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EFFECT OF FARMING SYSTEM ON COLOUR COMPONENTS OF WHEAT NOODLES

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ABSTRACT
Colour of noodles is definitely a key element of a consumer's buying decisions. It can be influenced by many factors. Conditions, under which is winter wheat grown, can be considered as one of these factors. The aim of this work was to evaluate colour of noodles that were prepared from winter wheat grown in ecological and integrated arable farming systems, after different forecrops with two levels of fertilization (fertilized and unfertilized) during the years 2009, 2010 and 2011. Winter wheat noodles were prepared from white flour and wholegrain flour and its colour was evaluated using the spectro-colorimeter. Colour was measured by three coordinates: lightness L*, red/ green value a* and yellow/ blue value b*. Wholegrain noodles had lower L* value, so they were darker than white flour noodles, with higher redness and higher yellowness. Colour of white flour noodles and wholegrain noodles was significantly influenced by crop nutrition (fertilized and unfertilized variants), farming system and meteorological conditions during experimental years. Wholegrain noodles from ecological system were darker, with lower lightness and higher redness compared to noodles from integrated system. White flour noodles from ecological system were also darker compared to noodles from integrated system. Fertilization decreased lightness of white flour noodles, on the contrary, fertilization increased the lightness and decreased the redness of wholegrain noodles. In non-fertilized treatment, ecological wheat noodles were darker, with higher redness and yellowness than noodles prepared from winter wheat grown in integrated arable farming system.

Keywords: ecological arable system; integrated arable system; wheat noodle colour

INTRODUCTION
The key quality attributes in the evaluation of noodles include texture and colour, which are important quality factors since they are associated with flour **(Chang and Wu, 2008)**. Flour colour influences the quality of end-use products of common wheat. It is determined by the content of yellow pigment in the endosperm. A high yellow pigment content is preferred for yellow alkaline noodles. A minimal addition of alkaline salts leads to an improved texture and yellowness, as well as the antioxidant functions, derived from its main component carotenoids during the aging process **(Zhang et al., 2009)**. Flour colour is mainly controlled by genetic factors, several studies mentioned the effects of the 1B.1R translocation on flour colour and yellow pigment content in common and durum wheat **(Liu et al., 2005)**.

Flour extraction rate has an important influence on noodle attributes, especially colour. Studies on dried noodles showed a decline in brightness and increase in yellowness with increased extraction rate **(Kruger et al., 1994; Lee et al., 1987)**. Noodle darkening increases with the increase of flour extraction rate. This is due to the action of polyphenol oxidase enzymes which are largely located in the bran layer **(Fuerst et al., 2006)**. Low flour extraction and ash levels are preferred for the manufacture of noodles with a clean and bright appearance. Low ash content (1.4% and less) in flour is always an advantage for noodles since flour ash is traditionally viewed as causing noodle discoloration. For white salted noodles, a white or creamy white colour is desirable with firm texture. The level of natural yellow pigment levels in flour is highly correlated with noodle colour, which is wheat variety dependent. For yellow alkaline noodles, a bright yellow colour is required. The primary component of yellow colour development in alkaline noodles is due to a pH dependent, chemically induced colour shift in water-soluble flour flavonoids, with a secondary effect due to flour xanthophylls **(Fu, 2008; Asentorfer et al., 2006)**. It is well known that the amber-yellow colour of semolina is due to the presence of natural pigments from carotenoid and xanthophyll families in wheat. As these pigments increase, the yellow colour detected by the human eye becomes brighter and more vivid. It is also known that semolina with a high pigment content do not always produce very yellow pasta. This is because carotenoids and xanthophylls have components which are affected by several oxidizing enzymes. It is important to have a durum wheat with a low content of the enzymes, exercising this negative action **(Landi, 1995)**. Since colour is a key element of a consumer's buying decisions, it is important to ensure noodle colour options availability on the market. The influence of farming system and plant nutrition pattern on colour components of wheat noodles on the basis of CIE L*a*b* readings is not broadly documented. In this study, the relationship between winter wheat noodle colour components, obtained from different farming systems, nutrition treatment and flour extraction rate was investigated.

