Noodle quality of winter wheat cultivated in sustainable farming systems

Kvalita rezancov z pšenice letnej formy ozimnej pestovanej v udržateľných systémoch hospodárenia

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Abstract

Field experiments were conducted at the Research Experimental Station Dolná Malanta, Western Slovakia during 2009 and 2010 on a Haplic Luvisol developed on proluvial sediments mixed with loess. The altitude of the experimental field was 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 561 mm. The aim of this work was to evaluate the quality of white and wholegrain noodles made from winter wheat (*Triticum aestivum* L.) grown in ecological and integrated farming system. A split - plot design was used with two main treatments, ecological (ES) and integrated (IS) cropping systems. The ecological system was composed of a six course 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 fertilised (F) and unfertilised (N) variants. The fertilised variant in ES was based on 40 t of manure while the IS also received 40 t of manure plus synthetic fertilisers. Based on the reached results, winter wheat noodle qualitative parameters were significantly affected by farming system, fertilisation, forecrop and by external impacts of the weather. Noodle quality evaluated by cooking time, volume and weight of cooked noodles, noodle absorption and by cooking loss showed higher values of each of the cooking quality parameters of wholegrain noodles, it also applies to longer cooking time or higher cooking loss. Noodles from the ecological farming system, especially wholegrain noodles, have better quality than noodles from the winter wheat cultivated in integrated farming system. The positive site of white noodles was their shorter cooking time and appropriate lower cooking loss. In ES was found longer cooking time of both types of noodles, but even so the values of cooking loss in ES was lower than in integrated system.

Keywords: ecological and integrated farming system, foods, noodles quality, *Triticum aestivum* L., winter wheat.

Abstrakt

Poľné experimenty boli zamerané na hodnotenie kvality rezancov získaných z bielej a celozrnnej pšeničnej múky, pričom pšenica letná, f. ozimná bola pestovaná v ekologickom aj integrovanom systéme hospodárenia. Získané výsledky dokumentujú, že kvalita rezancov bola štatisticky významne ovplyvnená systémom hospodárenia, predplodinou, hnojením a priebehom počasia. Dĺžka varenia, objem, hmotnosť varených rezancov, napučiavanie, väznosť vody, straty varením boli vyššie pri celozrnných rezancoch ako pri rezancoch bielych (z múky). Rezance z ekologického systému, najmä celozrnné, mali lepšiu kvalitu, ako rezance z integrovaného systému.

Kľúčové slová: ekologický a integrovaný systém hospodárenia, potraviny, kvalita rezancov, pšenica ozimná, *Triticum aestivum* L.

Detailný abstrakt

Poľné pokusy boli realizované na vedecko-výskumnej báze Dolná Malanta na západnom Slovensku počas rokov 2009 a 2010 na hnedozemi, ílovito-hlinitej. Nadmorská výška výskumnej oblasti je 178 m n. m.. Výskumná oblasť má kontinentálne podnebie s priemenou teplotou 19.7 °C v júli a -1,7 °C v januári, priemerný ročný úhrn zrážok 561 mm. Cieľom tejto práce bolo vyhodnotiť kvalitu múčnych a celozrnných rezancov vyrobených z pšenice letnej f. ozimnej (*Triticum aestivum* L.) pestovanej v ekologickom a integrovanom systéme hospodárenia. Ekologický systém pozostával zo 6-honového osevného postupu so striedaním plodín: bôb + lucerna – lucerna – pšenica letná forma ozimná – hrach siaty – kukurica na zrno – jačmeň jarný. V integrovanom systéme bol nasledovný osevný postup: pšenica letná forma ozimná – hrach siaty – pšenica letná forma ozimná – kukurica na zrno – jačmeň jarný – lucerna (3 roky na mimorotačnom hone). V oboch systémoch boli sledované dva varianty hnojenia, nehnojený a hnojený, ktorý v ES predstavoval aplikáciu 40 t/ha maštaľného hnoja a v IS aplikáciu 40 t/ha maštaľného hnoja + syntetické hnojivá. Na základe získaných výsledkov môžeme konštatovať, že kvalita rezancov bola preukazne ovplyvnená systémom hospodárenia, hnojením, predplodinou a vonkajšími vplyvmi počasia. Kvalita rezancov stanovená dĺžkou varenia, objemom a hmotnosťou varených rezancov, napučiavaním, väznosťou vody rezancov a stratami varením preukázala vyššie hodnoty všetkých parametrov pri celozrnných rezancoch, to sa týka aj dlhšej varivosti alebo vyšších strát varením. Z dosiahnutých výsledkov možno konštatovať, že v ekologickom systéme hospodárenia majú rezance, najmä celozrnné, lepšiu kvalitu než rezance vyrobené z pšenice pestovanej v integrovanom systéme hospodárenia. Pozitívom bielych rezancov (z múky) bol kratší čas varenia, a tomu zodpovedajúce nižšie straty varením.

