DE GRUYTER OPEN
DOI: 10.1515/agriceng-2016-0011

ISSN 2083-1587; e-ISNN 2449-5999
2016, Vol. 20, No.1, pp.111-118
Agricultural Engineering
www.wir.ptir.org

GEOMETRICAL FEATURES OF SEEDS OF NEW PUMPKIN FORMS

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ARTICLE INFO

Article history:
Received: September 2015
Received in the revised form: October 2015
Accepted: November 2015

Key words:
pumpkin seeds,
pumpkin forms,
geometrical features,
Digital Image Analysis

ABSTRACT

Plant growers are looking for new crops which would make farms and processing plants more profitable. Currently, in Poland, waste-free pumpkin processing is mainly associated with pumpkin seed production, oil extraction, pulverization of pumpkin oil cake to obtain pumpkin meal, the small-scale use of flesh in food production, but mainly the utilisation of flesh as a feed additive. During technological processes applied for the processing of pumpkin seeds it is important to be familiar with their physical characteristics. The aim of this study was to analyse the geometric characteristics of the seeds of new nine forms of the pumpkin variety Olga, which were bred by researchers from the Department of Plant Genetics, Breeding and Biotechnology at the Warsaw University of Life Sciences. Geometrical features were measured using the Digital Image Analysis (DIA) set, consisting of a digital camera (Nikon DXM 1200), computer and lighting (KAISER RB HF). The following geometrical features were measured: length, width, diameter, perimeter, area, circularity and elongation. Additionally, thickness of the seeds was measured by a calliper. Seeds of the studied forms of hull-less pumpkins differed from the standards in the dimensions and shape, whereas significant differences were demonstrated for the Olga variety standard. The most variable geometric characteristic of the seeds under study was area, while the least variable geometric characteristics of the pumpkin seeds turned out to be the circularity and width.

Introduction

Plant growers and processors are looking for new alternative crops which would make farms and processing plants more profitable, and oilseed pumpkin can offer this opportunity. The hull-less pumpkin belongs to the gourd family (*Cucurbitaceae*), and is a botanical cultivar of *Cucurbita pepo* var. *oleifera* Pietsch. or var. *styriaca* Greb. It emerged in the early 19th century in Styria, Austria, as a result of a spontaneous mutation in a single recessive gene (Winkler, 2000). Because of this mutation the hard hull was reduced to a thin membranous seed coat. The growing of oilseed pumpkin spread from Styria to Hungary and other countries because the extraction of edible oil from this cultivar was much cheaper and easier (Korzeniewska et al., 2013). Pumpkin seeds have interesting organoleptic properties and are a rich source of biologically active substances i.e. sterols, squalene, carotenoids and tocopherols (Gorjanović et al., 2011; Nawirska-Olszańska et al., 2013). According to Vujasinovic et al. (2010) seeds with a hard coat contain about 38%, and hull-less seeds 44% of fat. Due to a strong interest in the cultivation of hull-less pumpkins in Poland, it is appropriate to select seeds exhibiting the characteristics allowing the production of a yield being most beneficial to the particular processing area. Currently, the waste-free processing thereof is primarily associated with the production of seeds also known as "pepitas", extraction of oil, grinding the oil cake to produce pumpkin meal, and the occasional use of the flesh in the production of foodstuffs, but principally recycling it by adding to animal feed (Zduńczyk et al., 1998; Aziah and Komathi, 2009; Veronezi and Jorge, 2012). Drying the pumpkin seeds is an important part of their post-harvest processing, preparing them for further processing. The seeds, with an increase in their water content, change their physical properties, knowledge of which is necessary for designing the agricultural machinery and equipment used for both harvesting and drying the seeds and their transport and further processing, including grinding and squeezing (Horabik, 2011; Sosińska and Panasiewicz, 2012). Extensive knowledge of geometric characteristics of the raw material allows the selection of design solutions contributing to the increase in the efficiency of technological processes associated with obtaining the final product, in this case - oil.

Objective of the paper

Given the fact that during the various technological processes applied for the processing of pumpkin seeds it is important to be familiar with their physical characteristics, the aim of this study was to analyse the geometric characteristics of the seeds of new forms of the pumpkin variety Olga.