MATERIAL AND METHODOLOGY

Materials

Field experiments of ecological and integrated arable farming systems were conducted at the Research experimental station of the Faculty of Agrobiology and Food Resources in Nitra during 2009, 2010 and 2011 growing periods. Experiments were established on a Haplic Luvisol developed at proluvial sediments mixed with loess. The altitude of the experimental field is 178 m. The location has a continental climate with an average temperature 19.7 °C in July and -1.7 °C in January, an average annual precipitations are 561mm. Both arable farming systems were composed of six-course crop rotations. The ecological system was composed of the crop rotation: beans + alfalfa – alfalfa – winter wheat – peas – maize – spring barley. The integrated system consisted of the crop rotation: winter wheat – peas – winter wheat — maize – spring barley – alfalfa (3 years at the same plot). Subplots were fertilized (F) and unfertilized (NF). The fertilized variant in ecological system was based on 40 t of manure while the integrated system also received 40 t of manure plus synthetic fertilizers (Table 1), treatments were replicated four times. Sowing and harvesting dates, rainfall and average temperature calculated for vegetative period of the crop, synthetic fertilizer inputs ($kg.ha^{-1}$) applied in the integrated system are shown also in the Table 1. Nitrogen fertilizers were applied in three split applications. Winter wheat was grown within both farming systems, after different forecrops, fertilized and unfertilized variants. Winter wheat noodles were prepared from white flour and from wholegrain flour. Egg noodles with moisture of 30.5% were produced on the apparatus for pasta producing P3 (La Monferina) and were dried at 50 °C for 12 hours.

Milling

Winter wheat samples were milled without further conditioning on a Quadrumat Senior Mill (Brabender, Germany). Combined fractions I. + II. are referred to here as „white flour“. Wholegrain flour was obtained by grinding on the special mill PSY MP (Mezos, s.r.o, Czech Republic.

Colour Analysis

Noodle colour was evaluated using the spectrophotometer SP60 (X-Rite, Inc., Germany) which allows very accurate measurement of the basic optical properties of the surface. The International Commission on Illumination (CIE, Commission Internationale l'Eclairage) has standardized colour order system to derive values for describing colour. The CIE Colour System utilize three coordinates to locate a colour in a three-dimensional colour space and is used to compare the colours of two objects. Colour of an object is defined by three coordinates (L*a*b*). CIE L* values represent lightness, a* denotes the red/green value and b* the yellow/blue value. CIE L*a*b* uses Cartesian coordinates to calculate a colour in a colour space. The a* axis runs from left to right, from -60 (pure green) to +60 (pure red), + value indicates a shift toward red. The b* axis is at an angle of 90 degrees to a* axis. Values on the b* axis range from -60 (pure blue) to +60 (pure yellow), so + value represents a shift toward yellow, - value means a shift toward blue. The L* axis range from 0 (pure black) at the bottom to 100, which represents pure white.

Colour evaluation of cooked noodles was carried out in triplicate; analysis of variance was used for statistical evaluation. The statistical tests were performed with the software STATISTICA version 10.0.

RESULTS AND DISCUSSION

L*values

CIE L* values of wheat white flour noodles and wholegrain noodles were significantly (p ≤0,05) influenced by farming system (Table 2). Average lightness of white flour noodles was 75.92 and wholegrain noodles 56.46. There was significant variation between ecological and integrated system in both, white flour and wholegrain noodles. Noodles prepared from w. wheat grown in ecological system were darker with significantly lower CIE L* values. Crop nutrition also significantly influenced the lightness of noodles.

a*values

The mean CIE a* value for the white flour noodles was 0.92, for wholegrain noodles 9.8, what means that the redness (a*) of wholegrain noodles was almost ten times higher compared to white flour noodles. Significant differences were observed for a* value in wholegrain noodles between farming systems, the redness of ecological wholegrain noodles was higher than integrated noodles. However, there was no significant difference in the a* values in white flour noodles. Crop nutrition significantly influenced the redness of wholegrain noodles, with higher CIE a* value for non-fertilized variant. Variation between a* values for white flour noodles and two crop nutrition treatments was not significant.

b* values

The mean CIE b* value for wholegrain noodles was 20.52, for white flour noodles 18.83, the yellowness (b*) of wholegrain noodles was higher than white flour

Table 1 Crop management data for winter wheat 2009-2011.