Kľúčové slová: ekologický a integrovaný systém hospodárenia, potraviny, kvalita rezancov, pšenica ozimná, *Triticum aestivum* L.

Introduction

Quality requirements for bread have been well established but much more information is needed for a better understanding of noodle quality (He et al., 2004).

Asian noodles are different from Italian pasta products in ingredients used, the processes involved and their consumption patterns. Pasta is made from semolina (coarse flour usually milled from durum wheat) and water, and extruded through a metal die under pressure. It is a dried product. Asian noodles are characterized by thin strips slit from a sheeted dough that has been made from flour (hard and soft wheats), water and salt – common salt or alkaline salt. Noodles are often consumed in soup (Hou, Kruk, 1998).

Generally, flour from medium-hard to hard wheat, with low ash content, high flour whiteness, medium protein content, medium to strong gluten strength and high starchy viscosity was considered suitable for making dry white Chinese noodles (He et al., 2004; Zhang et al., 2005).

The key to finished product quality is to select wheat with the right qualities. Since noodles are very sensitive to the inclusion of sprout or disease damaged kernels, wheats for noodles should be dry, clean and not disrupt. The major quality criteria for noodle wheat are bran colour, kernel hardness, protein content, dough strength, and starch pasting properties (Crosbie & Ross, 2004). Execution of correct milling procedures is very critical to ensure the resulting noodle flour has bright colour, low ash content, low level of damaged starch, and fine particles (Park, Baik, 2004; Ross et al., 1997; Zhao, Seib, 2005).

During boiling, starch granules absorb water, swell, and gelatinize (Delcour et al., 2010), and protein extractabilities rapidly decrease as boiling proceeds, indicating further protein polymerization (Bruneel et al., 2010). This makes pasta a mixed polymer system with starch and protein as main structuring agents. Eating quality depends on two main parameters: viscoelastic behavior (particularly firmness after cooking) and surface condition (extent of disintegration). These determine product stickiness and degree of smoothness. Quality pasta tolerates moderate overcooking and has minimal cooking losses leading to a product with a smooth surface that has a certain firmness and resilience (Sissons et al., 2005). Cooking losses and surface stickiness are caused by excessive starch swelling. The latter can be prevented by the protein structure. Hence, pasta cooking quality largely depends on how the protein network withstands the starch swelling during cooking (Delcour et al., 2000a, b). In this view, a delicate competition during pasta cooking between (further) protein polymerization into a continuous network and starch swelling exists. An optimally cross-linked protein network traps starch particles in the network, restricts starch swelling and subsequent leaching, and promotes firmness in cooked pasta (Resmini, Pagani, 1983; Vansteelandt, Delcour, 1998). With insufficient cross-linking during cooking, the protein forms discrete masses lacking a continuous framework and pasta shows cooking losses, softness, and usually stickiness (Pagani et al., 1986; Resmini, Pagani, 1983). However, with excessive protein cross-linking during harsh drying, the proteins lack resilience to cope with starch swelling during cooking, which is also deleterious for cooking quality (Bruneel et al., 2010).

