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COLOUR STANDARD AND HOMOGENOUS GROUPS OF DRIED CARROTS OF 34 COMMERCIAL VARIETIES

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An instrumental method for determining the colour standard of dried carrots is proposed in the paper. Sensory analysis was made to verify the correctness of colour standard selection, and to determine homogenous groups of particular carrot varieties. The experimental material were 34 commercial varieties of carrot grown at the Vegetable Growing Station in Skierniewice in the year 2001. Colour standard determination and homogenous group selection based on instrumental measurement allowed replacing labour-consuming and expensive sensory analysis. The studies enabled determination of: the differences in the colour of dried carrots, the colour considered most desirable by consumers and the suitability of particular varieties for drying. A sensory evaluation was performed by ranking method, and instrumental measurement – with a spectrophotometer MiniScan XE Plus HunterLab. The following tests were used for statistical analysis: the non-parametric Friedman rank test, a test based on the Spearman coefficient of rank correlation and the multiple Duncan test. There was a statistically significant correlation ($p=0.05$) between the instrumental measurement and sensory evaluation. Particular carrot varieties showed statistically significant colour deviations from the standard. Statistical analysis of the results allowed distinguishing 13 homogenous groups, in terms of colour. The colour standard for dried carrots was obtained from the variety *kantata* (L*: 57.64; a*: 28.82; b*: 34.08). The variety *joba* differed from the standard to the highest degree and was characterized by the following parameters: L*: 49.83; a*: 11.91; b*: 19.82.

INTRODUCTION

In recent years, much attention has been paid to the quality of dehydrated food products, including carrots [Lin *et al.*, 1998]. The growing interest in carrot results from its high nutritive value and health properties. Carrot, compared with other vegetables, contains more β–carotene and vitamin B complex, as well as such valuable substances as saccharides, pectins, dyes or mineral compounds [Zadernowski & Oszmiański, 1994].

There is a close correlation between quality, colour and the so-called "consumption pleasure" [Taub & Singh, 1998]. According to Poznański [1980], as many as 87% of consumers judge food products, including dried carrots, by their external appearances. The visual appeal of goods is very important, and colour decides about consumer preferences in 40% of cases [Krokida *et al.*, 2001]. Following Mangels *et al.* [1993], the colour of carrots is determined by the concentration of α- and β-carotene, as they constitute over 90% of all carotenoids.

A sensory analysis holds a strong position among analytical methods for food quality assessment. It is considered complementary to the other methods and commonly applied while determining the sensory properties of both raw materials and ready-made goods, as well as their changes during technological processing or storing [Szymczak *et al.*, 2003]. Physical, chemical and microbiological analyses provide information on the properties of a given product, whereas sensory analyses – on the sensation they produce. A sensory analysis is very important, but due to its subjective character (experts are influenced by numerous physiological and psychological factors), it should be combined with instrumental techniques. Instrumental measurement of colour is easy and quick, so it may be treated as a direct method for an objective evaluation of the colour of food products [Baryłko-Pikielna, 1975]. Colour description by means of physical units allows obtaining very accurate results, due to specified clearly formulated definitions and terminology. Nowadays colour can be determined by thrichromatic colourimetry, promoted by the International Commission on Illumination, CIE. One of the colour description models applied most often to identify the colour of food products is the CIELab system [Francis & Clydesdale, 1975]. The colour is described by three coordinates in the colour space, which may be measured directly with a spectrophotometer. The CIELab system has been employed by many authors to evaluate changes in colour proceeding during technological processes, as well as to control the quality of vegetables and fruits, *e.g.* bananas [Maskan, 2000]. The parameters L*, a*, b* were applied to colour description. However, their values do not provide sufficient information on the differences or deviations from

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the standard. Sensory analysis is based on various methods [Baryłko-Pikielna, 1996]. The ranking method occupies a position in-between difference methods and scaling methods. In an instrumental evaluation a standard must be established and then deviations from this standard must be calculated and expressed in the form of indices: ΔL*(lightness), Δa*(redness), Δb*(yellowness), ΔE* (total colour difference), ΔC* (total saturation difference), ΔH* (total hue difference).

