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ESTIMATION OF DEGREE OF STARCH GELATINISATION IN INSTANT PASTA USING MEASUREMENTS OF VISCOSITY AND WATER ABSORPTION OF GROUND INSTANT PASTA DISPERSIONS

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A b s t r a c t. The study aimed at the determination of the possibility of estimating the degree of starch gelatinisation by measuring the physical properties of instant pasta. Therefore, pre-selected parameters such as dough moisture (33-35%), pre-drying temperature (35-55°C) and steaming time (120-360 s, temp. 95°C), which allowed to obtain instant pasta with varying degree of starch gelatinisation, were applied in this study. The physical properties of instant pasta with respect to solubility (WSI), water absorption (WAI), apparent viscosity of ground instant pasta dispersions and degree of starch gelatinisation (DG) were determined. The highest correlations were found between DG and WAI and between DG and viscosity ($p < 0.01$). The variability of DG can be explained in ca. 87% by the WAI ($R^2 = 0.87$) and in ca. 74% by the apparent viscosity of instant pasta dispersion ($R^2 = 0.74$). No significant correlation between DG and WSI was observed. It was demonstrated that the results obtained from the measurements of apparent viscosity of aqueous dispersion and WAI of instant pasta can be used for rapid estimation of DG.

K e y w o r d s: solubility, steaming, pasta dispersions

INTRODUCTION

Instant pasta and noodles have become increasingly popular not only due to their reasonable price and easy of preparation but also to their widely acceptable textural properties, taste and flavour. Instant noodles are commonly classified in the group of convenience foods which are designed to be cooked with minimum preparation in the kitchen (Cho *et al*. 2010, Kumoro *et al.* 2016).

Noodle quality is largely dependent on the physical and chemical changes of flour constituents during the processing and cooking process, such as gelatinisation of starch (DG) and denaturation of protein (Gatade and Sahoo 2015). One of the key processes in the manufacture of instant noodles is steaming. Steam temperature and pressure should guarantee high starch gelatinisation, which is required for the production of hot-air dried instant noodles (Fu 2008, Gat and Ananthanarayan 2015). The degree of cooking depends also on the original moisture content of the noodle and on steaming time (Fu 2008, Pronyk *et al.* 2008). A high degree of starch gelatinisation improves e.g. the water absorption capacity of noodles (Fu 2008). The gelatinisation of starch reduces the cooking loss (Gatade and Sahoo 2015). Low DG can lead to the perception of consuming raw or uncooked product, and to a mushy and soggy texture.

Since a high degree of starch gelatinisation is expected in instant noodles, the evaluation of DG is required during technological processing. The major drawback of some methods, especially the enzyme method used in DG determinations, is that they are time-consuming (Di Paola *et al.* 2003). Therefore, this drawback does not allow the inclusion of these methods in rapid quality control procedures during the manufacturing process. It seems that the measurement of other physical properties of instant pasta, such as apparent viscosity of pasta dispersion, or water absorption, could be a method allowing rapid determination of DG.

The present work attempts to determine the possibility of using viscosity measurements of pasta dispersion as a rapid method to determine the degree of starch gelatinisation. The effect of pre-drying and steaming treatment on the physical properties of instant pasta (WSI, WAI, % DG, apparent viscosity of pasta dispersions) and the matrix correlation between the instant pasta properties were determined. The steaming and pre-drying parameters were chosen to obtain instant pasta with varying degree of starch gelatinisation.

MATERIAL AND METHODS

The pasta was obtained through low-temperature extrusion. The process of production involved the use of only semolina (Assmannmühlen GES. M.B.H., Raasdorf, Austria, protein content 13.48% d.m., gluten 27.5%) and water. No addition of table salt or other substances improving the properties of the ready product was applied.

The process of production was conducted on the industrial scale, using a pasta press type MAC 400 (ITAL PAST, Italy, screw speed 41 rev/min, extrusion pressure 5.8-7.9 MPa). Dies allowing to obtain product with diameter of 3.3 mm and wall thickness of 0.6 mm were used. Extruder cylinder temperature was 32°C and head temperature was 30°C. After extrusion the pasta was subjected to preliminary drying in two successive tunnel type pre-driers (temp. 35-55°C). After the process of preliminary drying the pasta was subjected to steaming (steaming times of 120, 240 and 360 s, steaming temperature 95°C). After the process of steaming the pasta was subjected to short heating at 200°C (for 120 s) to evaporate water and to form a porous structure facilitating pasta rehydration. After the stage of steaming the pasta was subjected to final drying to achieve final moisture content of 10 ± 0.25% d.b. (drying temperature 65-35°C, relative air humidity 80-55%). In the produced pastas dry matter solubility index and the water absorption index were assayed (AACC, 56-20; with modifications), as well as the degree of starch gelatinisation (PN-A-79011-11) and the viscosity of water dispersions of ground pasta. The measurements were made in three replicates for each sample.

Water solubility index (WSI) and water absorption index (WAI). Samples of instant pasta of each treatment combination were ground with a laboratory mill (Perten Instruments, LM 120, sieve of 8 mm). Approximately 2 g of the instant pasta powder was suspended in 30 ml of distilled water (temp. 20°C), in a tarred 50 ml centrifuge tube, then stirred carefully and left for 15 min. Afterwards, the water-pasta suspensions were centrifuged (15 min; RCF 2200 g) in a laboratory centrifuge (MLW T24D, VEB MLW Medizintechnik, Germany). The supernatant (10 ml) was decanted into a weighing vessel and dried in a laboratory oven at 105°C until solid matter was obtained. The value of WSI was determined from the formula:

$$WSI = (W_{ds} \div W_{dm})\, 100\, (\%\, d.b.) \tag{1}$$

where: W_{ds} – dry matter of supernatant residue (g), and W_{dm} – dry matter of the original sample mass (g).

