Microwave Treatment and Drying of Germinated Pea

MICHAELA SKULINOVÁ[1], PAVEL KADLEC[1], JITKA KAASOVÁ[1], JANA DOSTÁLOVÁ[2], MONIKA ZÁTOPKOVÁ[2], VÁCLAV HOSNEDL[3] and JANA HRACHOVINOVÁ[3]

Institute of Chemical Technology, Prague – [1]Department of Carbohydrate Chemistry and Technology, [2]Department of Food Chemistry and Analysis, Prague; [3]Czech University of Agriculture in Prague – Department of Crop Production, Prague, Czech Republic

Abstract

SKULINOVÁ M., KADLEC P., KAASOVÁ J., DOSTÁLOVÁ J., ZÁTOPKOVÁ M., HOSNEDL V., HRACHOVINOVÁ J. (2002): **Microwave treatment and drying of germinated pea**. Czech J. Food Sci., **20**: 23–30.

It is possible to use germination of grain legumes as the most effective way of decreasing a high content of α-galactooligosaccharides which undesirably affect the nutritive value and acceptability of legumes. Content of α-galactooligosaccharides was reduced to 38% (Gotik cultivar) and to 45% (Grana cultivar) of the original value after 2 days of germination. The aim of further processing was to dry germinated pea to final moisture content 12–14%. Very interesting results were obtained when microwave heating was used as a preliminary treatment before hot air drying. Microwave treatment reduces the time of drying. The contents of soluble carbohydrates (sucrose, raffinose, stachyose and verbascose), proteins and trypsin inhibitor activity were determined as criteria of microwave heating effects on the chemical composition of germinated pea. Germinated pea was used for the preparation of pea soups and these pea dishes were sensory evaluated.

Keywords: germination; microwave; drying; pea; α-galactooligosaccharides

Grain legumes are important sources of energy and proteins, used in many parts of the world, for both animal and human nutrition. Grain legumes are an important and economic source of significant amounts of proteins, carbohydrates, vitamins and some minerals. The consumption of grain legumes in human diet is limited due to the presence of certain antinutritional factors (α-galactooligosaccharides, phytic acid, condensed tannins, polyphenols, protease inhibitors, α-amylase inhibitors and lectins) (ALONSO *et al*. 1998). α-galactooligosaccharides (raffinose family oligosaccharides RFO – raffinose, stachyose, verbascose etc.) are characterised by the presence of α(1–6) links between galactose residues and these linkages are not hydrolysed by the intestinal mucosal enzymes (FRIAS *et al*. 1994). Most researchers ascribe flatulence to the action of anaerobic intestinal microflora on these oligosaccharides that cannot be degraded by mammalian digestive enzymes (VIDAL-VALVERDE *et al*. 1993). Beneficial effects associated with the consumption of legumes are related to the slow rate of starch digestion and the high content of resistant starch in legumes (TRUSWEL 1992). WÜRSCH *et al.* (1986) showed that the rigid plant cell walls (dietary fibre) in legumes inhibit swelling and dispersion of starch during processing but the digestibility of starch can be affected by many other factors, such as starch granule structure and the proportion of amylose and amylopectin (BORNET 1993).

A wide range of processing techniques such as germination, dehulling, cooking, roasting, autoclaving, fermentation and extrusion have been used and tested to increase the utilization of legumes.

The aim of this paper is to evaluate germination, microwave (MW) treatment and hot-air drying effects on changes in soluble carbohydrates and proteins in germinated pea during these processes.

The work was presented as a poster to the 28th International Conference of Slovak Society of Chemical Engineering, 21.–25. 5. 2001, Tatranské Matliare, Slovak Republic.

MATERIAL AND METHODS

Plant Material

Samples of pea (*Pisum sativum* ssp. *sativum* L.) – cultivars Grana and Gotik, year of harvest 2000, locality Verovany in the Czech Republic – were supplied by the Central Institute for Supervising and Testing in Agriculture at Brno.

Germination Tests

Three methods of germination were used:

1. Germination on filter paper (method F). Seeds were incubated in 5 enclosed plates on filter paper, 50 g of seeds and 75 ml of water in each plate, further addition of 50 ml of water after 24 h, temperature 15°C, time of germination 48 h.

2. Germination in aerated water media (method W). Seeds were incubated in 9 aeration bottles, 80 g of seeds and 200 ml of water in each bottle, water was changed after 24 h, temperature 20°C, time of germination 48 h.

