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THE INFLUENCE OF MOISTURE CONTENT OF GRAIN ON POPPING VOLUME OF POPCORN HYBRIDS (*Zea mays l. everta*)
UTICAJ VLAŽNOSTI ZRNA NA ZAPREMINU KOKIČAVOSTI HIBRIDA KUKURUZA KOKIČARA (*Zea mays l. everta*)

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ABSTRACT

The percentage of moisture content at the moment of popping has the most significant impact on the popping volume of popcorn. In this research we observed the influence of the optimal moisture content of 14.2 % and lower moisture content (12, 10 and 8 %) on the popping volume of twelve popcorn hybrids. At moisture content of 14.2 % the highest popping volume was observed in ZP 611k (41.33 cm^3/g). Four popcorn hybrids had very good popping volume of over 39 cm^3/g and four hybrids achieved medium popping volume of 36-39 cm^3/g, while three popcorn hybrids had unsatisfactory popping volumes below 36 cm^3/g. Hybrid ZP 501k was the one with the lowest popping volume of 28.67 cm^3/g. By reduction of percentage of moisture content in the grain, significant reductions in popping volumes were observed - in average 37.68, 27.97, 16.93 and 3.79 cm^3/g, respectively. Analysis of variance showed that genotype, moisture content and their interaction had significant impact on the popping volume.

Key words: *popcorn, popping volume, moisture content.*

REZIME

Zapremina kokičavosti u najvećoj meri zavisi od sadržaja vlage u zrnu u momentu kokanja. Mnoga istraživanja pokazuju da je maksimalnu zapreminu kokičavosti moguće ostvariti pri sadržaju vlage u zrnu od oko 14%. Pri sadržaju vlage nižem od toga ne stvara se dovoljan pritisak za pucanje perikarpa i raspršivanje skrobnih zrna. Takođe i veći sadržaj vlage umanjuje zapreminu kokičavosti. U ovom istraživanju analiziran je uticaj optimalnog (14,2%) i smanjenog sadržaja vlage (12, 10, i 8%) u zrnu kukuruza kokičara na zapreminu kokičavosti. Posmatrano je 12 hibrida kokičara, stvorenih u Institutu za kukuruz "Zemun Polje". Pri optimalnom sadržaju vlage u zrnu najvišu zapreminu kokičavosti imao je hibrid ZP 611k (41,33 cm^3/g), a još četiri hibrida postiglo je veoma dobru zapreminu kokičavosti od preko 39 cm^3/g. Četiri hibrida ostvarilo je osrednju zapreminu kokičavosti, u rasponu od 36-39 cm^3/g, dok su tri hibrida bila sa niskom i nezadovoljavajućom zapreminom kokičavosti ispod 36 cm^3/g. Od toga je hibrid ZP501k pokazao izuzetno nisku zapreminu kokičavosti od samo 28,67 cm^3/g. Smanjenjem % vlage u zrnu opadala je i zapremina kokičavosti i za sadržaje vlage u zrnu od 14,2%, 12%, 10% i 8% prosečno je za sve hibride iznosila 37,68, 27,97, 16,93 i 3,79 cm^3/g. Analiza varijanse pokazala je da su na zapreminu kokičavosti značajan uticaj imali hibridi i sadržaj vlage u zrnu, a takođe i interakcija ova dva faktora. Ovo je potvrđeno i LSD testom koji naročito ukazuje na statistički značajne razlike u pogledu zapremine kokičavosti u odnosu na hibride i sadržaj vlage u zrnu.