Our research work was focused on determination of the winter wheat white and wholegrain noodle cooking quality, where winter wheat was grown in ecological and integrated farming system with two levels of fertilisation during the years 2009 and 2010. There are many scientific papers, in which cooking quality of noodles from the view of wheat grain composition is reported, but research works evaluating the influence of farming systems on noodle quality are missing.

Materials and Methods

Field experiments were conducted at the Research Experimental Station Dolná Malanta, Western Slovakia during 2009 and 2010 on a Haplic Luvisol developed on proluvial sediments mixed with loess. The altitude of the experimental field was 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 561 mm. The aim of this work was to evaluate the quality of noodles made from winter wheat (*Triticum aestivum* L.) grown in ecological and integrated farming system. A split - plot design was used with two main treatments, ecological (ES) and integrated (IS) cropping systems. The ecological system was composed of a six course 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 fertilised (F) and unfertilised (N) variants. The fertilised variant in ES was based on 40 t*ha of manure while the IS also received 40 t*ha of manure plus synthetic fertilisers (Table 1). Treatments were replicated four times. Sowing and harvesting dates, rainfall and average temperature calculated for vegetative period of the crop, synthetic fertiliser inputs (kg*ha^{-1}) applied in the IS are shown in the table 1. Nitrogen fertilisers were applied in three split applications.

Table 1. Crop management data for winter wheat 2009–2010
Tabuľka 1. Údaje o pestovaní pšenice ozimnej 2009-2010

Year	**Sowing date**	**Harvest date**	**Rainfall (mm)**	**Average temperat. (°C)**	**Nitrogen (kg*ha^{-1})**	**Phosphorus (kg*ha^{-1})**	**Potassium (kg*ha^{-1})**
2009	13/10/08	15/07/09	426	9.6	82.5	37.5	20.0
2010	07/10/09	28/07/10	610	8.8	62.5	7.5	40.0

The work presents the results of evaluating the noodles prepared from white flour obtained after wheat grain milling on the laboratory mill Brabender Quadrumat Senior and from wholegrain flour obtained by grinding on the special mill PSY MP. Egg noodles with moisture of 30.5% produced on the apparatus for pasta producing P3 (La Monferina) were dried in drier at 50 °C for 12 hours. Prepared pasta was packed, stored and analysed. Qualitative parameters of noodles included: cooking time (min.) (AACC 66-50) – represents the time in minutes which was necessary to complete cooking of 100 g noodles in 1 litre of drinking water; cooked noodle volume (cm^3) – cooked noodles were placed into measuring cylinder which was poured with 500 cm^3 of water. Increased volume in cm^3 was read from the calibration; cooked noodle weight (g) – cooked noodles were weighed on the analytical scales with precision of 0.001 g; noodles absorption (%) – represents amount of water in mass % which noodles absorbed during the cooking process; noodle swelling (cm^3) – represents the ratio between volume of noodles before cooking and noodles volume after cooking; cooking loss (%) (AACC 66-50) – amount of noodles sediment in mass %, created during the noodle cooking process.

Obtained data were statistically evaluated by analysis of variance (ANOVA) and the significant differences were calculated by LSD test. Significance was indicated at $P \leq 0.05$.

Results and Discussion

White flour noodle quality

Noodles were prepared from white flour, dried eggs and water in amount according to water absorption of an individual flour sample on the noodle maker La Monferina P3 and dried at 50 °C. Uniformly specified quantity of dried noodles from each sample of flour was cooked in the boiling water until it had showed signs of boiled (soft, glassy inside without white stripe).