3. Germination in a solution of hydrogen peroxide (method P). Seeds were incubated in 2 beakers, 100 g of seeds and 300 ml of 0.75% solution of H_2O_2 in each beaker, without aeration, temperature 20°C, time of germination 48 hrs.

Parameters of MW Oven and Laboratory Drier

Domestic MW oven Whirlpool MT 243/UKM 347 (Norrköpping, Sweden), frequency 2450 MHz, pulsed variable MW rated power output from 90 to 1000 W by a timer, inner volume 25.4 litre, without sample rotation during measurement.

Fan assisted dry air oven KCW 100 (LABSYSTEM CR) with adjustable temperature, electronic timer.

Experimental Set-up and Temperature Measurement in MW Treatment

A sample of treated material was placed in an open plastic rectangular container (dimensions 165 × 112 × 64 mm) in the middle of MW cavity. The teflon probe guide made to position NoEMI optic probes into pre-determined locations in measured samples was situated above this container. The temperature of samples was recorded during the heating period using a NoEMI fiber-optic temperature system – table-top unit ReFlex, with 2 channels, firm Nortech Fibronic Inc., Canada. The general characteristics of this system are as follows: ultra-fast general-purpose miniprobe, temperature range –40 to +250°C, response time 0.25 s, computer interface RS-232-C, analogue output 0–20 mA, data logging function. Temperature data were recorded in 2s intervals and explicated to a spreadsheet-compatible file MS Excel on PC. Temperature of sample was measured by one probe situated 50 mm to the right from the middle, just in the position where the highest temperature was achieved (Fig. 1). The location of temperature probe was 2 mm below the surface of sample.

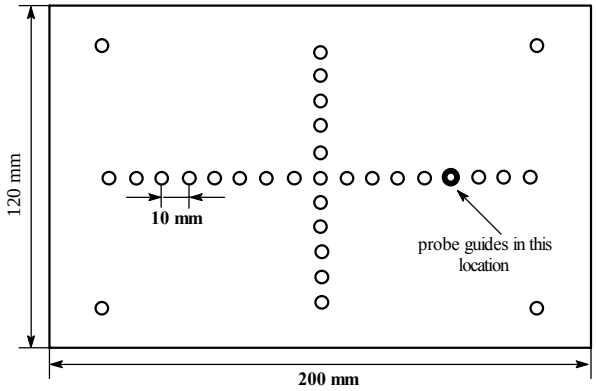

Fig. 1. Top view of a plastic probe guide used to guide temperature probes into pre-determined locations

Methodology of MW Measurement

MW oven was prewarmed every day before measurements of samples by heating 2 l water for 5 min. The absorbed power according to BSEN 60705 test (International Standard BSEN 60705 1995) was determined every day as well. Load of water for this test is 350 ± 5 g, initial water temperature 10 ± 2°C. Mean value of absorbed power (n = 22) corresponding to the rated power output 350 W was 298.42 W; standard deviation 8.5 and variation coefficient (relative standard deviation) 2.85%.

200 g of wet germinated pea was heated in MW oven, rated power output 350 W was stopped when the desired end temperature of heated sample 80°C was achieved. The temperature of germinated pea during microwave heating increased rapidly as a result of exposure to microwave energy, but drying proceeds slowly during this time. Microwave power was switched off after the temperature of 80°C was achieved and the pea sample was left for 1 min in the microwave cavity. The sample was stirred in the vessel and cooled to an ambient air temperature outside the microwave oven (1 min as well) and returned to the microwave oven. This cycle of heating and stirring with cooling was repeated five times until the temperature was the same at each place of the sample. A new sample was treated in MW oven after a 30-min break.

Determination of Drying Rate

Drying rate Φ_A (kg m^{-2} s^{-1}) was calculated according to the following equation:

$$\Phi_A = -(m_C/A) \times (\mathrm{d}X_A/\mathrm{d}t)$$

where: m_C – weight of dry material (kg)
A – surface area (m^2)
X_A – relative weight ratio of water of dried material (1)
t – time (s)

Conventional Drying

Germinated pea was dried in a laboratory fan assisted dry air oven at 50°C to the final moisture content 12–14%. 800 g of wet germinated pea on a squared sieve (362 × 363 mm, surface area A = 0.1314 m^2, 1 mm mesh) was placed on the upper shelf of a laboratory dry air oven. Surface temperature and moisture content of the sample were measured repeatedly in 40 min intervals until the final moisture content was achieved (about 18 hrs), final weight of dried material m_C = 312.12 g. The obtained data were used for a quantitative description of the drying process.