Ključne reči: *kukurz kokičar, zapremina kokičavosti, sadržaj vlage u zrnu.*

INTRODUCTION

Popcorn is not only one of the most popular snack food worldwide, but also is very nutritious food since it is low in energy and high in fiber (*Schepers, 1989*). The most important trait of popcorn, that differs this type of corn from others is formation of the large fine „flake" while heating up the grain. Commercially popping volume is very important, because commercial buyers buy popcorn hybrids by weight and sell the popped corn by volume (*Ceylan and Karaba, 2002*), thus maximizing final popped volume for a given initial popcorn weight maximizes popcorn sellers' profits (*Shimoni et al., 2002*). That is why the aim of the breeding programs besides maximizing yielding potential, is to improve quality of popped kernels (*Gökmen, 2004; Soylu and Tekkant, 2007; Srdić and Pajić, 2011*). However these two traits are generally in negative correlations, which present a great challenge to popcorn breeders (*Dumanović i Pajić, 1998; Pajić et al., 2006b; Srdić i Pajić, 2011; Pajić et al., 2012*).

Hosney et al. (1983) have explained popping mechanism such as the kernel pericarp acting as a pressure vessel, holding in steam and superheated water. Heating up the kernel over 177 ^{0}C makes the pressure inside the kernel of about 8 bar and then pericarp breaks releasing the pressure. Popcorn endosperm mainly consists of the hard endosperm, built out of closely packed, polygonal starch granule, without aerated subspace, with the size of 7-16 nm. Popcorn's ability to pop lies in the fact that the kernels contain a small amount of water stored in a circle of soft starch inside of hard outer casing. In the moment of explosion of pericarp, high pressure inside the grain causes the spreading of starch granules into the fine film.

Popping volume depends on many factors such as moisture content, genotype, physical properties of kernel, popping method, popping temperature, harvesting and handling practices (*Allerd-Coyle et al., 2000; Karabab, 2006, Mohamed et al., 1993; Song et al., 1991*). However moisture content is the most critical factor among all others, because it affects the rate and extent of pressure built up inside starch granules (*Hosney et al., 1983*).

Many researches indicate that the maximum popping volume could be obtained at the moisture content of 13 – 14 % (*Ziegler et al., 1985; Metzger et al., 1989; Allerd-Coyle et al., 2000; Pajić et al., 2006*). On the other hand optimum moisture content for maximum popping volume is also depending on the

genotype (*Haugh et al., 1976; Lin and Anantheswaran, 1988*), popping procedures such as hot air/oil popping or microwave popping (*Metzger et al., 1989; Dofing et al., 1990*), and kernel size (*Song and Eckhoff, 1994*). Lower moisture content does not provide enough pressure inside the grain necessary for exploding of pericarp and developing of starch granules. Nevertheless, higher moisture content also reduces popping volume by weakening pericarp and making it explode before building up enough pressure (*Hosney et al., 1983*).

In order to achieve maximum potential of popping volume popcorn hybrids must reach full maturity. Popcorn hybrids should be harvested when moisture content is below 20 %, with the optimum between 15-18 % moisture content (*Hosney et al., 1983*). The influence of the stress factors such as drought, frost or diseases and mechanical damages of the grain at harvest and post harvest treatments have significant impact on decrease in popping volume.

The aim of this study was to observe the relationship between popping volume and moisture content of the kernel in twelve popcorn hybrids. Also variations between popcorn hybrids and interactions genotype x moisture content were determined.

MATERIAL AND METHOD

Twelve popcorn hybrids selected in Maize Research Institute Zemun Polje were chosen for this experiment. Three of them were commercial hybrids (ZPSC 611k, ZPSC 614k and ZPTC 501k), while the other nine were experimental hybrids. The trial was set up according to the Randomized Complete Block Design with three replicates in 2013. The size of the elementary plot was 7 m^2, with 40 plants per genotype in two rows, i.e. with the sowing density of 57.142 plants/ha.

All hybrids were harvested at full maturity when their field moisture content was less than 18 %. Threshing was performed manually in order to protect pericarp from damaging, which lowers down number of popped kernels and popping volume. Samples for popping volume were dried by natural convection at room temperature to 14 % moisture, and lower moisture contents of 12 %, 10 % and 8 %. The samples were monitored until the desired moisture content was obtained. Moisture content was checked by Dickey-john GAK II moisture meter. Popping volume (PV) was determined by the standard procedure (MWVT- Metric Weight Volume Test), with the apparatus Cretors 2300w – Official Metric Wight Volume Tester, which performs popping of kernels with oil. Popping volume is presented by the volume of popped kernel (cm^3) per weight of the unpopped - fresh kernel (g). Samples of 250 g for each hybrid and moisture content were popped in three replications to obtain results of popping volume.