Most authors use the parameter a* or the index -a*/b* for a physical description of the colour green. Tijskens *et al.* [2001] described the colour of broccoli and green beans by means of the index -a*/b*. This index was also used for describing colour changes in broccoli during blanching and freezing [Gunawan & Barringer, 2000]. Kidmose and Hansen [1999] observed a high correlation between instrumental measurement, sensory analysis of yellowness and the chlorophyll content of cooked and stored broccoli. Dobrzański and Rybczyński [2000] used the CIELab system to evaluate the colour of apples and reported that this evaluation may be of great help in their objective classification and determination of consumer preferences, enabling proper selection of varieties. Avila and Silva [1999] in their studies on the kinetics of thermal degradation of colour in peach puree, used two combinations of parameters, *i.e.*: L*a*/b* and ΔE*. Shin and Bhowmik [1995] reported that these indices allow expressing total colour changes in food products. The index ΔE*, commonly applied to describe colour changes in food products during heating, can be also employed in the case of fruit pulp [Lozano & Ibarz,1997]. This all shows that there are many methods and indices allowing description of colour changes during technological processes.

The aims of the studies were as follows: to confirm the possibility of replacing a sensory evaluation of colour with an instrumental method, by showing a statistically significant correlation between the results of instrumental measurement and sensory analysis and to propose an instrumental method for determining the colour standard of dried carrots.

MATERIAL AND METHODS

The experimental material were 34 commercial varieties of carrot grown at the Vegetable Growing Station in Skierniewice, in the year 2001. Dried carrots were used just after harvest. They were cut into 10 mm cubes and convection-dried in a chamber dryer at a temperature of 40°C, for 18 h.

Sensory and instrumental analyses were made to determine the colour standard and arrange dried carrots by colour just after drying. The sensory evaluation was performed in a chamber, 159 cm×52 cm×73 cm, illuminated by two fluorescent lamps (power 20 W, luminance D65, voltage 220 V). All samples were prepared in the same way and consisted of 30 dried carrot cubes. They were placed on a white matt background. At the first stage ten experts made a visual evaluation of randomly selected samples by the ranking method, on the basis of colour stimuli. Dried carrots were arranged by quality (from the best to the worst) and given ranks on a scale of 1 to 34. Such factors as the stimulus intensity, uniformity of colour distribution in particular cubes and in the whole sample, lack of green or brown spots were taken into account in the sensory analysis. Its results allowed creating a cumulative series of types (a sum of successive arrangements). The other stage included instrumental measurement of colour, with a spectrophotometer MiniScan XE Plus (HunterLab) for a 10° observer, normalized light D65 and a 8° diaphragm. The colour was described on the CIELab scale. The colour of particular carrot varieties was measured on 30 cubes selected at random. To determine the standard, a decreasing series was formed for each colour component, which provided the basis for creating a cumulative series (a sum of three arrangements). The variety which received the lowest number of points was selected as standard. The determination of the colour standard allowed calculating the ΔE* index for each variety (the absolute difference between the colour and the standard) and to form another series. The absolute colour difference ΔE* from the standard was calculated for each variety, creating another series of types. The absolute colour difference ΔE* was determined from the formula:

$$\Delta E^* = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2} ,$$

where: ΔL* – the difference in lightness between the standard and the sample, Δa* – the difference in redness between the standard and the sample, Δb* – the difference in yellowness between the standard and the sample.

The results were analyzed statistically using the computer program STATISTICA 6.0 (StatSoft Inc.). The non-parametric Friedman rank test was applied and the Kendall coefficient of consistency was calculated to determine the reliability of the experts' opinions, the correlations between the results they obtained and the significance of differences in the colour of dried carrots representing particular varieties (as evaluated by the experts). Then a test based on the Spearman coefficient of rank correlation was employed to compare the series of types obtained as a result of sensory analysis and instrumental measurement (in terms of probability of a given variety being of better quality than the next in the series). A one-factor analysis of variance in a completely randomized design was made to verify the null hypothesis that there are no differences in the colour of dried carrots of different varieties. The experimental objects were divided, using the Duncan test, into significantly differing groups, homogenous in terms of the total colour deviation ΔE* from the standard.