Microwave Drying

Approximately 200 g of germinated pea in an open plastic rectangular container (dimensions 165 × 112 × 64 mm, surface area A = 0.01848 m^2) was placed in the middle of the MW oven cavity. Location of the temperature probe was the same as during MW treatment of sample, rated power outputs 500, 350 and 90 W were used. The sample was taken away when the end temperature of sample 80°C was achieved (+ 1 min delay in MW oven cavity + 1 min stirring of sample) and it was balanced by means of automatic drying electronic weights Precisa HA60 (Switzerland). This procedure was repeated as soon as the final moisture content was achieved. The final weight of MW dried material m_C was 88.87 g for rated power output 500 W, 87.01 g for 350 W and 93.46 g for 90 W. Drying time was the sum of times when the MW oven was switched on.

Extraction and Determination of Soluble Carbohydrates

Approximately 5 g of ground dry sample was homogenised in 20 ml of ethanol:water (80:20, v/v) and refluxed (boiled) for 60 min; 50 ml acetonitrile was added to the extract that was cooled down and supplied demineralised water to the volume 100 ml, filtered through a membrane filter 0.45 µm pore size and analysed by HPLC.

HPLC Determination

HPLC chromatography was used to determine sucrose and α-galactooligosaccharides (RFO – raffinose, stachyose and verbascose) (GÓRECKI *et al*. 1997; MUZQUIZ *et al*. 1992; KVASNIČKA *et al*. 1996). The conditions of HPLC chromatography were as follows: 5 µm column 250 × 4 mm (Tessek Ltd., Prague, CR) filled with Separon SGX NH_2; mobile phase: acetonitrile:water (65:35 v/v), flow rate 1 ml per min; ambient temperature; refractive detector Shodex Group, Japan Shodex RI SE-61.

TIA Determination

Glycine buffer pH 11 containing urea and EDTA was used for the extraction of proteins. The sample was extracted and stirred for 2 h and then it was centrifuged. Synthetic substrate BAPNA (N-α-benzoyl-DL-arginine-*p*-nitroanilide) was hydrolysed by trypsin and the absorbance of dislodged yellow *p*-nitroanilide was measured at 410 nm (GATTA *et al.* 1988).

Cooking Procedures of Pea Soup

200 g of soaked or germinated pea was boiled gently with 1300 ml of tap water in a covered pot for 30 min, mixed with black pepper, marjoram and roux and homogenised. 1400 ml of water was used in the case of 100 g dried germinated pea.

Sensory Evaluation

Sensory characteristics were determined under conditions specified by international ISO standards. Unstructured graphical scales with hedonic descriptions were used. The following characteristics were evaluated: appearance, colour, odour, flavour, texture and off-flavour (with intensity descriptions). Number of assessors: 16.

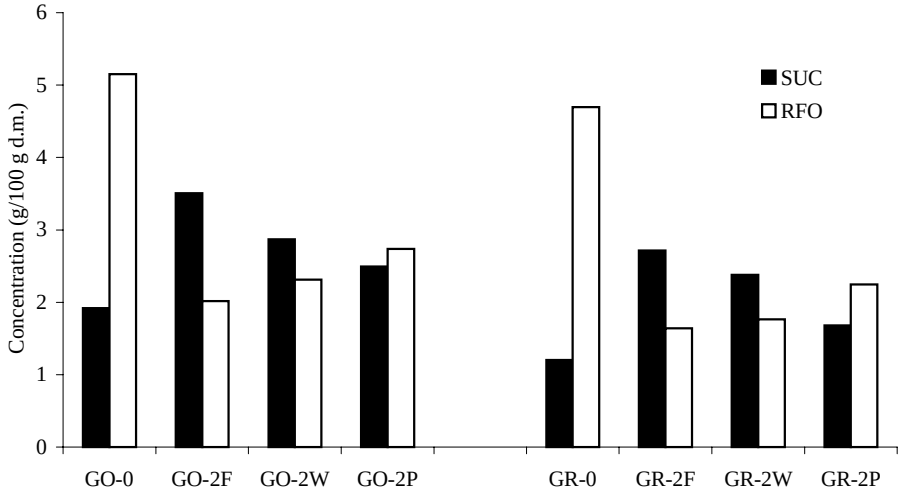

Fig. 2. Changes in sucrose and RFO during germination of pea cultivars Gotik and Grana