Data were analyzed by two-way analysis of variance (ANOVA) and the treatment means were compared using Fisher's least significant test – LSD ($p<0.01$).

RESULTS AN DISCUSSION

The highest popping volumes for each of the twelve popcorn hybrids were observed at 14.2 % moisture content, which is considered as optimal (*Hosney et al., 1983; Ziegler et al., 1985; Metzger et al., 1989; Pajić at al., 2006a*). All popcorn hybrids disregarding genotype achieved significantly higher estimates of PV at 14.2 % grain moisture than at any other. Average popping volume at this moisture content was 37.68 cm^3/g (Table 1).

Table 1. Average popping volumes of twelve popcorn hybrids at four moisture contents

Hybrid	Popping volume (g/cm^3) at moisture contents				Average
	14.2 %	12 %	10 %	8 %	
ZP 611k	41.33	29.33	18.17	2.83	22.92 b
ZP 614k	35.83	26.83	15.17	2.67	20.12 f
ZP 501k	28.67	22.17	12.17	2.00	16.25 g
ZP 606/1k	40.00	30.33	17.17	3.00	22.62 b
ZP 646/1k	38.17	26.17	16.67	5.00	21.50 d
ZP 645/1k	39.17	30.67	18.50	3.00	22.83 b
ZP 655/1k	36.83	26.33	16.00	4.50	20.92 e
ZP 656/1k	40.67	31.33	20.00	4.17	24.04 a
ZP 690/1k	38.67	29.67	17.67	5.33	22.83 b
ZP 686/1k	37.00	29.33	17.83	3.50	21.92 c
ZP 657/1k	40.33	28.50	18.00	4.50	22.83 b
ZP 658/1k	35.50	25.00	15.83	5.00	20.33 f
Average	37.68 a	27.97 b	16.93 c	3.79 d	21.59
Min	28.67	22.17	12.17	2.00	
Max	41.33	31.33	20.00	5.33	
$LSD_{0.05}$ (hybrids)	0.33				
$LSD_{0.05}$ (moisture content)	0.27				
$LSD_{0.05}$ (hyb x mc)	0.60				

Means followed by the same letter are not significantly different according to $LSD_{0.05}$

At 14.2 % grain moisture popping volume ranged from 41.33 cm^3/g to 28.67 cm^3/g. Commercial hybrid ZP 611k was the one with the highest popping volume of 41.33 cm^3/g. Four experimental hybrids (ZP 606/1k, ZP 645/1k, ZP 656/1k and ZP 657/1k) had very good popping volume of over 39 cm^3/g. Medium popping volume of 36-39 cm^3/g was found in four hybrids (ZP 646/1k, ZP655/1k, ZP690/1k and ZP686/1k), while three popcorn hybrids had unsatisfactory popping volumes below 36 cm^3/g (ZP 614k, ZP 501k and ZP 658/1k). Two out of three hybrids in this last group are commercial hybrid i.e. ZP 614k and ZP 501k. Hybrid ZP 501k was the one with the lowest popping volume of 28.67 cm^3/g. On the other hand those two hybrids are high yielding, and ZP 501k is commercially interesting because it achieves full maturity earlier. This points out to the ever present difficulty for popcorn breeders to satisfy market demands for high yielding and good quality popcorn hybrids (*Erić et al., 2003; Srdić and Pajić 2007; Srdić and Pajić 2011; Pajić et al., 2012*). Hybrid ZP 501k performed lowest popping volumes at all moisture contents and its average PV was also significantly lower than all other hybrids. The highest average PV was found for the experimental hybrid ZP 656/1k (24.04 g/cm^3), which was significantly higher than all other hybrids. This hybrid had the second highest PV value at 14.2 % grain moisture (40.33 g/cm^3), and the highest PV at 12 % and 10 % of grain moisture (Table 1).

