Technical Sciences, 2016, 19(4), 295–312

Quarterly peer-reviewed scientific journal
ISSN 1505-4675
e-ISSN 2083-4527
TECHNICAL SCIENCES
Homepage: www.uwm.edu.pl/techsci/

THE EFFECT OF DRYING AND LONG-TERM STORAGE ON COLOUR AND CAROTENOIDS CONTENT OF GIANT PUMPKIN (CUCURBITA MAXIMA)

Mariusz Sojak, Małgorzata Jaros, Monika Janaszek-Mańkowska, Jędrzej Trajer, Szymon Głowacki, Arkadiusz Ratajski

Department of Fundamental Engineering
Warsaw University of Life Sciences

Received 30 August 2016, accepted 26 October 2016, available online 26 October 2016.

Key words: Chemical composition, Clustering, Colour, Drying, Factor analysis, Pumpkin.

Abstract

The objective of this study was to characterise the quality of giant pumpkin dried in different conditions as well as to determine the best combination(s) of drying conditions, based on colour and chemical composition of dried material. Samples of three pumpkin cultivars (Amazonka, Justynka-957 and Ambar) were dried at five different temperatures (40°C, 50°C, 60°C, 70°C, 80°C) using three different drying methods (forced convection in tunnel dryer, natural convection in chamber dryer and hybrid drying which combined a tunnel drying and fluidized-bed drying). It has been shown that variability of samples resulted primarily from the redness, yellowness, lutein and β-carotene. Samples were scored based on the range of responses identified by factor analysis in order to find an optimal combination of cultivar, temperature and drying method. The three subsequent highest scores were obtained for samples of Ambar cultivar, dried using hybrid drying at 40, 60 and 80°C respectively.

Symbols:

L – colour lightness [–]
a – colour redness [–]
b – colour yellowness [–]
DM – dry matter [$g \cdot g^{-1}$]
TS – total sugars [$g \cdot g^{-1}$]
RS – reducing sugars [$g \cdot g^{-1}$]
LU – lutein [$mg \cdot g^{-1}$]

Correspondence: Mariusz Sojak, Katedra Podstaw Inżynierii, Szkoła Główna Gospodarstwa Wiejskiego, ul. Nowoursynowska 164, 02-787 Warszawa, phone: 22 59 346 16, e-mail: mariusz_sojak@sggw.pl

LY – lycopene [mg · g^{-1}]
BC – β-carotene [mg · g^{-1}]
B – pumpkin cultivar Ambar
Z – pumpkin cultivar Amazonka
J – pumpkin cultivar Justynka
F – forced convection in a tunnel dryer
N – natural convection in a chamber dryer
H – hybrid drying
C×D – interaction of cultivar and drying method
T – drying temperature [°C]
C – cultivar
D – drying method
RSQ – R-squared index [–]

Introduction

Consumption of pumpkin has increased all over the world in the last few years. Research proved that pumpkin has health benefits and can significantly contribute to the uptake of pro-vitamin A, especially lutein which is responsible for specific physiological functions (MURKOVIC et al. 2002, GUINÉ et al. 2011). Studies conducted by MURILLO et al. (2010) revealed that pumpkin possesses higher concentration of lutein compared to cabbage, carrot (twenty-fold higher), potato or tomato – the vegetables vastly recommended as the richest sources of lutein. Research report that pumpkin-rich diet has pharmacological activity and could reduce blood glucose (XIONG, CAO 2001, ZHANG et al. 2002, ZHANG, YAO 2002, CAI et al. 2003). The protein-bound polysaccharides in pumpkin have potential use as an anti-diabetic agent, because of ability to improve tolerance of glucose by reducing the blood glucose levels and increasing the levels of serum tolerance of glucose (ADAMS et al. 2011, CARVALHO DE et al. 2012). Pumpkin polysaccharides display therapeutic potential, which may be useful in prevention and treatment of diabetic complications, such as decreased myocardial compliance (ARONSON 2003), arteriosclerosis (THOMAS et al. 2005), peripheral neuropathy (WADA, YAGIHASHI 2005), cataracts (ROBINSON et al. 1983), retinopathy (ROBINSON et al. 1989), neuropathy (YOUNG et al. 1983) and kidney lesion (BURG 1995, WANG et al. 2012). Pumpkin is also a rich source of fibre and β-carotene – an immediate precursor of vitamin A. Fibre addition to foods is an alternative to compensate for the existent deficiency in the diet. Nowadays, the recommended dietary fibre intake is 25–30 grams a day. Total fibre content in pumpkin pulp is up to 0.784 ± 0.008 g · g^{-1}. Pumpkin contains also many water soluble components belonging to the cytoplasmic medium like globular proteins, mono-, di- and oligosaccharides, amino-acids, salts and organic acids (PLA et al. 2007). The fresh pumpkin contains 0.09÷0.1 mg · g^{-1} of vitamin C and 0.013–0.0106 mg · g^{-1} of vitamin E (TERAZOWA et al. 2001, MURKOVIC et al.

2002, KUNACHOWICZ et al. 2005). Pumpkin fruit is also a valuable source of other vitamins, like B6, K, thiamine and riboflavin as well as minerals, e.g., potassium, phosphorus, magnesium, iron and selenium (USDA 2004, NAWIRSKA et al. 2009, RAKCEJEVA et al. 2011).