RESULTS AND DISCUSSION

Changes in the composition of soluble carbohydrates for various methods of pea germination are shown in Fig. 2. These results confirm the hypothesis of RFO decline during germination of legumes and they are in accordance with (GÓRECKI *et al*. 1997; MUZQUIZ *et al*. 1992) and also with our previous paper (KADLEC *et al*. 2000a). As regards changes in proteins, their rise from the original value 25 g/100 g d.m. was minimal. These results are in agreement with (ALONSO *et al*. 1998), who reported a 3.5% increase in proteins after 48 hrs of pea germination. Designation of samples is as follows: GO – Gotik cultivar; GR – Grana cultivar, number after the dash means the number of days of germination, the last letter indicates the method of germination (F or W or P). Relative changes (%) in carbohydrates and proteins achieved during germination are shown below. While the content of proteins (PRO) was practically constant, changes in carbohydrates (CARB) are favourable from the nutritional point of view. Decreases in raffinose (RAF), stachyose (STA), verbascose (VER) and whole group of RFO and an increase in sucrose (SUC) were as follows:

	SUC	RAF	STA	VER	RFO	CARB	PRO
GO-0	100	100	100	100	100	100	100
GO-2F	182	46	41	29	39	78	100
GO-2W	149	34	48	49	45	73	104
GO-2P	130	71	49	45	53	74	102
GR-0	100	100	100	100	100	100	100
GR-2F	226	54	43	17	35	74	99
GR-2W	198	46	36	36	38	70	102
GR-2P	140	71	50	35	48	67	100

The best results were achieved for a comparative laboratory method of germination on filter paper (method F) and for germination in aerated water media (method W). The latter is recommended due to its technical conditions. Fig. 3 shows the relative distribution of RFO in various methods of germination. Distribution of raffinose, stachyose and verbascose after germination in aerated water media is similar like in both cultivars of dried pea.

The aim of further processing of pea after two-day germination is to dry it to the final moisture content of 12–14%. Various MW treatments and convective drying were tested in our previous paper (KADLEC *et al*. 2000b). Very interesting results were obtained when MW heating was used as a preliminary treatment before hot air drying. MW treatment is useful for wet germinated seeds as the first step of drying because moist heat is more effective than dry heat. The higher temperature of sample after MW treatment represents a more economical process than convective drying. Mean value of dry matter content of MW treated samples was 39.49% (n = 28), standard deviation 5.41 and coefficient of variation (relative standard deviation) 13.69%.

Concentrations of soluble carbohydrates (SUC, RAF, STA, VER and sum of α-galactooligosaccharides – RFO) in germinated pea (GO-2W), in germinated pea after MW treatment (GO-2WM) and in MW treated pea after hot air drying at 50°C to the final moisture content of 12–14% (GO-2WMD) are shown in Fig. 4. The values for dry pea before MW treatment (GO-0) are shown for comparison. The ratios RFO/SUC for original dry pea (GO-0), germinated (GO-2W), MW treated (GO-2WM) and MW treated and hot air dried pea (GO-2WMD) represent changes in the composition of soluble carbohydrates during these processes (Fig. 5).

