabbage heads started when heads were hard to the touch or when the first outer leaf was slightly cracked (not the whole head).
Cabbage heads were analyzed after removing the outer leaves.

Chemical analysis

Sugar content was analyzed according to Luff- Schoorl titrimetric method (EGAN et al., 1981). Dry matter content was determined by drying sample to constant weight, in an oven at 105 °C. Soluble solid content was determined using digital an ATR ST plus, Schmidt-Haensch refract meter, Germany. Crude protein content was analyzed by Kjeldhal method with a conversion factor of 6.25. Ash content was determined after incineration of samples in a muffle furnace at 550 °C for 6 h. The content of cellulose was determined according to the standard procedure of Kürschner-Hanak (KURSCHNER and HANAK, 1930).

Physical analysis

Raw cabbage head weight was measured by scale balance (Tovarna Tehtnic, Celje, Slovenia), and the width of raw cabbage was measured with nonius at the site of widest cabbage cross-section. The height of cabbage head was measured in the middle of the cross section from the stem base to the top of the cabbage head. Stem lenght of cabbage heads were also measured. All measurements were done on ten cabbage heads and descriptive statistics are presented in following tables.

Sensory analysis of raw cabbage

Raw cabbage heads were evaluated sensorially, by seven attributes in order to determine differences between the observed two cabbage varieties. Six trained panelists evaluated four cabbage heads from one cabbage sample. A scale from 0 = "*not dectetable*" to 15 = "*very strong*" was used for attributes: color of outer leaves, leaf venation,

leaf thickness, leaf elasticity cabbage heads compaction. Flavor was described as wetness and sweetness. The intesity of each attribute was rated by panelists by marking a 0-100 unstructured scale with the description of extreme points as previous reported (JOHANNINGSMEIER et al., 2007). Panelist also evaluated color of outer leaves from 0 ("*very light green*") to 15 ("*very dark green*"), compared to the adopted color standards.

Instrumental texture analysis

Cabbage leaf mechanical properties were analyzed by punch test on a texturometer TA-XT2 (Stable Micro Systems, England). Test settings were: test speed 1.0 mm/s, distance 10 mm, trigger force 5 g. For the measurements, the first two or three outer leaf layers were removed from the cabbage head. The next four leaves were then placed on the holed platform and punched with a spheric probe. The tissue between the main veins (midrib and 2° veins) was analysed. The exact punch position was on the left-hand side of the midway between leaf tip and base, between the midrib and the leaf margin, avoiding main veins. Measurings were repeated on four cabbage heads collected from one parcel. Mean burst strenght and mean distance to burst were determined as indicators of leaves hardness and elasticity.

Statistical analyses

Descriptive statistical analyses for all the obtained results have been expressed by means, standard deviation (SD), variance, minimums and maximums, for each cabbage cultivar. Collected data have been subjected to one-way analysis of variance (ANOVA) for the comparison of means. Furthermore, principal component analysis (PCA) has been applied successfully to classify and discriminate between different cabbage cultivars. The evaluation of one-way ANOVA and PCA analyses of the obtained results has been performed using StatSoft Statistica 10.0® software (StatSoft, Tulsa, OK).

Determination of normalized standard scores (SS)

Min-max normalization is one of the most widely used technique to compare various characteristics of complex samples determined using multiple assays, where samples are ranked based on the ratio of raw data and extreme values of the measurement used. Since the units and the scale of the data from various parameters are different, the data in each data set should be transformed into normalized scores, according to following equations:

$$\overline{x}_i = 1 - \frac{\max\limits_i x_i - x_i}{\max\limits_i x_i - \min\limits_i x_i}, \quad \forall i, \text{ in case of "the higher, the better" criteria, or}$$

$$\overline{x}_i = \frac{\max\limits_i x_i - x_i}{\max\limits_i x_i - \min\limits_i x_i}, \quad \forall i, \text{ in case of "the lower, the better" criteria,}$$

where: x_i represents the raw data.

Normalized scores of the most of physical, chemical and sensory properties were evaluated using the above written equations, except for a few parameters, which are evaluated according to optimal values, using trapezoidal function, as follows:

$$\overline{x}_i = \begin{cases} \min\limits_i x_i \le x_i < m, & \dfrac{x_i - \min\limits_i x_i}{m - \min\limits_i x_i} \\ m \le x_i < n, & 1 \\ n \le x_i < \max\limits_i x_i, & 1 - \dfrac{x_i - n}{\max\limits_i x_i - n} \end{cases}, \quad \forall i, \text{ in case of "optimal range" criteria,}$$

where: m and n are minimum and maximum of optimal range values (written in Tab. 1, 2, and 3).