As a seasonal crop fresh pumpkins are very sensitive to microbial spoilage even if stored at refrigerated conditions, thus they require processing, e.g. freezing or drying (GUINÉ et al. 2001, DOYMAZ 2007). Fresh, unprocessed pumpkin should be stored at temperature between 10 and 13°C and at relative air humidity between 50% and 70% (KITINOJA, KADER 2002). Approximate storage life is only 2÷3 months. When stored in low temperature, unfavourable physiological processes occur resulting in chill damage. For this reason drying seems to be the most reasonable method for pumpkin preservation. Dried pumpkin can be treated as final or semi-final product which may enrich basic foods in nutrients important for people (SOJAK, GŁOWACKI 2010). Convective drying is the most common method of food preservation for the reason of being the most efficient and the least expensive (PEREZ, SCHMALKO 2007). Therefore, using other drying technologies is not economically justified (except for scientific purposes). However, properly selected drying method may increase the quality of the final product (DIAMANTE, MUNRO 1993, ERTEKIN, YALDIZ 2004, LEWICKI 2006, SOJAK, GŁOWACKI 2010).

Heat processing of plant materials generally results in the loss of biologically active compounds (DIVYA et al. 2012). Also colour degradation or discolouration occur frequently as the effect of temperature or different drying treatments and is related mainly to pigment degradation, enzymatic or oxidative browning and Maillard reactions (DU 2009, WANG et al. 2011). As regards pumpkin CIE*Lab* colour parameters as well as chroma (C) and hue angle (h) are commonly used to monitor the quality of material dried in different conditions. Colour lightness (L) is reported as the most sensitive to changes of drying temperature, drying technique and drying pretreatments and also related to carbohydrates content (ALIBAS 2007, NAWIRSKA et al. 2009) and the occurrence of non-enzymatic browning reactions (GLIEMO et al. 2009). Chromaticity parameters a and h are regarded as temperature dependent and darkening indicators (FALADE, SHOGAOLU 2010). NAWIRSKA et al. (2009) reported that parameters a, b and L should gain high values to obtain the best colour of dried pumpkin slices. It was proved that pumpkin exposure to heat and oxygen leads to α- and β-carotene degradation followed by increase of *cis* isomers resulting in loss of yellowness (less observed as fading) (FALADE, SHOGAOLU 2010, LAGO-VANZELA et al. 2013). Nonetheless, colour changes resulting from dehydration are also cultivar dependent (KONOPACKA et al. 2010).

In this study convective drying of pumpkin was realised at different temperatures in a chamber dryer, tunnel dryer and fluidized bed dryer.

The objective of this study was to characterise the quality of giant pumpkin dried in different conditions as well as to determine the best combination(s) of cultivar and drying conditions, based on colour and chemical composition of dried material.

Materials and methods

Sample preparation and drying experiments

Sample material was taken from parenchyma of three giant pumpkin (*Cucurbita maxima* Duch.) cultivars: Amazonka (Z), Justynka-957 (J) and Ambar (B). Pumpkins were grown on the experimental field owned by the Department of Genetics, Breeding and Biotechnology at the Faculty of Horticulture, Biotechnology and Landscape Architecture, Warsaw University of Life Sciences-SGGW. Each cultivar was represented by ten (10) plants taken randomly from the experimental field. Parenchyma samples taken from the top (sunny) part of the fruit were washed, peeled, purified from seeds and cut into 10 mm cubes using industrial slicer. The samples for further studies were prepared according to the method described by MURKOVIC et al. (2002).

Samples were dried at five different temperatures (40°C, 50°C, 60°C, 70°C and 80°C) using three different drying methods (forced convection in a tunnel dryer (F), natural convection in a chamber dryer (N) and hybrid method (H), which consisted of (F) in the first phase and fluidized-bed drying in the second phase). Dried material was stored approximately five years under uncontrolled conditions in airtight dark containers, at mean temperature of 21.5±3.5°C and mean relative humidity of 50%±10% (ZANONI et al. 2007, DIVYA et al. 2012).

Sample characteristics

After five years of storage 37 of 45 samples were suitable for further analysis. Dried material was pulverised and analysed for dry matter content – DM (PN-R-04013: 1988), total sugars – TS and reducing sugars – RS according to the Luff-Schoorl method (FORTUNA et al. 2003), lutein – LU, lycopene – LY and β-carotene – BC using HPLC method. Colour of each sample was extracted from digital images and expressed as CIE*Lab* colour space coordinates. Pulverised samples were placed in dishes made from light scattering material. Colour images of samples were acquired using Canon flatbed scanner, model CanoScan 5600F. The device was equipped with 6-line colour CCD sensor, fluorescent lamp and the 48-bit input/output interface (16 bits for each RGB channel). Images of resolution of 300 dpi were acquired to sRGB

colour space. During scanning process all tools for automatic image enhancement had been disabled.

Mean brightness of Red, Green and Blue channel were extracted from each sample image and then linearly transformed to CIE*XYZ* colour space relative to D65 reference white. Nonlinear transformation of CIE*XYZ* to CIE*Lab* coordinates was done relative to illuminant D65 and observer 10°, according to CIE standard using 94.81, 100, 107.32 values as reference whites for X, Y and Z coordinates respectively (CIE 2004). Pumpkin colour was then characterised by three parameters: L – lightness (100 for white and 0 for black), a – colour redness or greenness ($-a$: green, $+a$: red), b – colour blueness or yellowness ($-b$: blue, $+b$: yellow).