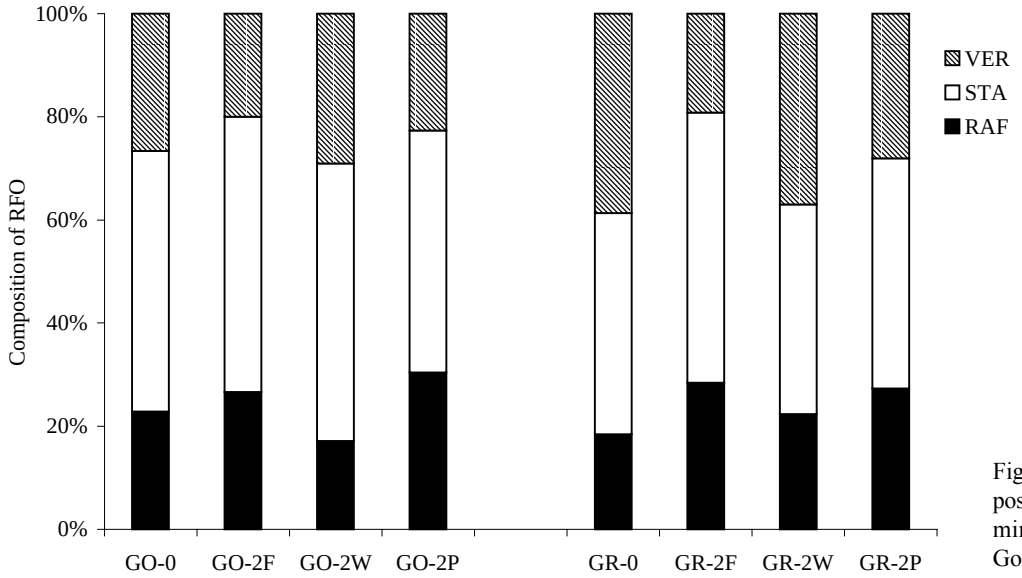

Fig. 3. Changes in the composition of RFO during germination of pea cultivars Gotik and Grana

	SUC	RAF	STA	VER	RFO	CARB	PRO
Germinated pea	100	100	100	100	100	100	100
After MW	97–128	60–144	81–171	70–144	78–156	92–144	100–103
After drying	80–120	55–77	44–110	49–80	49–80	66–103	99–103

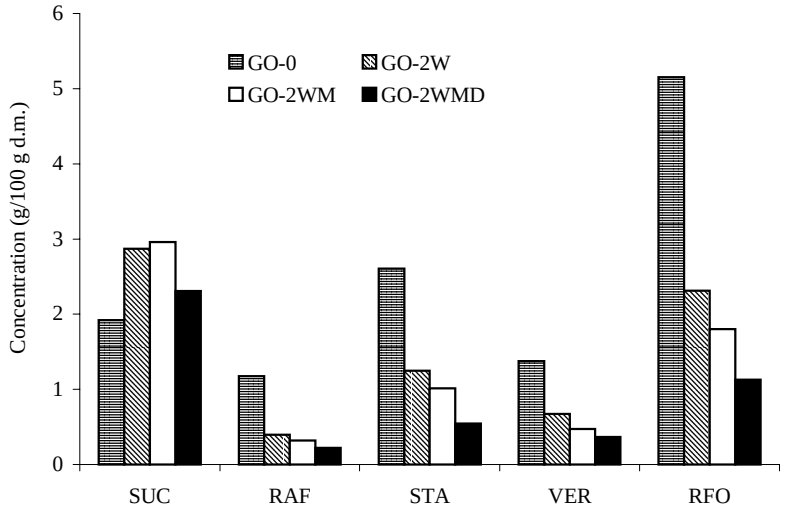

Fig. 4. Changes in soluble carbohydrates during germination in water media, microwave treatment and drying – Gotik cultivar

Contents of some carbohydrates show positive (above 100%) or negative (below 100%) changes. Contents of proteins were slightly increased.

These changes in RFO content may be caused by ongoing hydrolysis of RFO, thermal decomposition of sucrose, Maillard reaction between sugars and amines, utilization of galactose in metabolism, etc. Explanation of these reasons will be a subject of the next study.

An example of relative distribution of RFO during germination in water media, MW treatment and hot air drying for Gotik cultivar is represented in Fig. 6. Distribution of raffinose, stachyose and verbascose during these treatments is without changes.

As regards changes in TIA, the highest decrease in TIA was observed after 2 days of germination (to 34.7%). TIA was reduced after MW heating to 35.2% and after conventional drying to 38.5%. It is possible to improve the nutritional quality of pea cultivars with high content of TIA (such as Gotik cultivar) by the above-mentioned processes.

Drying curves and relation between drying rate and moisture content were used to compare conventional hot air drying and MW drying of germinated pea. Drying curve is a time dependence of relative weight ratio of water X_A. The relative weight ratio of water X_A = 0.12 (comparative value for dry pea) was achieved by conventional drying of germinated pea after 1027 min, whereas by means of MW treatment this value was achieved: after 128 min at 90 W power output, after 25 min at 350 W and after 18 min at 500 W (Fig. 7).