The sum of normalized scores of a sample for different measurements, when averaged give a single unit less value termed as SS, which is a specific combination of data from different measuring methods with no unit limitation. This approach also enables the ease of employing some other set of cabbage cultivars to this elaboration in the future comparisons. SS for physical, chemical and sensory quality for cabbage are calculated and the results are presented in Tab. 1, 2, 3 and 4.

Results and discussion

Chemical properties of raw cabbage, cultivar "*Futoški*" and hybrid "*Bravo*" are shown in Tab. 1. The obtained results for the content of sugar, soluble solids, ash and proteins are in line with other authors (HOLZAPFEL et al., 2003; MARTÍNEZ et al., 2010). Standard scores for chemical properties have been evaluated (Tab. 1), showing that cultivar "*Futoški*" achieved slightly higher result (especially for lower cellulose and protein content). Chemical parameters were coded as C_1-C_6, as designated in Tab. 1.

According to the experimental results, regarding physical characteristics of the cabbage head, there were statistically significant differences in all parameters, except for the stem lenght. Tab. 2 shows that mean value of the height/width ratio, for hybrid "*Bravo*", is close to 1 (0.97). This means that the hybrid had almost regular round shape, whereas cultivar "*Futoški*" had distinctively oval-shaped heads (0.85). This is a good feature of "*Futoški*"cabbage head, because oval heads allow more dense packing of cabbage heads in fermentation barrels, in comparison with round-headed cabbage cultivars and hybrids. Densely packed heads contribute to the achievement of more favorable conditions for anaerobic fermentation. Evaluated standard scores for physical attributes are presented in Tab. 2. Hybrid "*Bravo*" was scored much higher regarding physical properties. Physical properties were coded as P_1-P_5 (Tab. 2).

Sensory characteristics are shown in Tab. 3, and they were evaluated by their intensity in order to characterize and compare between cabbage cultivar "*Futoški*" and hybrid "*Bravo*". The results showed that cabbage cultivar "*Futoški*" had a lighter colored outer leaves. Cultivar "*Futoški*" leaves had less pronounced venation, a desirable characteristic in culinary practice which is in accordance with other authors (BALKAYA et al., 2005). Heads of hybrid "*Bravo*" are very compact, while cultivar "*Futoški*" heads are loose. Calculated standard scores for sensory evaluation (Tab. 3) showed that cultivar "*Futoški*" performed better regarding its geometrical and color attributes, and also organoleptic features. Sensory attributes were coded as S_1-S_{13}, (3). Textural properties of cabbage leaves for the analyzed cabbage cultivar and hybrid are presented in Tab. 4. Skin strength represented hardness of cabbage leaves and Bravo had higher value (1064.39) for hardness than cultivar "*Futoški*" (727.83) which has a gentler structure. That can be explained by higher content of cellulose in hybrid "*Bravo*" (Tab. 1). Distance indicates elasticity of cabbage leaves; raw hybrid "*Bravo*" showed higher elasticity (79.34) than cultivar "*Futoški*" (78.86).

The PCA allows a considerable reduction in a number of variables and the detection of structure in the relationship between measuring parameters, different cabbage cultivars that give complimentary information.

For visualizing the data trends and the discriminating efficiency of the used descriptors, a scatter plot of samples using the first two principal components (PCs) issued from PCA of the data matrix is obtained (Fig. 1). As can be seen, there is a neat separation of the two varieties of cabbage, according to the used assays for all chemical, physical and sensory characteristics. Quality results showed that the first two principal components, accounting for 50.52 % of the total variability can be considered sufficient for data representation and the first two principal components for integrated chemical, physical

Tab. 1: Chemical characteristics of raw cabbage, cultivar "Futoški" and hybrid "Bravo" (g/100g).