Data analysis

Unbalanced ANOVA for three-way factorial design with incomplete evaluation of interactions in terms of temperature was realised to characterise variability of samples (Tab. 1). Multiple comparison procedure was realised using Tukey-Kramer test. The main effects of cultivar, drying method and temperature were studied. Since there was no replications for drying temperatures only interaction of cultivar and drying method (C×D) was considered.

Table 1

Unbalanced three-way factorial design

40°C	50°C	60°C	70°C	80°C
BH		BH		BH
BN		BN		BN
BF	BF	BF	BF	BF
JH	JH	JH	JH	
JN	JN		JN	JN
JF	JF	JF	JF	JF
ZH	ZH	ZH	ZH	ZH
ZN	ZN	ZN	ZN	ZN
	ZF		ZF	ZF

Exploratory factor analysis (EFA) with varimax orthogonal rotation was applied to determine features that most explained variability of samples. On this basis features with the highest discriminant ability were selected as responses to 37 combinations of pumpkin cultivar (C), drying temperature (T) and drying method (D). Number of valid factors was determined upon Keiser criterion (eigenvalue criterion).

To investigate similarities of dried material as well as to rank the drying treatments cluster analyses were applied using Ward's minimum-variance procedure. An optimal number of clusters was determined on the basis of R^2 (RSQ) index (SARLE 1983).

Based on the full set of variables samples were divided into optimal number of clusters. Then, one-way ANOVA and Tukey-Kramer multiple comparison procedure were used to characterise each cluster on the optimal level of hierarchy.

Additionally, to obtain the best CTD combination(s), cluster analyses were performed using each response $r = (1, 2, ..., n)$ derived from EFA as a predictor. Based on the range of mean responses in each cluster, a normalised value s (score) between 0 and 1 was allocated to each cluster member. The higher rank represented more desirable response. Then, a scoring method was chosen to determine the best combination of CTD which maximised total score. For multiple responses, partial scores were combined into total score (S). Hence, the total score for each treatment was calculated according to NADIAN et al. (2016) using the following equation:

$$S = \left(\prod_{r=1}^{n} S_r\right)^{n^{-1}} \tag{1}$$

All analyses except cluster analyses were performed in STATISTICA 12 (StatSoft Inc., Tulsa, OK, USA). Cluster analyses were carried using SAS 9.4 (SAS Institute Inc., Cary, NC, USA).

Results and discussion

Three-way unbalanced ANOVA was performed to study the effects of cultivar and drying treatment on colour and basic chemical composition of samples. Tables 2, 3, 4 and 5 present means, standard deviations and homogeneous groups only for significant effects.

The effect of temperature

The effect of temperature was negligible for most characteristics except for reducing sugars and colour lightness (Tab. 2). Significant differences in RS were observed only between samples dried at 40°C and 80°C whereas samples dried at other temperatures formed three superimposed homogeneous groups. Colour lightness decreased while temperature increased but only samples dried at 80°C were significantly darker compared to samples dried at lower temperatures. These results confirm the conclusions on the sensitivity of L parameter to drying temperature reported by ALIBAS (2007) as well as the connection of high lightness values and high carbohydrates content reported by NAWIRSKA et al. (2009). Darkening of samples dried at high temperatures is in agreement with other results reported for pumpkin (ROONGRUANGSRI,

BRONLUND 2016) and may occur as the effect of Maillard reaction, responsible for nonenzymatic browning (SEVERINI et al. 2005) as well as from high concentration of colorants (in this case carotenoids) which was suggested by LEWICKI and DUSZCZYK (1998) as the effect of water removal and its substitution by air as well as surface deformation (shrinkage) during convective drying.

Table 2

Three-way ANOVA results: the effect of temperature*

Variable	Statistic	T [°C]				
		40	50	60	70	80
RS	Mean	0.18^{a}	0.16^{ab}	0.15^{abc}	0.14^{bc}	0.13^{c}
	SD	0.02	0.02	0.02	0.02	0.03
L	Mean	71.47^{a}	70.21^{a}	70.49^{a}	68.19^{a}	63.23^{b}
	SD	4.29	4.66	3.12	3.43	5.22

Means with the same letter do not differ significantly at $\alpha = 0.01$.

The effect of cultivar

Studied cultivars differed significantly in dry matter and carotenoids content (Tab. 3). Cultivar Ambar characterised with the highest DM while no significant differences were observed for the other two cultivars. Ambar and Amazonka contained significantly more lutein than Justynka. Moreover, Ambar was the richest in lycopene and β-carotene and as regards these substances each cultivar differed significantly from the others. Lycopene content in dried Ambar samples was almost five times higher than in Justynka and nine times higher than in Amazonka samples. Pumpkin cultivar affected also colour lightness and yellowness. The darkest but the most yellow colour was characteristic for Amazonka samples which differed significantly from the lightest samples of Justynka and the least yellow samples of Ambar. One may observed some relationship between yellowness and lycopene content. Cultivars with high content of lycopene were less yellow but characterised with higher L which is rather obvious considering that lycopene is a red colorant. The differences in total carotenoids content between cultivars Ambar and Amazonka dehydrated by convective drying at 60°C (1.32 and 4.86 mg · g^{-1} respectively) are in agreement with results obtained by NAWIRSKA et al. (2009). Nonetheless, cultivar Ambar dried at 80°C characterised with total carotenoids content of 1.86 mg · g^{-1} which was over two times higher comparing to carotenoids content observed for Amazonka cultivar (0.76 mg · g^{-1}). Since the drying experiment was unbalanced, the significance of C×T interaction could not be tested but results obtained for 80°C may be explained (to some extent) by the cultivar ability to retain carotenoids in high drying temperatures. From the other hand, the difference in total carotenoids content observed between