RESULTS AND DISCUSSION

Sensory analysis

Statistical analysis of the results showed a high value of the Kendall coefficient of consistency (at the significance level $p=0.05$ the Kendall coefficient was 0.95). This value shows a high level of consistency of ordering between particular experts, as well as significant differences in the colour of dried carrots. The sensory analysis enabled determining the colour standard for dried carrots, which was obtained from the variety *kantata*.

Instrumental measurement

Table 1 presents the values of the parameters L*, a*, b*, and index ΔE* for 34 carrot varieties, and the ranks corresponding to particular varieties in the series. A one-factor

TABLE 1. Results of instrumental measurement and sensory analysis of the colour of dried carrots of 34 commercial varieties.

Instrumental measurement							Sensory analysis	
Carrot variety	L*	a*	b*	A sum of ranks L*a*b*	Homogenous groups in terms of ΔE*	Homogenous groups in terms of DE*	Carrot variety	A sum of ranks from 10 arrangements
kantata	57.641	28.82^{1}	34.08^{1}	3	0^{1}	a	*kantata*	18
macon	51.20^{16}	28.49^{2}	31.55^{2}	20	6.93^{2}	b	*macon*	22
allret	56.78^{2}	25.01^{5}	27.88^{7}	14	7.32^{3}	b	*allret*	44
nektarina	53.41^{9}	25.08^{7}	29.15^{4}	20	7.49^{4}	b	*nektarina*	45
maxima	55.99^{4}	22.89^{16}	28.37^{6}	26	8.39^{5}	bc	*maxima*	63
canada	52.45^{11}	24.93^{6}	27.96^{8}	25	8.92^{6}	bcd	*canada*	41
recoleta	55.15^{6}	21.24^{20}	28.75^{5}	31	9.60^{7}	cde	*recoleta*	202
px 302295	51.40^{14}	24.89^{9}	26.83^{9}	32	10.34^{8}	cdef	*px 302295*	91
55503	51.80^{12}	26.29^{3}	25.83^{14}	29	10.42^{9}	defg	*55503*	68
fayette	54.13^{8}	24.77^{10}	23.99^{25}	43	11.43^{10}	efgh	*fayette*	198
px308596	49.99^{22}	25.75^{4}	25.58^{17}	43	11.85^{11}	fgh	*px 308596*	140
55501	51.79^{13}	23.45^{14}	25.15^{20}	47	11.95^{12}	fghi	*55501*	118
senator	55.66^{5}	17.65^{30}	30.30^{3}	38	11.95^{13}	fghi	*senator*	265
sunset	56.54^{3}	20.28^{23}	25.62^{19}	45	12.07^{14}	fghi	*sunset*	222
sirocco	51.02^{17}	22.35^{18}	26.28^{11}	46	12.11^{15}	fghi	*sirocco*	146
sircana	50.16^{20}	23.48^{15}	26.17^{12}	47	12.13^{16}	fghi	*sircana*	128
kazan	52.73^{10}	20.95^{21}	25.99^{15}	46	12.30^{17}	fghi	*kazan*	161
tito	50.84^{18}	24.44^{11}	24.75^{22}	51	12.35^{18}	ghi	*tito*	246
fridor	50.77^{19}	22.65^{17}	25.68^{18}	54	12.47^{19}	hi	*fridor*	127
bejo 1834	49.45^{25}	25.02^{8}	25.41^{16}	49	12.51^{20}	hi	*bejo 1834*	69
carlo	54.89^{7}	18.84^{27}	26.35^{10}	44	12.92^{21}	hi	*carlo*	244
katmandu	49.05^{27}	24.15^{12}	25.16^{21}	60	13.23^{22}	hi	*katmandu*	141
rs 942115	51.39^{15}	23.79^{13}	23.49^{26}	54	13.29^{23}	hi	*rs 942115*	293
nun 7375	49.08^{26}	21.27^{19}	26.20^{13}	58	13.87^{24}	i	*nun 7375*	178
55502	48.82^{28}	20.31^{24}	23.96^{24}	76	15.89^{25}	j	*55502*	149
vitana	49.90^{23}	18.19^{28}	24.58^{23}	74	16.22^{26}	j	*vitana*	307
bejo 1888	48.62^{29}	20.35^{22}	21.72^{29}	80	17.48^{27}	jk	*bejo 1888*	215
merida	46.83^{31}	19.21^{25}	22.09^{27}	83	18.79^{28}	kl	*merida*	257
bejo 1991	48.14^{30}	18.08^{29}	21.52^{30}	89	19.06^{29}	kl	*bejo 1991*	204
55504	45.71^{33}	17.68^{31}	22.10^{28}	92	20.25^{30}	l	*55504*	288
bangor	45.66^{34}	18.92^{26}	21.09^{32}	92	20.26^{31}	l	*bangor*	287
px 307596	50.02^{21}	15.60^{32}	19.95^{33}	86	20.79^{32}	lm	*px 307596*	305
cascade	45.84^{32}	14.22^{33}	21.61^{31}	96	22.53^{33}	mn	*cascade*	330
joba	49.83^{24}	11.91^{34}	19.82^{34}	92	23.46^{34}	n	*joba*	340