Statistical analysis of flour noodle quality showed that every factor (farming system, forecrop, year, crop nutrition) statistically significantly affected most of the noodle quality parameter. Ecological farming system showed better values of noodle quality in 5 parameters, out of six, in comparison with IS as follows: cooked noodle volume +2.56 cm^3; swelling +0.15 cm^3; cooked noodle weight +3.02 g; noodle absorption +12.09%. Cooking time in ecological system was at about 0.12 min. longer and although cooking loss was about 1.24% lower than in IS (Table 2). Parameter cooking loss was statistically significant. Cooking loss is undiserable and according to Wu et al. (1987), it should not exceed 10% of the dry weight of noodles. Based on this argument we can consider that only noodles in unfertilised variant, in 2009 and noodles from winter wheat cultivated after pea, exceeded the level of 10% of cooking loss.

Table 2. White flour noodle quality 2009-2010
Tabuľka 2. Kvalita bielych rezancov 2009-2010

Factors	Parameters	Cooking time (min.)	Cooked noodle volume (cm^3)	Swelling (cm^3)	Cooked noodle weight (g)	Noodle absorption (%)	Cooking loss (%)
Farming system	ES	5.75 a	67.25 b	3.74 b	74.61 b	198.44 b	8.45 a
	IS	5.63 a	64.69 a	3.59 a	71.59 a	186.35 a	9.69 b
Forecrop	Alfalfa	5.83 b	67.50 b	3.75 b	74.44 b	197.77 b	7.50 a
	Barley	5.38 a	64.13 a	3.56 a	71.23 a	184.92 a	9.94 b
	Pea	5.75 ab	62.50 a	3.47 a	69.78 a	179.11 a	13.27 c
Year	2009	6.00 b	66.67 b	3.70 b	74.25 b	196.99 b	12.83 b
	2010	5.33 a	64.42 a	3.58 a	70.94 a	183.76 a	5.72 a
Crop nutrition	F	5.58 a	65.50 a	3.64 a	72.45 a	189.82 a	8.23 a
	N	5.75 a	65.58 a	3.64 a	72.73 a	190.93 a	10.32 b

Legend: ES = ecological system; IS = integrated system; F = fertilised variant; N = non-fertilised variant. Statistical analysis was performed by each factor.

Factor year/weather conditions and forecrop influenced every parameter of noodle quality in range of high statistical significance. The highest diffrence was observed in cooking loss, in 2009 was achieved value 12.83% and in 2010 it was only 5.72%. According to Dick and Youngs (1988) and Alamri et al. (2009) cooking loss of 7% to 8% and below can be acceptable for good quality dried pasta. In 2010 the noodles had shorter cooking time but the other parameters showed higher/better values in 2009, namely cooked noodle volume, swelling, cooked noodle weight and noodle absorption. Based on this argument we can note that our white noodles was of average quality.

The best values of noodle quality were reached after forecrop alfalfa. Differences between noodle quality parameters after forecrops spring barley and peas were not statistically significant, except cooking loss. After pea, the cooking loss was the highest, 13.27%.

Application of fertilisers showed statistical effect only on parameter cooking loss, where the fertilised variant resulted in positively lower cooking loss (8.23%) in comparison with unfertilised variant (10.32%). Fertilisation (or manure application in ES) had no significant effect on majority of cooking quality parameters (cooked noodle volume and weight, swelling and noodles absorption).

The characteristics prefered in dry noodles are a white appearance, minimum disintegration during cooking, and a smooth surface without defects. In the research work by Oh et al. (1985) in which the surface firmness of cooked noodles from soft and hard wheat flours was investigated, stated that the optimum cooking time of the white flour noodles from soft wheat were 10 minutes and they showed the average cooking loss of 6.5%. Hard wheat noodles required longer cooking than soft wheat noodles. Our samples of winter wheat (soft) white noodles, in comparison with these results, had shorter cooking time (average 5.67 min.), but on the other hand had higher cooking loss (average 9.55%) was achieved.