Ambar samples dried at 60 and 80°C (even if not significant) may result from the ease of extraction of these substances which might be protected or combined with other products at lower temperatures and released (available) at higher temperatures. Similar conclusions were proposed by LAGO-VANZELA et al. (2013).

Table 3

Three-way ANOVA results: the effect of cultivar*

C	Statistic	DM	LU	LY	BC	*L*	*b*
B	mean	0.94^{a}	1.28^{a}	0.18^{a}	0.50^{a}	69.44^{a}	27.06^{b}
	SD	0.02	1.29	0.12	0.38	2.96	3.94
J	mean	0.92^{b}	0.57^{b}	0.05^{b}	0.22^{c}	71.57^{a}	34.15^{ab}
	SD	0.01	0.51	0.03	0.06	4.24	11.76
Z	mean	0.92^{b}	1.04^{a}	0.03^{b}	0.36^{b}	65.04^{b}	42.79^{a}
	SD	0.01	0.29	0.01	0.17	5.23	17.91

Means with the same letter do not differ significantly at $\alpha = 0.01$.

The effect of drying method

Significant effects of drying method were observed in case of lutein, β-carotene and colour lightness (Tab. 4). Samples subjected to hybrid drying were significantly more rich in carotenoids compared to samples undergone drying in a tunnel or chamber dryer. Moreover, samples subjected to natural convection contained least carotenoids and were significantly lighter than the others. This suggests that natural convection favoured the loss of carotenoids (in this case lutein and β-carotene) which involves also differences in colour. Similar dependency between colour lightness and drying method was reported by HENRIQUES et al. (2012). Hot-air drying is considered to be the most destructive drying method in terms of carotenoids retention and product discoloration since carotenoids rapidly lose their activity when heated in the presence of oxygen, especially at higher temperatures (LEŠKOVÁ et al. 2006,

Table 4

Three-way ANOVA results: the effect of drying method*

D	Statistic	LU	BC	*L*
F	mean	0.73^{b}	0.31^{b}	67.72^{b}
	SD	0.44	0.14	4.81
N	mean	0.56^{b}	0.28^{b}	71.24^{a}
	SD	0.57	0.14	4.40
H	mean	1.52^{a}	0.47^{a}	67.05^{b}
	SD	1.04	0.38	5.28

Means with the same letter do not differ significantly at $\alpha = 0.01$.

WANG et al. 2011). Research results reported by other authors indicates that the loss of carotenoids activity may be avoided by using hot-air drying in low temperatures (ROONGRUANGSRI, BRONLUND 2016), freeze-drying which eliminates high temperature and oxygen from drying process (NAWIRSKA et al. 2009, DIRIM, ÇALIŞKAN 2012) or starch coatings (LAGO-VANZELA et al. 2013) to protect carotenoids from oxidation during convective drying.

The effect of cultivar and drying method interaction

Significant C×D interaction effects were observed in case of dry matter, lutein, β-carotene and yellowness (Fig. 1). Regarding DM significance of C×D interaction occurred mainly due to variation of this parameter in samples obtained by hybrid method. The highest dry matter content was specific for samples dried using natural convection (Fig. 1*a*). *Ambar* samples characterised with the highest content of DM, while the lowest content of DM was specific for Amazonka samples. Slightly lower values of DM were characteristic for samples dried in a tunnel dryer. As regards the hybrid method DM content in Ambar samples dropped significantly while in case of Justynka the same parameter significantly increased.

The content of lutein (Fig. 1*b*) in Ambar and Amazonka samples was also significantly affected by C×D interaction. Lutein content in Ambar samples dried using chamber or tunnel dryer dropped significantly in comparison to samples obtained by hybrid method. In general each cultivar characterised