	Total sugar content	**Total dry matter**	**Soluble solids content**	**Ash content**	**Cellulose content**	**Proteins content**
Codes	C_1	C_2	C_3	C_4	C_5	C_6
Cultivar "*Futoški*", SS=0.82, N=33 samples						
Average	5.94	9.34	7.20	0.63	0.58	1.50
St. dev	1.09	0.99	0.72	0.07	0.41	0.34
Min.	4.16	7.00	5.33	0.51	0.07	0.96
Max.	8.06	12.05	8.30	0.77	1.85	2.28
Variance	1.18	0.99	0.52	0.00	0.17	0.11
Hybrid "*Bravo*", SS=0.73, N=10 samples						
Average	6.14	9.46	7.39	0.64	1.09	1.35
St. dev	1.29	0.76	0.91	0.09	0.58	0.19
Min.	4.13	8.17	5.50	0.51	0.30	1.14
Max.	7.56	10.48	8.13	0.84	1.78	1.79
Variance	1.66	0.58	0.82	0.01	0.34	0.04
Polarity	+	7-10	6-8	+	-	-

Polarity: '+' = the higher the better criteria, '–' = the lower the better criteria.

Tab. 2: Physical characteristics of raw cabbage heads, cultivar "*Futoški*" and hybrid "*Bravo*"

	Weight (g)	**Width (cm)**	**Height (cm)**	**Stem length (cm)**	**Height/width relation**
Codes	P_1	P_2	P_3	P_4	P_5
Cultivar "*Futoški*", SS=0.47, N=33 samples					
Average	1797.95	17.67	14.98	6.89	0.85
St. dev	434.80	1.47	1.35	1.08	0.04
Min.	1015.50	14.75	12.25	4.50	0.76
Max.	2651.25	20.00	17.50	9.25	0.91
Variance	189047	2.18	1.83	1.17	0.00
Hybrid "*Bravo*" , SS=0.77, N=10 samples					
Average	1383.75	14.55	14.02	6.78	0.97
St. dev	458.78	1.51	1.55	1.06	0.07
Min.	620.00	11.88	10.63	4.75	0.85
Max.	2244.50	16.88	16.38	8.25	1.08
Variance	210478	2.27	2.40	1.11	0.00
Polarity	1500-2000	15-19	12-15	-	-

Polarity: '+' = the higher, the better criteria, '–' = the lower, the better criteria.

and sensory properties.

PCA graph showed good discrimination characteristics between cultivar "*Futoški*" and hybrid "*Bravo*", which were found different mostly due to variables located on the right side of factor plane, C_5 (cellulose content), P_5 (height/width ratio of cabbage head) and a few sensory parameters (S_4 -, color of outer leaves, S_5 - leaf nervature, S_6 - leaf thickness, S_{10} - head density and S_{13} - acerbity). All of these characteristics are considered inappropriate for cabbage head used for fermentation, and samples having the lowest C_5, P_5, T_1, S_4, S_5, S_6, S_{10} and S_{13}, located at the left side of PCA biplot graphic seems to be the better than others. Samples located at the left side of graph also showed better SS results, 0.67-0.76. Best sample for cabbage cultivar "*Futoški*" was sample 9, while sample 34 was the best for hybrid "*Bravo*". The chemical characteristics for optimal sample 9, were: C_1=7.20; C_2=9.09; C_3=7.50; C_4=0.64; C_5=0.17 and C_6=1.19, while physical properties were: $P_1=2.0\cdot10^3$; P_2=19.75; P_3=16.25; P_4=6.50; P_5=0.82. Textural characteristics were: T_1=505.96; T_2=79.08, while sensory attributes gained for optimal sample 9 were: S_1=1.00; S_2=0.50; S_3=1.00; S_4=1.87; S_5=2.33; S_6=1.97; S_7=11.98; S_8=1.63; S_9=1.60; S_{10}=2.57; S_{11}=5.77; S_{12}=7.68 and S_{13}=4.97. Sensory attributes gained for optimal sample 34, for hybrid "*Bravo*" were: C_1=7.20; C_2=8.17; C_3=7.83; C_4=0.51; C_5=0.30; C_6=1.30; $P_1=1.5\cdot10^3$; P_2=16.00; P_3=13.63; P_4=6.00; P_5=0.85; T_1=1007.13; T_2=78.51; S_1=0.25; S_2=1.00; S_3=0.75; S_4=8.90; S_5=9.05; S_6=10.33; S_7=4.30;

Tab. 3: Sensory evaluation of raw cabbage, cultivar "*Futoški*" and hybrid "*Bravo*"