Materials and methods

Nine novel hull-less forms of Olga pumpkin cultivar (samples 1-9) and two reference varieties Junona (sample 10) and Olga (sample 11), were bred by researchers from the Department of Plant Genetics, Breeding and Biotechnology at the Warsaw University of Life Sciences (SGGW) in 2014 on the experimental field of "Szarłat" company. During the crossing of plants Junona was a female form.

The analysis of geometric features of 100 seeds randomly selected from each sample, carried out with the use of a set of Digital Image Analysis, consisting of a digital camera, a Nikon DXM 1200 (resolution 1280 x 1024 pixels = 1.4 million pixels), lighting KAISER RB HF with 4 x 36 W fluorescent lamps with colour temperature of approx. 5400K, a computer with video capture cards designed for Digital Camera DXM 1200, and LUCIA G ver. 4.80 software (Laboratory of Universal computer Image Analysis).

Seven geometrical features: length (*L*), width (*W*), equivalent diameter (*D*), perimeter projection (*P*), projected area (*A*), circularity (*C*) and elongation (*E*) were measured. Feature values were determined in the LUCIA G software using the following formulas (Lucia User's Guide 2001):

– *P* – perimeter is the total boundary measure. It includes both the outer and inner boundary. The perimeter is calculated from four projections (*Pr*) in the directions 0 (Pr_0), 45 (Pr_{45}), 90 (Pr_{90}) and 135 (Pr_{135}) degrees using Crofton's formula:

$$P = \pi \cdot \frac{(Pr_0 + Pr_{45} + Pr_{90} + Pr_{135})}{4}$$

- A – area is a principal size criterion. In a non-calibrated system, it expresses the number of pixels; in a calibrated one, it expresses the projected area.
- D –equivalent diameter is a size feature derived from the area (A). It determines the diameter of a circle with the same area as the corresponding object:

$$D = \sqrt{(4 \cdot \frac{A}{\pi})}$$

- C – circularity equals to 1 only for circles, all other shapes are characterized by circularity smaller than 1. It is a derived shape measure, calculated from the area (A) and perimeter (P) according to the formula:

$$C = \frac{4 \cdot \pi \cdot A}{P^2}$$

- E – elongation is determined as a ratio of length (L) and width (W) features according to the formula:

$$E = \frac{L}{W}$$

Two features, circularity and elongation, are useful for shape characteristics.
Moreover, the thickness (T) of the seeds was measured using a manual calliper.

The results of the work were analysed using Statistica ver. 12.5 PL software (StatSoft, Kraków, Poland). The differentiation of seed samples by the geometrical features was assayed using a two-way analysis of variance with the Duncan test at $p \leq 0.05$ significance level. The relationships between the studied features were determined by the Pearson linear correlation coefficients at $p \leq 0.05$ significance level. Principal Component Analysis (PCA) at $p \leq 0.05$ significance level was used to show variation in new forms and standard cultivars of pumpkin.

Results and discussion

The size of the seeds is determined by three dimensions i.e. length (L), width (W) and thickness *(T)*. The width and thickness are usually determined based on the largest cross-section of the seed.

The seed dimensions are a varietal characteristic, and regardless of changes to the climatic and soil conditions, the $L : W : T$ ratio has an approximately constant value (Grochowicz, 1994).

The geometrical characteristics of studied pumpkin seeds was presented in Table 1.

Seeds representing the Olga variety standard (sample 11) had the shortest length (19.23 mm). For comparison, the value of this parameter for the Junona variety standard (sample 10) was 21.43 mm. Jafari et al. (2012) analysed the seeds cultivated in Iran, and obtained a similar value for the seeds of a *Cucurbita maxima* variety (20.5 mm), and a much lower one for the seeds of a *Cucurbita pepo* variety (from 15.5 mm to 16.7 mm). An analysis of the geometric characteristics of pumpkin seeds cultivated in Iran was also a subject of a study by Khodabakhshian (2011), who studied the physical characteristics of seeds of the Zaria and Gaboor varieties of the *Cucurbita maxima* species depending on the moisture content of the seeds.