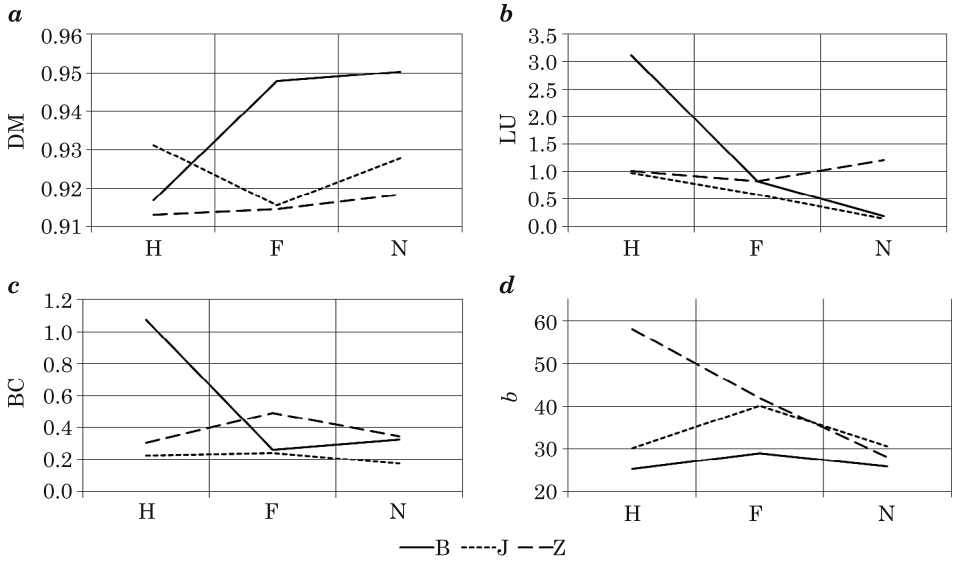

Fig. 1. The effect of C\D interaction on DM (*a*), LU (*b*), BC (*c*) and *b* (*d*)

with the highest, medium and the lowest content of lutein if dried using H, F and N drying method respectively. The exception from this rule was observed for Amazonka samples dried in a chamber dryer. In this case lutein content was higher compared to samples obtained by other drying methods. Concerning β-carotene significantly different reaction to drying method was observed in Ambar samples (Fig. 1*c*). Two other cultivars characterised with the highest content of BC if dried in a tunnel dryer and slightly (but not significantly) lower content of this substance if dried using other methods. In case of Ambar BC content was significantly higher (also compared to other cultivars) in samples obtained by hybrid method than in samples undergone drying in tunnel or chamber dryer.

Regarding yellowness of Justynka and Ambar, the highest values of this parameter were observed in samples dried in a tunnel dryer and slightly lower in case of samples dried using other methods (Fig. 1*d*). Generally, variation in yellowness of Justynka and Ambar samples was not affected by C×D interaction. Yellowness of Amazonka was no exception from this rule as regards samples dried in a tunnel or chamber dryer. However, dried material obtained by hybrid method characterised with significantly higher yellowness than the other samples.

Determination of the best discriminants of samples

Exploratory factor analysis resulted in four factors that met the Kaiser criterion (Fig. 2). First four factors explained variation of samples in almost 80%. Table 5 presents factor pattern for analysed data. The highest contribution to total between-sample variation was observed for the first (26.07%) and the second (22.46%) factor. Variables a and b had the largest loadings on the first factor (0.89 and – 0.95 respectively) whereas the second factor consisted of high positive loadings on BC and LU (0.93 and 0.86 respectively). Therefore factor 1 may be interpreted as a colour measure (redness and yellowness) while factor 2 primarily measures samples' content of carotenoids. Moreover, the first component is a contrast of redness against yellowness with the opposite signs of its factor loading, which means that more red sample is less yellow. Considering variance explained by extracted factors, variables b, a, BC and LU (in this specific order) are the most essential responses for combination of CTD which means that they are the best discriminants of samples. This result is in agreement with previously mentioned reports where carotenoid content is considered as an important parameter for the determination of the final quality of dehydrated pumpkin as it is a determining factor in both colour and nutritional quality of the product (DIRIM, ÇALIŞKAN 2012).

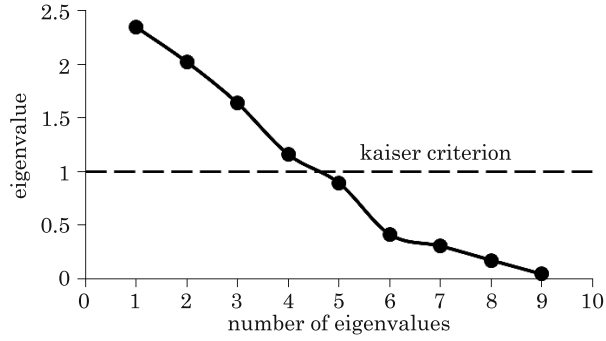

Fig. 2. Scree plot

Table 5

Factor pattern

Variable	Factor 1	Factor 2	Factor 3	Factor 4
DM	0.09	-0.24	-0.15	-0.89
TS	-0.03	0.18	0.60	-0.06
RS	-0.26	0.01	0.82	0.21
LU	0.13	**0.86**	0.01	0.12
LY	0.08	0.51	0.26	-0.70
BC	0.05	**0.93**	0.08	-0.06
L	0.39	-0.41	0.64	-0.24
a	**0.89**	0.15	-0.21	0.09
b	**-0.95**	-0.06	-0.06	0.26
Variance explained	1.94	2.14	1.59	1.49
% of total variance	26.07	22.46	18.19	12.89

Cluster analysis

Clustering procedure was applied to full set of variables to characterise samples' variation. RSQ value of 0.798 indicated three clusters as the optimal level of hierarchy (Fig. 3). Figure 4 displays tree diagram which indicates the