Lowering the percentage of moisture content in popcorn kernel, popping volume was significantly reduced. On average for 12 hybrids it was 27.97 g/cm^3 at 12 %, 16.93 at 10 % and 3.79 g/cm^3 at 8 % grain moisture. At grain moisture of 12 % popping volume of popcorn hybrids ranged from 22.17-31.33 g/cm^3. In general hybrids that had higher PV at 14.2 % moisture content also produced higher PV at 12 % and 10 % moisture content. Popping volume at 10% moisture content ranged from 12.17-20.00 g/cm^3, while at 8 % moisture content it was almost undetectable 2.00-5.33 g/cm^3 (Table 1). Popping volumes at two

lower grain moistures gave extremely unsatisfactory results not only in quantity but also in quality of popcorns.

Analysis of variance showed that popping volume was significantly affected by the genotype. Moisture content and interactions of these two factors also had significant impact on this trait (Table 2). Significant influence of the genotype in the expression of the popping volume is found in many researches (*Dofing et al., 1991; Ziegler, 1994*). This was verified by the LSD test that indicated significant differences in popping volumes over hybrids, observed moisture contents and their interactions. Average estimates of popping volumes at four moisture contents significantly differed among each other.

Table 2. ANOVA for popping volume

Sources of Variation	Degrees of Freedom	Mean Square	ANOVA
Replication	2	0.063	
Hybrids	11	50.50	**
Moisture content	3	7657.56	**
Hyb x MC	33	7.40	**
Error	94	0.13	

** - *Significant at the 0.01 probability level*

CONCLUSION

The most important quality trait of popcorn is popping volume. It has been hugely investigated by researchers because of its impact on the commercial value of popcorn hybrids. It is also been correlated with desirable consumer attributes such as fine texture. Popping volume has been proven to be the most affected by the moisture content in the grain. Our study showed that the highest popping volume was obtained at 14.2 % moisture content for each of the twelve popcorn hybrids. Commercial hybrid ZP 611k had the highest popping volume (41.33 cm^3/g). Very good popping volume of over 39 cm^3/g was also observed in four experimental popcorn hybrids (ZP 606/1k, ZP 645/1k, ZP 656/1k and ZP 657/1k). Medium popping volume of 36-39 cm^3/g was found in four hybrids (ZP 646/1k, ZP655/1k, ZP690/1k and ZP686/1k), while three popcorn hybrids had unsatisfactory popping volumes below 36 cm^3/g (ZP 614k, ZP 501k and ZP 658/1k). The hybrid ZP 501k was the one with the lowest popping volume of 28.67 cm^3/g. Lowering the percentage of moisture content, popping volume significantly decreased. On average for 12 hybrids it was 37.68, 27.97, 16.93 and 3.79 cm^3/g, respectively. Analysis of variance showed that genotype and moisture content as well as their interaction had significant impact on the popping volume. This was verified by the LSD test that indicated significant differences in popping volumes over hybrids, observed moisture contents and their interactions.

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REFERENCES

Allerd-Coyle,T.A., Toma, R.B., Reiboldt, W., Thaku, M. (2000). Effects of moisture content, hybrid variety, kernel size and microwave wattage on the expansion volume of microwave popcorn. International Journal of Food Sciences and Nutrition, 51, 389-394.

Ceylan, M., Karaba E. (2002). Comparison of sensory properties of popcorn from various types and sizes of kernel. Journal of the Science of Food and Agriculture, 82,127-133.

Dofing, S.M., Thomas-Compton, M.A., Buck, J.S. (1990). Genotype x popping method interaction for expansion volume in popcorn. Crop Science, 30, 62-65.

Dofing, S.M., N. D. Croz-Mason and M.A. Thomas-Compton (1991). Inheritance of expansion volume and yield in two popcorn x dentcorn crosses. Crop Sci. 31, 715-718.