Table 1.
Geometrical features of seeds of different form Olga variety and two standards

Sample number		*L* (mm)	*W* (mm)	*D* (mm)	*T* (mm)	*P* (mm)	*A* (mm^2)	*C* (-)	*E* (-)
1	$\overline{x}$	22.48 g	11.02 b	15.03 fg	2.68 bcd	54.42 g	177.74 fg	0.75 a	2.04 f
	SD	0.88	0.27	0.46	0.28	2.08	10.77	0.03	0.07
	CV	3.92	2.46	3.04	10.26	3.83	6.06	3.72	3.43
2	$\overline{x}$	20.80 a	10.39 a	13.99 b	2.68 bcd	49.99 b	154.76 ab	0.77 bc	2.00 de
	SD	1.03	0.62	0.72	0.27	2.55	14.02	0.02	0.06
	CV	4.94	5.95	5.15	9.90	5.10	9.06	2.67	3.15
3	$\overline{x}$	21.04 bc	10.48 a	14.08 b	2.17 a	51.05 bcd	156.73 b	0.75 a	2.01 de
	SD	1.32	0.51	0.76	0.15	2.68	14.09	0.03	0.06
	CV	6.27	4.91	5.39	6.69	5.26	8.99	3.67	2.96
4	$\overline{x}$	21.62 de	10.84 b	14.58 cde	2.74 cd	52.10 de	167.10 cd	0.78 c	2.00 d
	SD	0.93	0.38	0.47	0.23	2.37	10.90	0.04	0.08
	CV	4.32	3.53	3.23	8.46	4.55	6.52	4.76	4.21
5	$\overline{x}$	21.44 cd	10.91 b	14.55 cd	2.48 bcd	52.58 e	170.04 de	0.76 a	1.99 d
	SD	1.91	1.23	1.37	0.28	6.01	23.04	0.04	0.17
	CV	8.92	11.24	9.44	11.18	11.43	13.55	5.86	8.40
6	$\overline{x}$	22.56 g	11.15 b	15.14 ef	2.87 e	54.95 fg	180.25 ef	0.75 a	2.02 g
	SD	0.54	0.30	0.31	0.24	2.32	7.29	0.04	0.03
	CV	2.40	2.65	2.04	8.22	4.23	4.05	5.08	1.28
7	$\overline{x}$	20.70 b	11.33 c	14.63 cde	2.84 cde	50.88 bc	169.29 cde	0.81 e	1.84 b
	SD	1.18	1.17	1.23	0.18	3.56	27.54	0.03	0.12
	CV	5.71	10.29	8.42	6.47	7.00	16.27	3.96	6.43
8	$\overline{x}$	21.97 ef	10.84 b	14.78 def	2.51 b	52.85 ef	172.41 def	0.77 bc	2.03ef
	SD	0.98	0.49	0.66	0.27	2.58	12.53	0.02	0.06
	CV	4.48	4.50	4.45	10.70	4.88	7.27	3.12	3.11
9	$\overline{x}$	22.13 fg	11.40 c	15.25 g	2.63 bc	53.82 fg	182.93 g	0.79 d	1.94 c
	SD	0.68	0.32	0.39	0.17	1.60	9.43	0.02	0.05
	CV	3.06	2.80	2.58	6.34	2.97	5.16	2.71	2.59
10	$\overline{x}$	21.43 cd	10.76 b	14.41 c	3.01 e	51.94 cde	163.41 c	0.76 ab	1.99 d
	SD	0.90	0.37	0.49	0.19	2.21	10.91	0.02	0.06
	CV	4.18	3.44	3.39	6.27	4.26	6.67	3.11	3.14
11	$\overline{x}$	19.23 a	10.77 b	13.75 a	2.80 cd	47.97 a	148.88 a	0.81 e	1.79 a
	SD	0.95	0.49	0.64	0.20	2.68	13.72	0.04	0.07
	CV	4.94	4.55	4.65	7.14	5.59	9.22	4.51	3.80
All	$\overline{x}$	21.42	10.91	14.58	2.68	52.05	168.10	0.78	1.97
	SD	1.37	0.75	0.89	0.31	3.47	18.60	0.04	0.12
	CV	6.41	6.84	6.11	11.71	6.66	11.07	4.83	6.09

$\overline{x}$ – mean value; SD – standard deviation; CV – variation coefficient (%); a, b, c, … – mean value in columns marked with the same letter are not significantly different ($p \leq 0.05$)