– superscripts denote ranks for particular varietes in the series

analysis of variance provided the basis for rejecting the null hypothesis that there are no differences in colour between the means for the experimental objects. However, such a statement is too general as it does not tell which of them differ, and which do not. Therefore, it is necessary to combine the means into homogenous groups, for which the hypothesis that the means in a group are equal will not be refuted at the level of significance adopted. It is also necessary to compare the mean values with the standard. In our studies the experimental objects were divided, using the Duncan test, into significantly differing groups, homogenous in terms of the total colour deviation ΔE* from the standard. The standard error in the Duncan test oscillated around 3. Following these assumptions, at the significance level of $p=0.01$, we obtained large groups characterized by considerable differentiation. The results were elaborated applying a criterion established by the International Commission on Illumination, CIE, [Heidelberg, 1999]. Absolute colour differences ΔE* are classified according to this criterion, to correspond with colour perception by man. Table 1 presents the results of the multiple Duncan test, where one of the criteria was that absolute colour differences between 0 and 2 are unrecognizable. The colour standard was obtained from the variety *kantata*, and the group consisting of the following carrot varieties: *macon*, *allret*, *nektarina*, *maxima*, *canada* was homogenous in terms of colour and characterized by the lowest deviation from the standard.

In the case of points in space, the similarity of their location is reflected not only by their distance from a given standard point, but also direction. Figure 1 shows the distances between the points characterizing particular varieties in the colour space L*a*b*. The direction of colour changes is the same for all varieties because the standard was characterized by the highest values of all the coordinates. Therefore, the grouping of points characterizing particular varieties according to the index ΔE* seems to be correct.

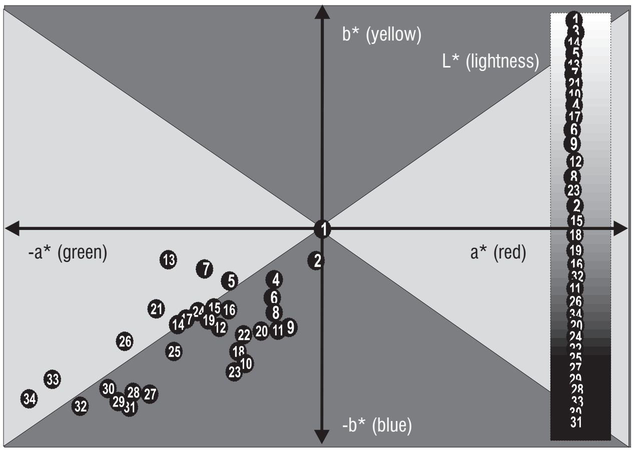

FIGURE 1. Distances between the points characterizing particular varieties in the colour space Lab.

Comparison of the results of sensory and instrumental analyses

The series of types obtained during sensory analysis (*i.e.* a sum of ranks from ten arrangements) was compared with the series of types obtained during instrumental measurement (based on the parameters L*, a*, b* and ΔE*) and with the cumulative series of types. The coefficients of correlation between them are given in Table 2. At the significance level of $p=0.01$, the Spearman coefficient of correlation between ordering by the sensory analysis and ΔE* was 0.88. This indicates high consistency of evaluations, a highly significant correlation between them, and proper selection of the physical index of colour description. The values of the coefficient of correlation R for a* and ΔE* show that both indices ensure similar effectiveness, but the colour of carrots (and many other food products) is described by indices consisting of both quantitative (ΔL*) and qualitative (Δa* and Δb*) components. The difference between the standard and the sample most similar to it is much bigger than the difference between any two samples in the series.