	Shape	Violet color presence	Coverage with leaves	Color of outer leaves	Leaf venation	Leaf thickness	Leaf elasticity	Head section color	Root color	Head density	Wetness	Sweetness	Acerbity
Codes	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}
Cultivar "*Futoški*", SS=0.85, N=33 samples													
Average	0.84	0.93	0.94	4.46	4.50	5.28	9.37	3.15	2.77	5.89	6.05	7.97	3.09
St. dev	0.15	0.17	0.13	1.53	1.26	2.00	1.95	1.09	1.27	2.46	1.76	1.72	1.95
Min.	0.50	0.25	0.50	1.87	2.33	1.97	4.70	1.45	1.23	2.13	3.13	4.03	0.35
Max.	1.00	1.00	1.00	8.77	7.63	9.30	12.50	6.13	6.87	10.43	9.35	11.40	8.37
Variance	0.02	0.03	0.02	2.35	1.59	4.00	3.80	1.20	1.60	6.05	3.10	2.96	3.80
Hybrid "*Bravo*", SS=0.36, N=10 samples													
Average	0.13	1.00	0.45	10.41	11.36	10.65	3.50	4.16	4.03	12.62	4.99	6.24	6.19
St. dev	0.18	0.00	0.39	1.14	1.23	2.59	1.89	2.01	1.43	0.87	2.80	2.04	2.93
Min.	0.00	1.00	0.00	8.13	9.05	4.77	1.83	1.80	2.20	10.93	2.20	3.20	2.33
Max.	0.50	1.00	1.00	11.65	13.00	12.85	7.45	7.73	6.30	13.70	10.38	9.47	11.03
Variance	0.03	0.00	0.15	1.31	1.51	6.71	3.56	4.05	2.06	0.75	7.86	4.17	8.58
Polarity	+	-	+	-	-	-	+	-	-	-	+	+	-

Polarity: '+' = the higher, the better criteria, '–' = the lower, the better criteria

Tab. 4: Texture analysis of cabbage leaves, cultivar "*Futoški*" and hybrid "*Bravo*".

	Skin Strength (g)	Elasticity (mm)
Cultivar "*Futoški*", SS=0.95, N=33 samples		
Average	727.83	78.86
St. dev	232.20	0.63
Min.	396.08	77.55
Max.	1351.17	79.97
Variance	53914.61	0.40
Hybrid "*Bravo*", SS=0.83, N=10 samples		
Average	1064.09	79.34
St. dev	237.66	0.53
Min.	654.54	78.51
Max.	1421.58	80.25
Variance	56484.28	0.28

S_8=2.93; S_9=3.50; S_{10}=12.57; S_{11}=3.60; S_{12}=5.37 and S_{13}=3.67. The main differences between these two samples were due to before mentioned characteristics C_5, P_5, S_4, S_5, S_6, S_{10} and S_{13}, especially in sensory evaluation.

Conclusions

A comparative analysis of raw cabbage properties for domestic variety "*Futoški*" and hybrid "*Bravo*" showed that raw cabbage cultivar "*Futoški*" has good physical, chemical, texture and sensory characteristics desirable for fermentation process. The optimal characteristics for both cabbage cultivars were determined. Standard score analysis showed that "*Futoški*" cultivar is dominant within almost all characteristics of major importance for fermentation process.

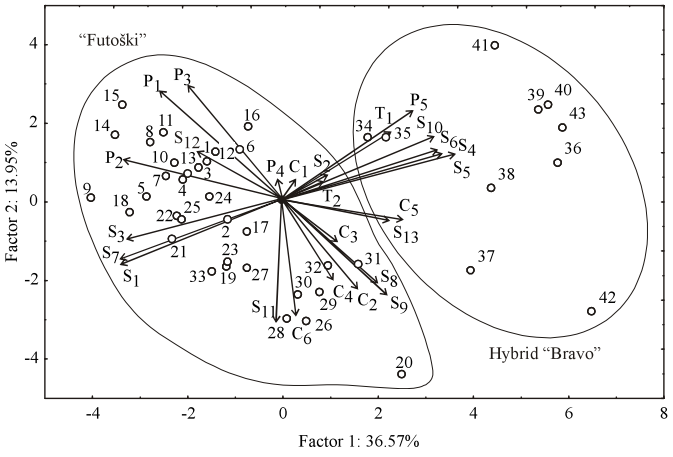

Fig. 1: Biplot for characteristics of cabbage heads.

This is especially evident after PCA analysis, which showed very neat discrimination between these two cultivars. Analysis showed that both cabbages have adequate sugar content needed for fermentation process.

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