For very dry seeds (moisture content of 4%), the length was 14.90 mm (Zaria variety) and 15.86 mm (Gaboor variety), while the width was 6.91 mm (Zaria variety) and 5.17 mm (Gaboor variety). Seeds with high moisture content (20%) had the following lengths: 17.55 mm (Zaria variety) and 18.96 mm (Gaboor variety), while their width was as follows: 8.93 mm (Zaria variety) and 7.94 mm (Gaboor variety). Jafari et al. (2012) also report a range for this characteristic to be from 7.3 mm to 9.0 mm for the seeds of a *Cucurbita pepo* variety. The seeds studied in our experiment have a much bigger width ranging from 10.48 mm (sample 3) to 11.40 mm (sample 9).

The length turned out to be a more variable characteristic than the width of the seeds, which is indicated by the values of the variation coefficients (6.84% vs 6.41%).

The figures below illustrate the differences in the distribution of the length (Fig. 1a) and the width (Fig. 1b) of pumpkin seeds.

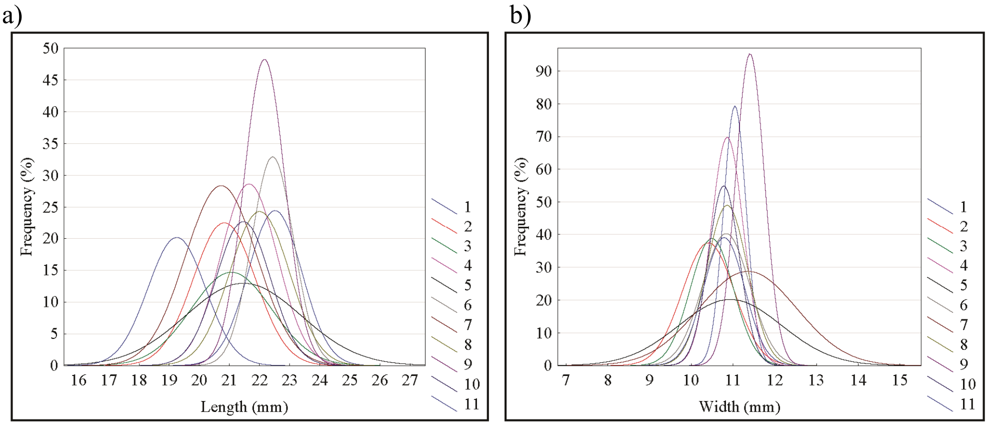

Figure 1. Length (a) and width (b) distribution of pumpkin seed samples

Sample 9 was the most uniform in terms of the length and width, while sample 5 was the most diversified. Another analysed geometric characteristic was an equivalent diameter. The value of this characteristic ranged from 13.75 mm (sample 11, Olga variety standard) to 15.25 mm (sample 9).

Thickness of the analysed seeds ranged from 2.17 mm (sample 3) to 3.01 mm (sample 10, Junona variety standard). The average value of this parameter for all samples was 2.68 mm.

The perimeter depends on the number and depth of seed surface deformations. The seeds of sample 6 had the longest perimeter (54.95 mm), while the seeds comprising the Olga variety standard (sample 11) had the shortest one.

The area was the most variable geometric characteristic of the seeds under study. The value of this parameter ranged from 148.88 mm^2 (sample 11, Olga variety standard) to 182.93 mm^2 (sample 9). For the Olga variety standard, characterised by the smallest area, the value of this parameter ranged from 121.70 mm^2 to 170 mm^2. In turn, the Junona variety standard (sample 10) had, in the studied population, seeds within the range from 139.70 mm^2 to 182.09 mm^2.

The geometric characteristic differentiating the studied samples to the smallest extent was the circularity of seeds. Average values of this characteristic describing the shape of seeds ranged, for all samples, from 0.75 (samples 1 and 6) to 0.81 (samples 7 and 11). For comparison, the circularity of pumpkin seeds of a *Cucurbita maxima* species, depending on the moisture content and seed variety, ranged from 0.45 (Gaboor variety with a moisture content of 4%) to 0.61 (Zaria variety with a moisture content of 20%) (Khodabakhshian, 2010).