Dumanović, J., Pajić, Zorica (1998). Specifični tipovi kukuruza. Institut za kukuruz "Zemun Polje", Beograd.

Erić, U., Pajić Zorica, Videnović, Jelena (2003). Uticaj genotipa i spoljne sredine na prinos i zapreminu kokičavosti hibrida kukuruza kokičara (Zea mays L. everta). J. Sci. Agric. Research, 64, 27-33.

Gökmen, S. (2004). Effects of moisture content and popping method on popping characteristics of popcorn. Journal of Food Engineering, 65, 357-362.

Haugh, C.G., Lien, R.M., Hanes, R.E., Ashman, R.B. (1976). Physical properties of popcorn. Trans. Am. Soc. Agric. Eng. 19, 168.

Hosney, R.C., Zeleznak, K., Abdelrahman, A. (1983). Mechanism of popcorn popping. J. Cereal Sci. 1, 43-52.

Karabab, E. (2006). Physical properties of popcorn kernels. Journal of Food Engineering, 72, 100-107.

Lin, Y.E., Anantheswaran, R.C. (1988). Studies on popping of popcorn in a microwave oven. Journal of Food Science, 53, 1746-1749.

Metzger, D.D., Hsu, H.K., Ziegler, K.E., Bern, C.J. (1989). Effect of moisture content on popcorn popping volume for oil and hot air popping. Cereal Chemistry, 66, 247-248.

Mohamed, A.A., Ashman R.B., Kirleis A.W. (1993). Pericarp thickness and other kernel physical characteristics relate to microwave popping quality of popcorn. Journal of Food Scineces, 58, 342-346.

Pajić, Zorica, Srdić, Jelena, Todorović, Goran (2006a). Effects of the popcorn grain moisture content on the popping volume. Journal on Processing and Energy in Agriculture (former PTEP), 10, 122-123.

Pajić, Zorica, Srdić, Jelena, Filipović, M. (2006b). Odnos rodnosti i zapremine kokičavosti hibrida kukuruza kokičara (Zea mays L. everta). Selekcija i semenarstvo, 12, 81-83.

Pajić Zorica, Srdić, Jelena, Todorović. G., Babić, M., Radosavljević, Milica (2012). Odnos prinosa zrna i drugih važnih osobina kukuruza kokičara (Zea mays L. everta). Selekcija i semenarstvo, 18, 27-32.

Schepers, A. (1989). Popcorn takes on new flavors, fat and sodium. Enivron. Natur. 12, 4-5.

Shimoni, E., Dirks, E.M. Labuza, T.P. (2002). The relationship between final popped volume of popcorn and thermal-physical parameters. Lebensmittel-Wissenschaft und Technolgie, 35,93-98.

Song, A., Eckhoff, S.R., Paulsen, M., Litchfield, J.B. (1991). Effects of kernel size and genotype on popcorn popping volume and number of unpoppedn kernels. Cereal Chemistry, 68, 464-467.

Song, A., Eckhoff, S.R. (1994). Optimum popping moisture content for popcorn kernels of different sizes. Cereal Chemistry, 71, 458-460.

Soylu, S., Tekkant, A. (2007). Interactions among expansion volume and kernel properties in various popcorn genotypes. Journal of Food Engineering, 8, 336-341.

Srdić Jelena, Pajić Zorica (2011). Variability of yield and kernel quality parameters of popcorn hybrids (Zea mays L. everta). Journal on Processing and Energy in Agriculture (former PTEP), 15 (2), 84-86.

Ziegler, K.E., R.B.Ashman , G.M. White, D.S. Wyson (1985). Popcorn production and marketing. Iowa Cooperation Extension Services Publ. NCH-5, Iowa, USA.

Ziegler, K.E.and R.B. Ashman (1994). Popcorn. In: Speciality Corns, CRC Press Inc., Ames, Iowa, 179.

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