TABLE 2. Coefficients of correlation between the colour indices obtained by instrumental measurement and the results of a sensory evaluation of dried carrots, p=0.01.

Parameter	L*	a*	b*	L*a*b*	ΔE*
R	0.46	0.84	0.73	0.77	0.88

This results from the fact that the standard was characterized by an intensive orange colour, so the values of its parameters a* and b* differed considerably from the other in the series.

The sensory analysis confirmed the results of colour standard selection by instrumental measurement. The standard was obtained from the variety *kantata* and was characterized by the following parameters: L*: 57.64, a*: 28.82, b*: 33.79. Dried carrots of this variety were characterized by a light, intensive orange-red colour, evenly distributed both in the cube and the whole sample, without green or brown spots. The colour of the variety *joba*, which differed from the standard to the highest degree, was characterized by an unevenly distributed dark brown colour, with visible green spots, and the following parameters: L*: 49.83; a*: 11.91; b*: 19.82.

CONCLUSIONS

There was a statistically significant correlation between the instrumental measurement and sensory evaluation of colour, which confirms that a sensory analysis can be replaced with instrumental measurement. An instrumental method for determining the colour standard of dried carrots was proposed and applied to evaluate the colour of 34 commercial varieties of carrot. The standard was obtained from the variety *kantata* and was characterized by the following parameters: L*: 57.64, a*: 28.82, b*: 33.79. Dried carrots of this variety were characterized by a light, intensive orange-red colour, evenly distributed both in the cube and the whole sample, without green or brown spots. The calculation of the index of absolute colour difference ΔE* allowed observing deviations from the standard and determining the significance of differences in the colour of dried carrots representing 34 varieties. The homogenous group comprising five varieties (*macon*, *allret*, *nektarina*, *maxima*, *canada*) showed the lowest colour deviation from the standard.

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WZORZEC BARWY ORAZ JEDNORODNE GRUPY SUSZU POCHODZĄCEGO Z 34 ODMIAN MARCHWI

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W pracy zaproponowano metodykę wyboru wzorca barwnego metodą instrumentalną. Do oceny poprawności wyboru wzorca jaki i ustalenia jednorodnych grup poszczególnych odmian marchwi przeprowadzono analizę sensoryczną. Do badań użyto 34 przemysłowych odmian marchwi pochodzących z uprawy Zakładu Warzywniczego w Skierniewicach w roku 2001. Ustalenie wzorca barwnego oraz wyselekcjonowanie grup jednorodnych w pomiarze instrumentalnym umożliwiło wyeliminowanie konieczności stosowania subiektywnej i kosztownej analizy sensorycznej. Badania pozwoliły na określenie różnic barwy suszonej marchwi, a także określenie pożądanej przez konsumenta barwy suszu marchwiowego oraz przydatności poszczególnych odmian do suszenia. Ocenę sensoryczną przeprowadzono wg „metody kolejności" natomiast pomiar instrumentalny wykonano za pomocą spektrofotometru MiniScan XE Plus firmy HunterLab (tab. 1). Do oceny statystycznej wyników wykorzystano następujące testy: nieparametryczny test rang Friedmana, test oparty o współczynnik korelacji rangowej Spearmana oraz wielokrotny test rozstępu Duncana. Zaobserwowano statystycznie istotną ($p=0.05$) zależność pomiędzy pomiarem aparaturowym i oceną sensoryczną oraz statystycznie istotne odchylenia barwy poszczególnych odmian od wzorca. Analiza statystyczna uzyskanych wyników pozwoliła na wyodrębnienie 13 grup jednorodnych jakościowo. Wzorzec pochodził z odmiany *kantata* (L^*: 57,64; a^*: 28,82; b^*: 34,08). Odmiana *joba* charakteryzowała się parametrami najbardziej odbiegającymi od wzorca i posiadała następujące parametry: L^*: 49,83; a^*: 11,91; b^*: 19,82 (rys. 1).