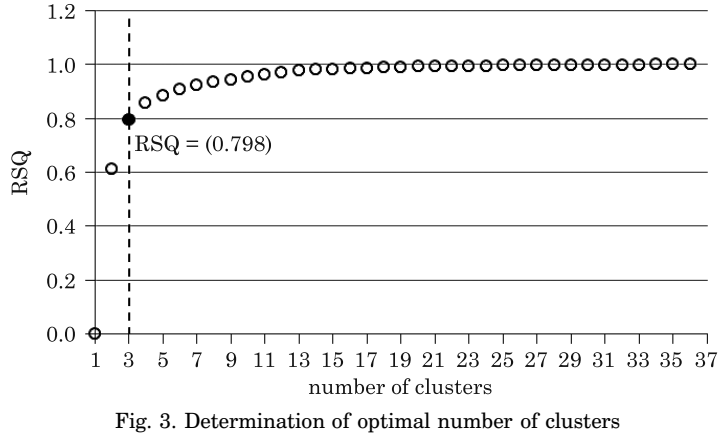

Fig. 3. Determination of optimal number of clusters

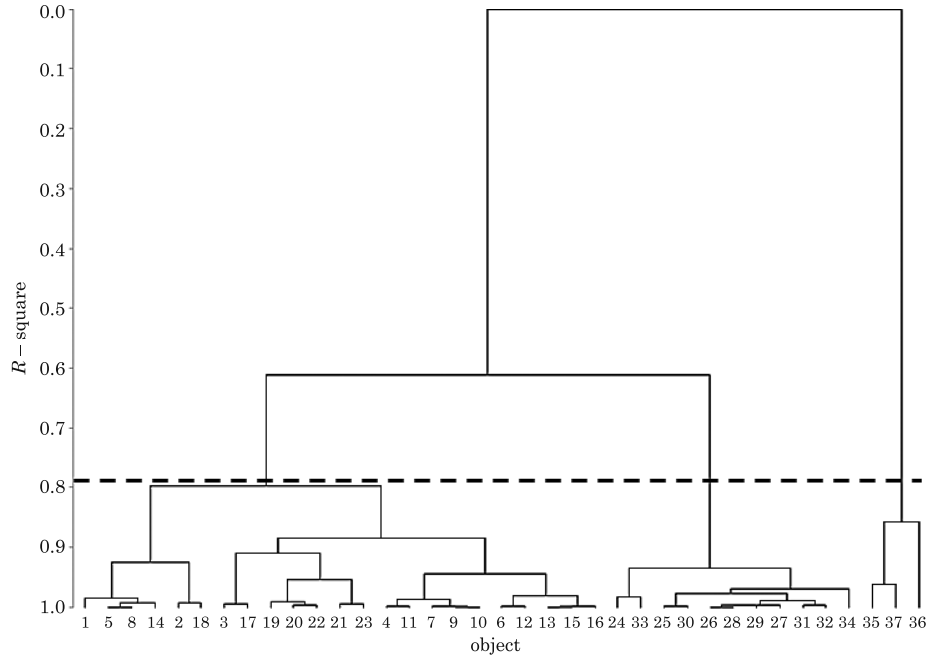

Fig. 4. Tree diagram obtained with respect to all characteristics of samples

cluster membership of each CTD combination in the cluster tree. The cluster name (object number rather than sample label) and RSQ are displayed on the horizontal and vertical axes, respectively. The lowest level of tree diagram consists of leaves being representation of CTD combinations. As the clustering algorithm proceeds leaves are clustered to form branches which are further joined to form root. The RSQ indicates similarity between leaves or branches, thus branches separated by the dashed line consist of leaves with similar characteristics. Plotting the first two factors using cluster membership as an identifier revealed three separate groups of samples (Fig. 5). It clearly proves that the optimal number of clusters has been determined properly, reinforcing the preceding conclusion.

One-way analysis of variance has been performed to evaluate the variability between clusters at the optimal level of hierarchy. Significant differences were observed only in terms of LU, LY, BC, L, a and b variables (Tab. 6). Cluster 2 differed significantly from the others in carotenoids content but differences between the first and the third cluster in terms of these substances were negligible. No significant differences in terms of colour were observed between the first and the second cluster whereas the third cluster characterised with significantly lower lightness and redness as well as significantly higher yellowness than samples within other clusters. Generally one may

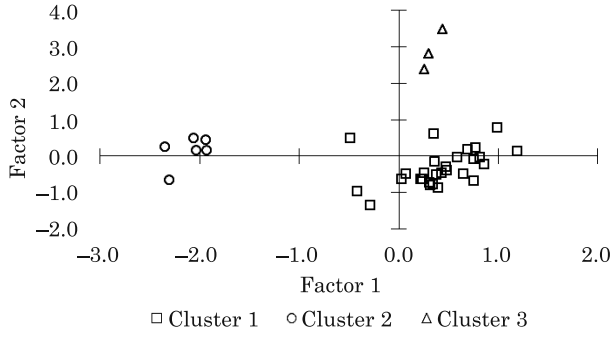

Fig. 5. Cluster membership vs. factor pattern

Table 6

ANOVA results and homogeneous groups for clusters

Cluster	Statistic	LU	LY	BC	*L*	*a*	*b*
1	Mean	0.74^{a}	0.07^{a}	0.28^{a}	70.23^{b}	4.38^{a}	29.64^{a}
	SD	0.50	0.09	0.13	3.98	1.21	4.03
2	Mean	3.12^{b}	0.26^{b}	1.07^{b}	67.93^{ab}	4.26^{a}	25.20^{a}
	SD	0.68	0.02	0.09	2.75	0.42	1.34
3	Mean	0.78^{a}	0.03^{a}	0.34^{a}	61.60^{a}	1.35^{b}	65.40^{b}
	SD	0.41	0.01	0.12	4.62	0.40	3.89

Means with the same letter do not differ significantly at $\alpha = 0.01$.

conclude that the second cluster contains samples rich in carotenoids and of light, red rather than yellow colour. However, the third cluster represented samples significantly less rich in carotenoids and darker, less red and consequently more yellow than samples within the second cluster.