Rabah, Abdennour (2012) examined an effect of adding dry gluten powder to common wheat flour on cooking quality of noodles. They concluded that the addition of dry gluten powder to common wheat flours reduced cooking loss of noodles but also noodles cooking weight. According to these results we can suppose that from winter wheat flour with higher content of gluten can be produced the noodles with lower cooking loss and noodles cooking weight. This assumption can be confirmed by our results, where in ecological farming system, after forecrop alfalfa, in the 2010 and in the fertilised variant there was found higher amount of wet gluten (Lacko-Bartošová, Smatanová, 2012) and cooking loss in all of this cases had lower or the lowest values. The same effect of the amount of wet gluten on the noodle cooking loss was showed also on the wholegrain noodles.

Wholegrain flour noodle quality

The wholegrain noodle quality was significantly influenced by every factor, mainly by farming system, forecrop and weather conditions.

Hihger values of noodle quality were obtained in ecological farming system. It was observed noodle absorption with value of 246.04% in ES, which is related to subsequent higher cooked noodle volume (79.75 cm^3), cooked noodle weight (86.51 g) and swelling (4.43 cm^3). Noodles in ES had longer cooking time about 0.57 min. and lower cooking loss about 1.61% compared to IS (Table 3).

Weather conditions affected every evaluated parameter of noodle quality. Higher values of parameters were reached in 2010, except the cooking loss. Just cooking loss, as with flour noodles, showed the highest difference between years. In 2009 it had value 17.25% and in 2010 had value only 11.66%. Noodle absorption in 2010 was higher about 13.08%; cooked noodle volume and weight about 3.67 cm^3 and 3.27 g; and swelling about 0.21 cm^3 compared in 2009. Weather conditions had opposite effect on quality of wholegrain flour noodle in most evaluated parameters than on white flour noodle.

Table 3. Wholegrain flour noodle quality 2009–2010
Tabuľka 3. Kvalita celozrnných rezancov 2009-2010

Factors / Parameters		Cooking time (min.)	Cooked noodle volume (cm^3)	Swelling (cm^3)	Cooked noodle weight (g)	Noodle absorption (%)	Cooking loss (%)
Farming system	**ES**	12.13 b	79.75 b	4.43 b	86.51 b	246.04 b	13.38 a
	IS	11.56 a	77.75 a	4.32 a	84.63 a	238.50 a	14.99 b
Forecrop	**Alfalfa**	12.00 b	79.67 c	4.42 c	86.40 c	245.61 c	12.50 a
	Barley	11.88 b	78.13 b	4.34 b	84.93 b	239.70 b	16.29 b
	Pea	10.75 a	75.25 a	4.18 a	82.46 a	229.84 a	16.62 b
Year	**2009**	11.42 a	76.58 a	4.25 a	83.62 a	234.47 a	17.25 b
	2010	12.08 b	80.25 b	4.46 b	86.89 b	247.55 b	11.66 a
Crop nutrition	**F**	12.17 b	78.83 a	4.38 a	85.88 b	243.50 b	13.46 a
	N	11.33 a	78.00 a	4.33 a	84.63 a	238.52 a	15.44 b

Legend: ES = ecological system; IS = integrated system; F = fertilised variant; N = non-fertilised variant. Statistical analysis was performed by each factor.

Fertilisation positively influenced the quality of wholegrain noodles in parameters: noodle weight, absorption, cooking loss.

Noodle quality was affected also by factor forecrop. Evaluation of this parameter showed the highest values after forecrop alfalfa in noodle absorption, cooked noodle volume, weight and swelling. The lowest cooking loss (12.50%) and the longest cooking time (12 min.) were also reached after alfalfa. On the other hand the lowest values of noodle quality were observed after pea with cooking time 10.75 min., noodle absorbtion 229.84%, cooked noodle volume and weight 75.25 cm^3 and 82.46 g, swelling 4.18 cm^3. The cooking loss was the highest = 16.62%. Differences between quality parameters evaluated after barley were intermediate but statistically significant compared to forecrop alfalfa and pea.

In the Table 4 there is a comparison of effect of flour structure and farming systems on the cooking quality of noodles. Statistical analysis showed that flour structure had significant influence on the cooking quality parameters, except cooking loss. White flour noodles had shorter cooking time and lower cooking loss in comparison with wholegrain noodles, but the other quality parameters was better in wholegrain noodles (cooked noodle volume and weight, swelling, noodle absorption).