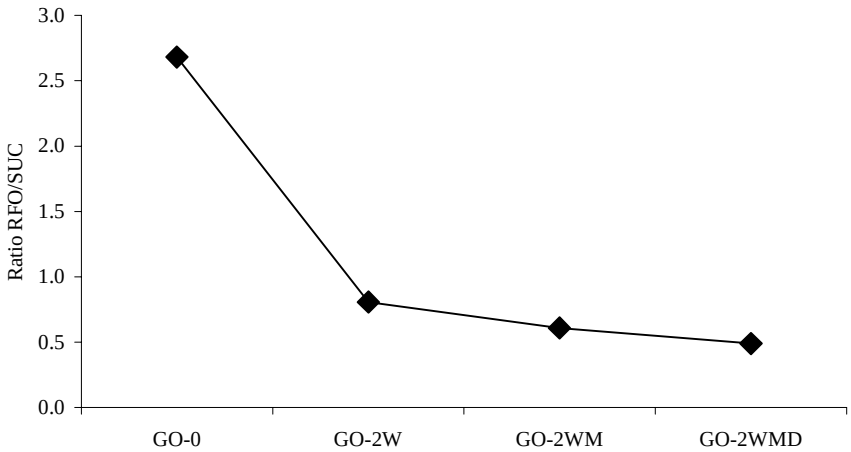

Fig. 5. The ratio RFO/SUC during germination in water media, microwave treatment and drying – Gotik cultivar

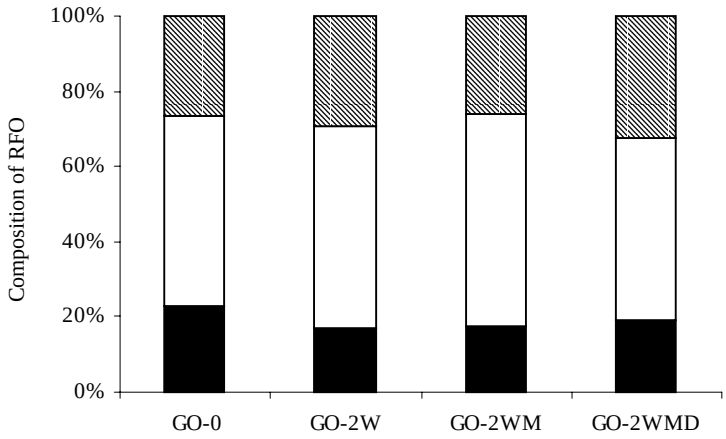

Fig. 6. Changes in the composition of RFO during germination in water media, microwave treatment and drying – Gotik cultivar

The relations between drying rate Φ_A and moisture content of pea for microwave and hot air drying are different (Fig. 8). MW drying in the first stage is characterised by a period of increasing drying rate, the highest drying rate was achieved for relative weight ratio of water X_A = 0.92 –0.96, and a period of decreasing drying rate follows. The highest drying rate increases with power output. The course of hot air drying is characterised by a period of

Tab. 1. Sensory characteristics of soups prepared from original, germinated and germinated dried peas

Sample	Acceptability (100% = excellent, 0% = rather bad, for off-flavours 100% = very strong, 0% = very weak)					
	Appearance	Colour	Flavour	Taste	Texture	Off-flavours
Grana	74 ± 14	72 ± 21	76 ± 18	80 ± 14	73 ± 14	83 ± 17
Grana 2G	70 ± 18	65 ± 20	77 ± 17	80 ± 16	69 ± 13	84 ± 21
Grana 2GD	71 ± 15	67 ± 14	51 ± 25	66 ± 14	53 ± 22	76 ± 18
Gotik	70 ± 13	66 ± 17	65 ± 18	71 ± 14	69 ± 18	83 ± 11
Gotik 2G	68 ± 22	62 ± 23	59 ± 27	61 ± 21	62 ± 18	70 ± 24
Gotik 2GD	70 ± 12	63 ± 15	48 ± 15	56 ± 19	60 ± 19	73 ± 16