Figure 6 represents the results of cluster analysis for 37 CTD combinations with respect to their impact on *b* (Fig. 6*a*), *a* (Fig. 6*b*), BC (Fig. 6*c*) and LU (Fig. 6*d*). Dashed line indicates the clustering level at which objects within each cluster are the most similar. This specific level of hierarchy was determined in such a way that the RSQ value at each level n (RSQn) was compared with the RSQ value at the previous level n^{-1} (RSQn^{-1}). If (RSQn – RSQn^{-1}) started to be greater than 0, number of clusters n was considered to provide the greatest similarity of objects before they variance starts to grow considerably within each cluster. Levels of hierarchy determined hereby were 13, 8, 13 and 13 for *a*, *b*, BC and LU respectively. Each branch or leave separated by the dashed line, received a partial score (s) between 0 and 1 based on mean values of its responses (*b*, *a*, BC and LU). All partial scores obtained for each CTD combination were calculated by equation (1) and presented as a total score (S) in Table 7.

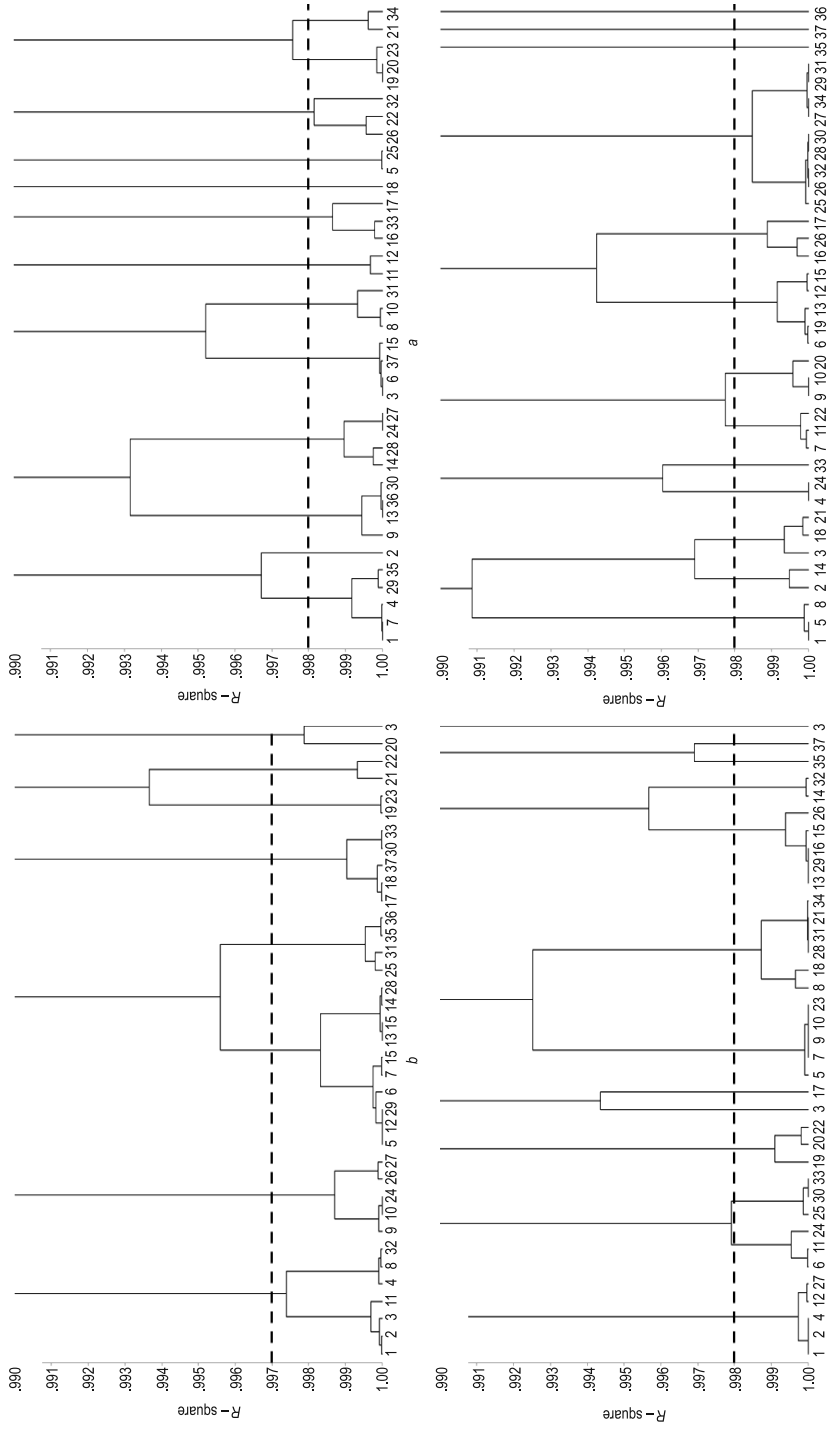

Fig. 6. Tree diagrams obtained with respect to *b* (*a*), *a* (*b*), BC (*c*) and LU (*d*)