A statistical analysis of the obtained results using PCA (Fig. 2) indicates a relatively big difference between the studied forms of the Olga variety (sample 1–9) and the standard of this variety (sample 11) in terms of the geometric characteristics of samples. Geometrical characteristic of seeds of the Junona variety (sample 10) was similar to that of forms marked with Nos 4, 5, and 8. However, seeds of forms marked with Nos 7 and 9 were different from other forms.

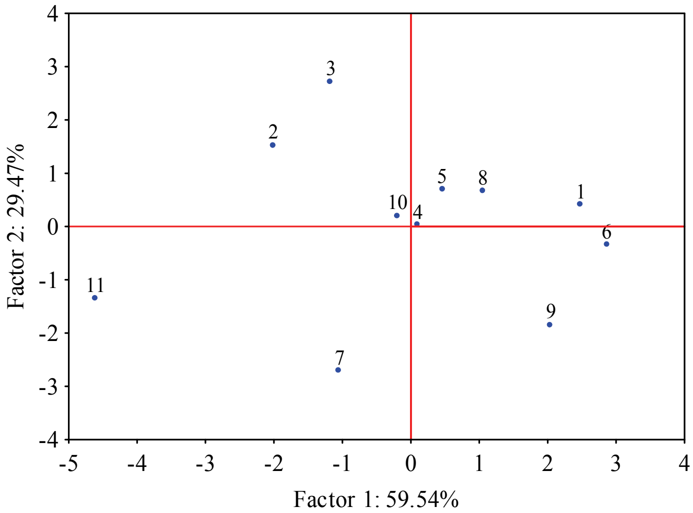

Figure 2. Score plot of the two first principal components after PCA analysis of all geometrical features of pumpkin seed samples

A correlation analysis demonstrated significant correlations between the length and the width, equivalent diameter, perimeter, and the projected area (r in the range of 0.87-0.98). The equivalent diameter of the seeds also had the greatest effect on both the perimeter and the projected area. The shape coefficients (circularity and elongation) depended, to the greatest degree, on the length (Table 2).

Table 2.
Correlation coefficients of geometrical features analysed samples

	L	*W*	*D*	*T*	*P*	*A*	*C*	*E*
L	-							
W	0.87	-						
*D*r	0.88	0.78	-					
T	n.s.	n.s.	n.s.	-				
P	0.98	n.s.	0.93	n.s.	-			
A	0.87	0.78	1.00	n.s.	0.93	-		
C	-0.64	n.s.	n.s.	n.s.	n.s.	n.s.	-	
E	0.78	n.s.	n.s.	n.s.	0.67	n.s.	-0.90	-

n.s. – not statistically significant ($p \leq 0.05$)

Conclusions

1. Seeds of the studied forms of hull-less pumpkins differed from the standards with regard to dimensions and shape, whereas significant differences were demonstrated for the Olga variety standard.
2. Seeds of the new pumpkin forms were characterised by the width comparable to that seeds of Olga variety (a change smaller than 6%) but were longer (a change by 8-17%), which resulted in their greater elongation (a change by 3-14%).
3. Circularity and width turned out to be the least variable geometric characteristics of the pumpkin seeds under study, while the area was the most variable characteristic.

References

Aziah, A.A.N., Komathi, C.A. (2009). Physicochemical and functional properties of peeled and unpeeled pumpkin flour. *Journal of Food Science*, *74*(7), 328-333.

Gorjanović, S. Ž., Rabrenović, B. B., Novaković, M. M., Dimić, E. B., Basić, Z. N., Sužnjević, D. Ž. (2011). Cold-pressed pumpkin seed oil antioxidant activity as determined by a DC polarographic assay based on hydrogen peroxide scavenge. *Journal of the American Oil Chemists' Society*, *88*(12), 1875-1882.

Grochowicz, J. (1994). *Maszyny do czyszczenia i sortowania nasion*. Wydawnictwo Akademii Rolniczej w Lublinie. ISBN 83-901612-9-X.

Horabik, J. (2011). Stan badań z zakresu właściwości fizycznych surowców roślinnych w aspekcie ich przetwarzania. Ekspertyza. Maszynopis. *Agroinżynieria Gospodarce*.