Growing season	Sowing date	Harvest date	Rainfall (mm)	Average temperature (°C)	Nitrogen ($kg.ha^{-1}$)	Phosphorus ($kg.ha^{-1}$)	Potassium ($kg.ha^{-1}$)
2008 – 2009	13/10/08	15/07/09	426	9.6	82.5	37.5	20.0
2009 – 2010	07/10/09	28/07/10	610	8.8	62.5	7.5	40.0
2010 – 2011	12/10/10	13/07/11	326	8.6	76.0	30.0	120.0

Table 2 Effect of farming system, crop nutrition and year on colour evaluation of wheat noodles.

		white flour noodles		
		lightness L*	**colour a***	**colour b***
Crop nutrition	F	74.49 a	0.95 a	19.14 a
	NF	77.34 b	0.88 a	18.51 a
Farming system	ES	75.58 a	0.92 a	19.05 a
	IS	76.26 b	0.92 a	18.60 a
Year	2009	79.92 c	1.75 c	22.54 c
	2010	74.95 b	0.88 b	20.03 b
	2011	72.89 a	0.12 a	13.91 a
Standard error		±3.479	±0.717	±3.869

		wholegrain noodles		
		L*	**a***	**b***
Crop nutrition	F	57.45 b	8.82 a	20.35 a
	NF	55.47 a	9.35 b	20.69 a
Farming system	ES	55.61 a	9.24 b	20.65 a
	IS	57.32 b	8.93 a	20.39 a
Year	2009	57.06 a	10.15 c	21.01 b
	2010	55.42 b	8.44 a	19.58 a
	2011	56.91 a	8.67 b	20.97 b
Standard error		±2.594	±0.974	±0.897

Legend: F = fertilized; NF = non-fertilized; ES = ecological system; IS = integrated system.

noodles. The difference was significant (Table 3). Variations between CIE b* values for farming systems and crop nutrition, both white flour and wholegrain flour noodles, were not significant (Table 2).

There was significant variation for all colour components L*a*b* caused by variable meteorological conditions during three growing seasons (years 2009 – 2011).

Effect of fertilisation on colour components was significant (Table 3). CIE L*a*b* values were significantly different for farming system in non-fertilized treatment. Ecological wheat noodles were darker (lower L*), with higher redness (a*) and yellowness value (b*). No significant effect of farming system on CIE L*a*b* values was recorded under fertilized conditions. The effect of wholegrain flour and white flour on noodle colour components showed the same tendency under both, fertilized and non-fertilized treatment. Wholegrain noodles were darker, with higher redness and yellowness.

The correlation between the L* value and a* value, but also b* value, was positive, significant ($r^2 = 0.79$;

Table 3 Winter wheat noodle colour evaluation, effect of fertilisation.

		non-fertilized treatment		
		lightness L*	**colour a***	**colour b***
Farming system	ES	65.82 a	5.32 b	20.08 b
	IS	66.99 b	4.92 a	19.11 a
Noodles	W	55.47 a	9.35 b	20.68 b
	Fl	77.34 b	0.88 a	18.51 a
Standard error		±11.426	±4.344	±2.876

		fertilized treatment		
		L*	**a***	**b***
Farming system	ES	66.04	4.84	19.61
	IS	65.91 n.s.	4.93 n.s.	19.88 n.s.
Noodles	W	57.45 a	8.82 b	20.35 b
	Fl	74.49 b	0.95 a	19.14 a
Standard error		±3.479	±0.716	±3.869

Legend: ES = ecological system; IS = integrated system; W = wholegrain flour noodles; Fl = white flour noodles.

Table 4 Correlation analysis of CIE L*a*b* values.

white flour noodles			wholegrain noodles		
	a*	**b***		**a***	**b***
L*	0.79 **	0.71 **	**L***	-0.39 *	0.02
a*		0.89 **	**a***		0.58 *

Marked values are significant at ** p <0.01, * p <0.05.

r^2 = 0.71) for white flour noodles. Low CIE a* values in white flour noodles are strongly correlated with lightness (L*). For wholegrain noodles the correlation between L* and a* value was negative, but not strong (r^2 = -0.39). The correlation between L* and b* value was not significant (Table 4).