2G = peas germinated for two days

2GD = peas germinated for two days and dried

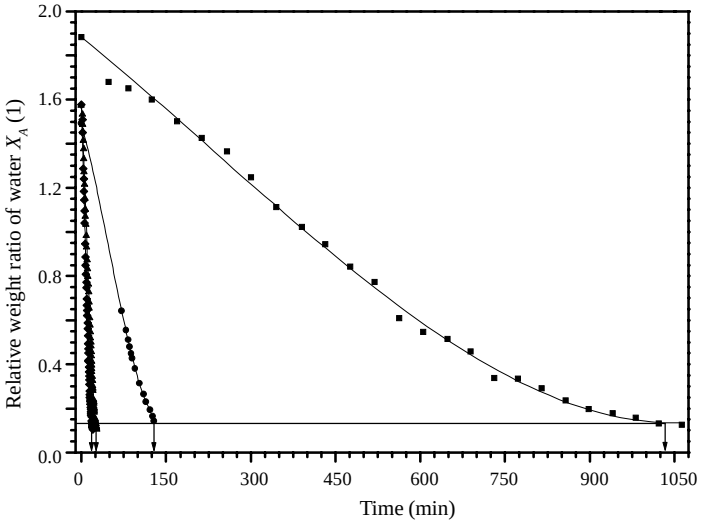

Fig. 7. Drying curve of Gotik cultivar – relation between moisture content and time of drying

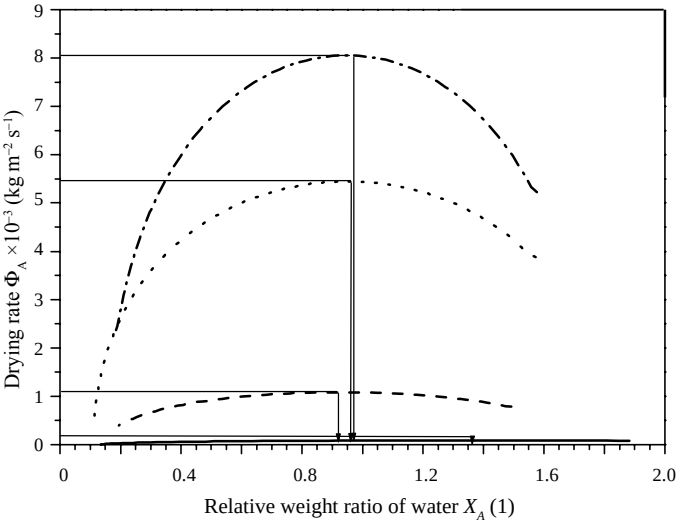

Fig. 8. Relation between drying rate and moisture content of Gotik cultivar

— Conventional drying
- - Microwave drying – 90 W
··· Microwave drying – 350 W
-·-· Microwave drying – 500 W

decreasing drying rate only. The highest value of drying rate for conventional hot air drying is 12.1 times lower than the drying rate for MW rated power output 90 W, 60.7 times lower for 350 W and 89.8 times lower for 500 W MW drying.

Compared with conventional drying, the course of MW treatment of germinated pea is much faster. From the practical point of view, the combination of MW treatment and conventional drying is most profitable because it enables to reduce the drying time in the first and final periods of drying.

The sensory characteristics of soups prepared from original, germinated and germinated dried peas are shown in Table 1. The acceptance of flavour and odour of soups prepared from germinated Grana was higher while in the case of appearance, colour and texture it was lower than for soups from the control sample of pea. The differences were not statistically significant. The differences in the acceptance of soups prepared from fresh germinated pea and dried germinated pea were not statistically significant with the exception of flavour. Flavour was worse for soups prepared from dried germinated pea Grana. Acceptances of dishes from fresh germinated pea were high.

CONCLUSION

The effect of germination and MW heating process combined with conventional drying was studied to improve the nutritional quality of pea. After two days of germination a significant decrease in α-galactooligosaccharides in pea and a decrease in TIA was achieved while the content of proteins slightly increased. The benefit of MW treatment is a shortened and improved drying process and the above-mentioned changes in carbohydrates and proteins. Chemical composition of germinated pea is favourable from the nutritional point of view, the acceptances of dishes from fresh and dried germinated pea were high according to sensory evaluation.

It is possible to propose the following method of pea processing: (1) two days of germination in aerated water media, (2) MW heating of wet germinated seeds, stopped at 80°C, (3) conventional drying by hot air (50°C) to the final moisture 12–14%.

References

ALONSO R., ORÚE E., MARZO F. (1998): Effects of extrusion and conventional processing methods on protein and antinutritional factor contents in pea seeds. Food Chem., **63**: 505–512.

BORNET F. (1993): Technological treatments of cereals. Repercussions on the physiological properties of starch. Carbohydr. Polym., **21**: 195–203.