Table 7
Scores obtained for CTD combinations based on tree diagrams of *b*, *a*, BC and LU variables

Label	B60F	J40H	Z50F	J50H	Z40N	Z70N	J60H	Z50N	J60F	J70F	Z70F	Z60N	B70F
Object	1	2	3	4	5	6	7	8	9	10	11	12	13
s_b	0.81	0.81	0.81	0.81	0.88	0.88	0.88	0.81	0.73	0.73	0.81	0.88	0.88
s_a	0.47	0.42	0.62	0.47	0.30	0.62	0.47	0.67	0.57	0.67	0.78	0.78	0.57
s_{BC}	0.16	0.16	0.57	0.16	0.08	0.21	0.08	0.12	0.08	0.08	0.21	0.16	0.04
s_{LU}	0.38	0.34	0.31	0.09	0.38	0.21	0.13	0.38	0.16	0.16	0.13	0.21	0.21
Total score (S)	0.39	0.37	0.54	0.28	0.30	0.39	0.25	0.39	0.27	0.28	0.36	0.39	0.26
Label	J70H	B50F	Z60H	Z80N	J80F	Z50H	Z40H	Z80H	Z80F	Z70H	B40F	B60N	J50N
Object	14	15	16	17	18	19	20	21	22	23	24	25	26
s_b	0.88	0.88	0.88	1.00	1.00	0.10	0.00	0.18	0.18	0.10	0.73	0.92	0.73
s_a	0.52	0.62	0.87	0.87	1.00	0.04	0.04	0.00	0.16	0.04	0.52	0.30	0.16
s_{BC}	0.00	0.04	0.04	0.49	0.12	0.31	0.31	0.12	0.31	0.08	0.21	0.24	0.04
s_{LU}	0.34	0.21	0.25	0.25	0.31	0.21	0.16	0.31	0.13	0.25	0.09	0.00	0.00
Total score (S)	0.00	0.27	0.30	0.57	0.44	0.12	0.00	0.00	0.18	0.09	0.29	0.00	0.00
Label	J50F	B40N	J80N	B80N	J70N	J40N	B80F	J40F	**B60H**	**B40H**	**B80H**		
Object	27	28	29	30	31	32	33	34	**35**	**36**	**37**		
s_b	0.73	0.88	0.88	1.00	0.92	0.81	1.00	0.00	**0.92**	**0.92**	**1.00**		
s_a	0.52	0.52	0.47	0.57	0.67	0.16	0.87	0.00	**0.47**	**0.57**	**0.62**		
s_{BC}	0.16	0.12	0.04	0.24	0.12	0.00	0.24	0.12	**0.93**	**0.82**	**1.00**		
s_{LU}	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	**0.83**	**0.62**	**1.00**		
Total score (S)	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	**0.76**	**0.72**	**0.89**		

The highest total score (0.89) was determined for cultivar *Ambar* dried at 80°C using hybrid method (B80H). Two subsequent but lower scores (0.76, 0.72) were obtained for samples of the same cultivar, dried using also hybrid method at 60°C and 40°C respectively (B60H and B40H). All these samples were members of the same, second cluster. These results are partially in agreement with those reported by ROONGRUANGSRI and BRONLUND (2016). The authors proposed 60°C as the optimal temperature of hot-air drying of pumpkin powder since the moisture content and water activity values were within acceptable limits for safe storage.

Conclusions

Results of this study showed that cultivar and drying method considerably affected the quality of dried pumpkin. Dried material obtained by a combination of tunnel drying and fluidized-bed drying characterised with high content of carotenoids despite of slightly weaker colour parameters. In general, this drying method maintained the quality of dried material on a reasonable level.

The highest contribution to the variability of samples had redness, yellowness, β-carotene and lutein content. With respect to colour and selected

chemical components, samples of dried pumpkin were divided into three groups which differed significantly in colour and a total content of carotenoids.

Scoring function allowed to find conditions of hybrid drying which resulted in simultaneous maximisation of lutein, β-carotene, redness and yellowness of dried pumpkin samples. *Ambar* samples dried at 80°C using hybrid method proved to be the best combination of cultivar and drying conditions. Moreover, with respect to colour and chemical composition, the best three combinations were B80H, B60H and B40H, which formed separate cluster. Samples within this cluster were significantly more rich in β-carotene and lutein than the others.

However, further research are necessary to study thoroughly the effect of drying temperature on colour and nutritional value of pumpkin samples subjected to hybrid drying and a long-term storage.

Additional studies should also provide more information on whether lutein, β-carotene, redness and yellowness are sufficient enough to monitor the quality of dried pumpkin and how they change thorough out the drying process considering different drying methods. And finally further studies are necessary to analyse the specificity of fluidised bed drying of convectively pre-dried pumpkin samples in terms of carotenoids and colour retention.

Acknowledgements

The authors are grateful to Dr. Aleksandra Korzeniewska and her team from the Department of Plant Genetics, Breeding, and Biotechnology at the Faculty of Horticulture, Biotechnology and Landscape Architecture, Warsaw University of life sciences – SGGW for providing research material used in this study.

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