Miskelly (1984) studied the influence of components contributing to the colour and brightness of flour, flour paste, and Chinese and Japanese style noodles. Differences in brightness and yellowness were attributable to a multitude of factors including wheat cultivar, milling extraction rate, protein content, starch damage, and brown and yellow pigments. Most of the variation was attributed to genetic factors, but growing environment and milling procedures were also important. Noodle brightness is related inversely to protein content and to flour-grade colour. Lutein is a yellow plant pigment that belongs to the carotenoid family, namely to Xanthophylls. It acts as an effective antioxidant, it protects the organism against heart diseases and cancer **(Šivel et al., 2014)**.

Humphries et al., (2004) analysed whole-meal wheat, including common, durum varieties, and triticale samples for their carotenoid content and colour. A positive correlation between CIE b* (yellowness) and lutein concentration was shown, there was little correlation between CIE L* or CIE a* (redness) and lutein, α or β carotene. In contrast, the b* value correlated well with the concentration of α and β carotene, but those wheat groups with the lowest CIE b* values did not have a strong correlation. Study has identified CIE b* as a useful diagnostic for rapid screening of wheat varieties for lutein content and was also indicative of the provitamin A carotenoid content. In our experiment, variation in CIE b* values caused by farming system, crop nutrition treatment and flour extraction rate was lower than variation in CIE a* value. We assumed, that differences in CIE L* and CIE a* values can't be attributable to one factor – the concentration of carotenoids.

Ma et al., (2007) showed that N fertilizer increased the redness and yellowness, while brightness decreased. **Wang et al., (2004)** reported that wheat grain protein content strongly correlated with noodle colour.

In small quantities, flavonoids are also present in cereals, located in the pericarp **(Dykes and Rooney, 2007)**. In our previous study, higher concentration of total flavonoid and free flavonoid content was found in wholegrain flour compared to white flour. Free flavonoids represented 77.9% of the total content for wholegrain flour and 68.7% for white flour. Significant effect of farming system and fertilization treatment on free and total flavonoid contents was recorded for wholegrain flour. Concentrations of phenolic compounds were significantly higher in wholegrain flour in all, free, bound and total content. In contrary, farming system showed significant differences in white flour, when total, free and bound phenolic contents were higher in ecological system. Fertilization treatment was significant also for white flour **(Kosík et al., 2014)**. It is estimated that flavonoids account for approximately two thirds of the phenolics in our diet and the remaining one third are from phenolic acids **(Liu, 2004)**.

Large controlled studies with a more factorial approach to the effect of the different components involved in cultivation systems have shown that the ecological production is more likely to favour the synthesis of secondary compounds in food plants. Both environmental factors and production methods have been shown to affect plant growth and composition including the content of secondary bioactive metabolites that may be important to health **(Holmboe-Ottesen, 2010)**.

Bran is a key factor in determining wholegrain products health benefits. Bran has higher vitamin and mineral contents than endosperm, high antioxidant activity and higher secondary metabolites content. These characteristics give wheat bran and wholegrain food very interesting nutritional properties, by reducing the risks of developing chronic diseases **(Liu, 2007; Li et al., 2007; Kosík et al., 2014)**.

Bednářová et al., (2015) concluded that breads produced of blue coloured wheat wholemeal flour were not below the average in sensory properties and its market position could be very high in the future, due to the content of health promoting substances.

Variation in concentration of phytochemicals caused by growing environment and milling extraction rate may affect the colour of end product. A brown or red hue in pasta is detrimental to consumer acceptance in many countries where a bright amber colour is preferred **(Owens, 2011)**.

CONCLUSION

Colour of noodles is an important quality factor influencing the decision of a consumer. Farming system, fertilization, flour extraction rate, forecrop and weather conditions during growing period of winter wheat may have significant effect on the colour of wheat noodles. Colour was measured by three coordinates: lightness L*, red/ green value a* and yellow/ blue value b*. Wholegrain noodles had lower L* value, so they were darker than white flour noodles, with higher redness and higher yellowness. Wholegrain noodles from ecological system were darker, with lower lightness and higher redness compared to noodles from integrated system. White flour noodles from ecological system were also darker compared to noodles from integrated system. Fertilization decreased lightness of white flour noodles, on the contrary, fertilization increased the lightness and decreased the redness of wholegrain noodles. In non-fertilized treatment, ecological wheat noodles were darker, with higher redness and yellowness than noodles prepared from winter wheat in integrated arable farming system. Since colour is a key element of buying preferences, increased interest of consumers for more healthy, wholegrain food may shift their acceptance of darker colour of pasta.

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