FRIAS J., VIDAL-VALVERDE C., BAKHSH A., ARTHUR A.E., HEDLEY C. (1994): An assessment of variation for nutritional and non-nutritional carbohydrates in lentil seeds (*Lens culinaris*). Plant Breed., **113**: 170–173.

GATTA C., PIERGIOVANNI A.R., PERRINO P. (1988): An improved method for the determination of trypsin inhibitor levels in legumes. Lebensm.-Wiss. Technol., **21**: 315–318.

GÓRECKI R.J., PIOTROWICZ-CIESLAK A., OBENDORF R.L. (1997): Soluble sugars and flatulence-producing oligosaccharides in maturing yellow lupin (*Lupinus luteus* L.) seeds. Seed Sci. Res.,**7**: 185–193.

KADLEC P., KAASOVÁ J., BUBNÍK Z., POUR V. (2000a): Effect of germination and microwave treatment on chemical composition of pea. In: Proc. Int. Conf. Microwave Chemistry. Antibes, Francie: 241–243.

KADLEC P., RUBECOVÁ A., KAASOVÁ J., BUBNÍK Z., POUR V. (2000b): Microwave heating and drying of germinated pea. In: Proc. 14th Int. Congr. CHISA '2000. Prague (CD ROM).

KVASNIČKA F., AHMADOVÁ-VAVROUSOVÁ R., FRIAS J., PRICE K.R., KADLEC P. (1996): A rapid HPLC determination of raffinose family oligosaccharides in pea seeds. J. Liq. Chromatogr. Rel. Technol., **19**: 135–147.

MUZQUIZ M., REY C., CUADRADO C., FENWICK,G.R. (1992): Effect of germination on the oligosaccharide content of lupin species. J. Chromatogr., **607**: 349–352.

TRUSWEL S.A. (1992): Glycaemie index of foods. Eur. J. Clin. Nutr., **46**: 91.

VIDAL-VALVERDE C., FRIAS J., PRODANOV M., TABERA J., RUIZ R., BACON J. (1993): Effect of natural fermentation on carbohydrates, riboflavin and trypsin inhibitor activity of lentils. Lebensm.-Wiss. Technol., **197**: 449–452.

WÜRSCH P., DEL VEDOVO S., KOELLREUTTER B. (1986): Cell-structure and starch nature as key determinations of the digestion rate of starch in legume. Amer. J. Clin. Nutr., **43**: 25–29.

Received for publication September 5, 2001
Accepted after corrections December 18, 2001

Souhrn

SKULINOVÁ M., KADLEC P., KAASOVÁ J., DOSTÁLOVÁ J., ZÁTOPKOVÁ M., HOSNEDL V., HRACHOVINOVÁ J. (2002): **Mikrovlnný ohřev a sušení naklíčených semen hrachu**. Czech J. Food Sci., **20**: 23–30.

Klíčení luštěnin se používá jako jeden z nejefektivnějších způsobů ke snížení vysokého obsahu α-galaktooligosacharidů, které nepříznivě ovlivňují nutriční hodnotu a spotřebu luštěnin. Po dvou dnech klíčení byl snížen obsah α-galaktooligosacharidů na 38 % (odrůda Gotik) a 45 % (odrůda Grana) původní hodnoty. Cílem dalšího zpracování bylo sušení naklíčeného hrachu na konečnou vlhkost 12–14 %. Velmi zajímavých výsledků bylo dosaženo při použití mikrovlnného ohřevu před vlastním horkovzdušným sušením. Účinek mikrovlnného ohřevu se projevil ve zkrácení a zlepšení sušení. Dále byl sledován vliv mikrovlnného ohřevu na změny ve složení rozpustných sacharidů (sacharosa, rafinosa, stachyosa, verbaskosa), proteinů a aktivity trypsin inhibitoru. Naklíčený hrách byl použit k přípravě hrachových polévek, které byly senzoricky vyhodnoceny.

Klíčová slova: klíčení; mikrovlny; sušení; hrách; α-galaktooligosacharidy

Corresponding author:

Prof. Ing. PAVEL KADLEC, DrSc., Vysoká škola chemicko-technologická, Ústav chemie a technologie sacharidů, Technická 5, 166 28 Praha 6, Česká republika

tel.: + 420 2 33 33 70 70, fax: + 420 2 33 33 99 90, e-mail: pavel.kadlec@vscht.cz