Table 4. White flour and wholegrain flour noodles comparison
Tabuľka 4. Porovnanie bielych a celozrnných rezancov

	Cooking time (min.)	Cooked noodle volume (cm^3)	Swelling (cm^3)	Cooked noodle weight (g)	Noodle absorption (%)	Cooking loss (%)
WF	5.69 a	65.75 a	3.67 a	73.1 a	192.39 a	9.07 a
WGF	11.84 b	78.75 b	4.37 b	85.57 b	242.27 b	14.18 a

Legend: ES = ecological system; IS = integrated system; WF = white flour noodles; WGF = wholegrain flour noodles.

Table 5. Correlation analysis of winter wheat white flour noodles cooking quality
Tabuľka 5. Korelačná analýza kvality rezancov z bielej múky pšenice ozimnej

	Cooking time (min.)	Cooked noodle volume (cm^3)	Swelling (cm^3)	Cooked noodle weight (g)	Noodle absorption (%)	Cooking loss (%)
CT	1.00	0.77**	0.77**	0.77**	0.77**	0.58**
CNV		1.00	1.00**	0.95**	0.95**	0.19
S			1.00	0.95**	0.95**	0.19
CNW				1.00	1.00**	0.28
NA					1.00	0.28
CL						1.00

Legend: CT - cooking time, CNV - cooked noodle volume, S - swelling, CNW - cooked noodle weight, NA - noodle absorption, CL - cooking loss.

Table 6. Correlation analysis of winter wheat wholegrain noodles cooking quality
Tabuľka 6. Korelačná analýza kvality rezancov z celozrnnej múky pšenice ozimnej

	Cooking time (min.)	Cooked noodle volume (cm^3)	Swelling (cm^3)	Cooked noodle weight (g)	Noodle absorption (%)	Cooking loss (%)
CT	1.00	0.76**	0.76**	0.81**	0.81**	-0.58**
CNV		1.00	1.00**	0.94**	0.94**	-0.79**
S			1.00	0.94**	0.94**	-0.79**
CNW				1.00	1.00**	-0.82**
NA					1.00	-0.82**
CL						1.00

Legend: CT - cooking time, CNV - cooked noodle volume, S - swelling, CNW - cooked noodle weight, NA - noodle absorption, CL - cooking loss.

High correlation coefficient 1.00** affirmed the dependence between cooked noodle volume and swelling, and between cooked noodle weight and noodle absorption of white flour noodles (Table 5). The higher was the cooked noodle volume, the higher was also swelling of noodles. Cooking quality parameters positive correlated, except cooking loss. Cooking loss positively correlated with only cooking time (0.58**).

Similar values of correlation analysis as found on white noodles were showed on wholegrain noodles (Table 6). High correlation coefficient 1.00** confirmed the dependence among cooked noodles volume and swelling, and among cooked noodle weight and noodle absorption. Cooking quality parameters were positively correlated, except cooking loss. Correlation analysis showed strong negative correlation between cooking loss and all of the other quality parameters.

Correlation analysis of white flour noodles and wholegrain noodles was diametrically different. Correlation relating to cooking loss was negatively affected by all factors.

Conclusions

Reached results of our work proved that winter wheat noodle cooking quality was statistically significantly affected by factor farming system, weather conditions, forecrop and by fertilisation.

Noodle cooking quality evaluated by cooking time, volume and weight of cooked noodles, noodle absorption and by cooking loss showed higher values of each of the parameters of wholegrain noodles. It also applies to long cooking time or high cooking loss, what does not fall into positives of cooking quality.

Noodles from the ecological farming system, especially wholegrain noodles, have better cooking quality than noodles from the winter wheat cultivated in integrated farming system. In ES was found longer cooking time of both types of noodles, but even so the values of cooking loss in ES was lower than in integrated system.

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