Jafari, M., Goli, S. A. H., Rahimmalek, M. (2012). The chemical composition of the seeds of Iranian pumpkin cultivars and physicochemical characteristics of the oil extract. *European Journal of Lipid Science and Technology*, *114*(2), 161-167.

Khodabakshian, R. (2011). Mechanical strength and physical behavior of pumpkin seed and its kernel. *Thai Journal of Agricultural Science*, *45*(1), 37-43.

Korzeniewska, A., Witek, M., Gałecka, T., Niemirowicz Szczyt, K. (2013). Ocena wybranych cech dyni zwyczajnej *(Cucurbita pepo subsp. pepo var. styriaca Greb.)* o nasionach bezłupinowych. *Polish Journal of Agronomy*, *12*, 32-37.

Lucia User's Guide (2001). *System for image processing and analysis*. Laboratory imaging.

Nawirska-Olszańska, A., Kita, A., Biesiada, A., Sokół-Łętowska, A., Kucharska, A. Z. (2013). Characteristics of antioxidant activity and composition of pumpkin seed oil in 12 cultivars. *Food Chemistry*, *139*(1-4), 155-161.

Sosińska, E., Panasiewicz, M. (2012). Wpływ wilgotności pestek dyni na wybrane właściwości fizyczne. *Acta Scientiarum Polonorum, Technica Agraria*, *11*(3-4), 47-53.

Veronezi, C. M., Jorge, N. (2012). Bioactive Compounds in Lipid Fractions of Pumpkin (Cucurbita sp.) Seeds for Use in Food. *Journal of Food Science, 77*(6), 653-657.

Vujasinovic, V., Djilas, S., Dimic, E., Romanic, R., Takaci, A. (2010). Shelf life of cold-pressed pumpkin (Cucurbita pepo L.) seed oil obtained with a screw press. *Journal of the American Oil Chemists' Society*, *87*(12), 1497-1505.

Winkler, J. (2000). The origin and breeding of the hull-less seeded Styrian oil pumpkin varieties in Austria. *Cucurbit Genetics Cooperative Report*, *23*, 101-104.

Zduńczyk, Z., Minakowski, D., Frejnagel, S., Flis, M. (1998). Skład chemiczny i wartość pokarmowa makuch z dyni. *Rośliny Oleiste*, *19*(1), 206-209.

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CECHY GEOMETRICZNE NASION NOWYCH FORM DYNI

Streszczenie. Hodowcy roślin szukają nowych roślin, które sprawiają, że gospodarstwa i zakłady przetwórcze są bardziej opłacalne. Obecnie w Polsce, bezodpadowe przetwarzanie dyni jest związane przede wszystkim z produkcją nasion dyni, wydobyciem oleju, rozdrabnianiem makucha do postaci mączki dyniowej, wykorzystaniem na małą skalę miąższu w produkcji żywności, ale przede wszystkim wykorzystanie miąższu jako dodatku do pasz. Podczas procesu technologiczne stosowanego do obróbki nasion dyni ważna jest znajomość ich cech fizycznych, dlatego celem niniejszej pracy była analiza cech geometrycznych nasion nowych dziewięciu form odmiany dyni Olga, które zostały wyhodowane przez naukowców z Katedry Genetyki, Hodowli Roślin i Biotechnologii Uniwersytetu Przyrodniczego w Warszawie. Cechy geometryczne były mierzone za pomocą zestawu do Cyfrowej Analizy Obrazu (DIA) składającego się z kamery cyfrowej (Nikon DXM 1200), komputera i oświetlenia (KAISER RB HF). W pracy zostały zmierzone takie cechy geometryczne jak: długość, szerokość, średnica zastępcza, obwód, pole powierzchni, kolistość i wydłużenie. Dodatkowo zmierzono grubość nasion za pomocą suwmiarki. Nasiona badanych form dyni bezłuskowej różniły się od standardów wymiarami i kształtem, przy czym istotne różnice wykazano w porównaniu ze standardem odmiany Olga. Najbardziej zmienną cechą geometryczną badanych nasion było pole powierzchni, natomiast najmniej zmienne okazały się takie cechy jak kolistość i szerokość.

Słowa kluczowe: nasiona dyni, formy dyni, cechy geometryczne, cyfrowa analiza obrazu