The WAI was calculated as the ratio of the remaining gel mass in the centrifuge tube to the dry matter of the original sample mass:

$$WAI = (W_{g} \div W_{dm})\, 100\, (\%\, d.b.) \tag{2}$$

where: W_g – gel weight (g), and W_{dm} – dry matter of the original sample mass (g).

Degree of starch gelatinisation (DG). The study involved the use of a method consisting in enzymatic hydrolysis of starch in samples subjected to complete gelatinisation and not gelatinised (PN-A-79011-11:1998). Next, the content of reducing sugars was assayed iodometrically. The degree of gelatinisation was determined as the percentage ratio of the content of reducing sugars in samples subjected to complete gelatinisation and not gelatinised, taking into account the reagent test.

Apparent viscosity measurements. The apparent viscosity of dispersions was determined using a rotary rheometer (Mettler-Toledo AG, Switzerland, software RSI Orchestrator version V6.5.8; share rate 1200 s^{-1}). Coaxial cylinders without the bottom cylinder guard were used as the measurement system. Dispersions (10% w/w; 300 ml) were prepared by mixing a specified amount of ground instant pasta with distilled water (50°C). The suspensions, in 350 ml beakers, were kept in a laboratory shaker (Elpin type 357, “Elpin Plus” s.c., Lubawa, Poland; 50°C; amplitude 3; frequency 200 rev min^{-1}). They were allowed to stabilise for 1 h. The beakers were covered to prevent evaporation during testing. During viscosity measurements, agitation was stopped and the cylinders (maintained at the temperature of measurement) were immersed in the dispersions.

The results were reported as means ± standard deviations of three replicates. Data were subjected to the appropriate ANOVA test, followed by Duncan test for means to determine significant differences (SAS software version 9.2). The coefficients of linear correlation (Pearson, $p \leq 0.05$) between the physical properties of instant pasta were also determined.

RESULTS AND DISCUSSION

Pastas of instant type should be characterised by a high degree of starch gelatinisation (DG). The DG values of the analysed pastas fell within the range from 45 to 74%, while WSI values were in the range of 6.83-9.35% d.b. One of the main factors affecting DG is dough moisture. Correct dough moisture should ensure a high degree of swelling of starch granules, thus increasing the degree of starch gelatinisation at the stage of steaming. The study confirmed data known from the literature, that is an increase of DG with increase of dough moisture (Tab. 1) was observed. Increase of dough moisture from 33 to 35% caused an increase of DG by 54, 50 and 25%, respectively, for steaming times of 120, 240 and 360 s. Increase of dough moisture can, therefore, significantly reduce the time of steaming of pasta. Pasta obtained from dough with low moisture was characterised by lower water absorption. Low water absorption can cause slower hydration of those products and a deterioration of culinary properties.

The parameters of preliminary drying had a significant effect on pasta properties. The range of the drying parameters, i.e. temperature and ventilation intensity, were selected so as to allow achieving stable shape of the extruded pasta, with simultaneous limitation to the minimum of water loss prior to the process of steaming that might have a detrimental effect on DG. The highest degree of starch gelatinisation was characteristic of pasta samples dried at the lowest temperatures (35/45°C). Depending on the time of steaming, the values of DG fell within the range of 69.6-74.7%. Relatively high dough moisture and low water loss during preliminary drying were conducive to more intensive gelatinisation of starch.

An extension of the time of steaming, irrespective of the remaining parameters, leads to an increase of starch gelatinisation and WAI. Products with high WAI are more efficient in satiating hunger and also give the feeling of satiety. Whereas, no significant effect of steaming time on WSI was observed. The obtained instant pastas were characterised by low values of WSI (6.83-9.35% d.b.). Low value of WSI is very important from the nutritional point of view. Products characterised by low WSI will undergo slow digestion (Brennan *et al.* 2012, Sobota *et al.* 2015). The highest increase of DG with extension of steaming time was noted at the lowest dough moisture level applied (33%). The extension of steaming time, in this case from 120 to 360 s, caused an increase of DG by 32%.

Table 1. Experimental design with values of independent and dependent variables of instant pasta

S. no.	Independent variables				Responses			
	Moisture of dough (%)	Drying temp. (°C) I	Drying temp. (°C) II	Time of steaming (s)	WSI (% d.b)	WAI (% d.b.)	% DG	Apparent viscosity (Pa s)
1	35	35	45	120	8.3 B ± 0.4	293 C ± 18	69.6 B ± 1.4	0.01 A ± 0.0008
2	35	35	45	240	8.08 CB ± 0.4	322 B ± 8	70.4 B ± 0.2	0.0102 A ± 0.0002
3	35	35	45	360	7.81 CB ± 0.4	344 A ± 6	74.4 A ± 0.1	0.0096 BA ± 0.0002
4	34	40	45	120	9.35 A ± 0.3	269 D ± 1	56.3 D ± 3.9	0.0093 BC ± 0.0003
5	34	40	45	240	9.21 A ± 0.8	283 DC ± 3	60.4 C ± 1.3	0.0086 DE ± 0.0003
6	34	40	45	360	9.33 A ± 0.2	310 B ± 11	61.5 C ± 0.2	0.0089 DC ± 0.0003
7	33	45	55	120	7.29 CD ± 0.2	238 E ± 3	45 E ± 0.1	0.0081 E ± 0.0001
8	33	45	55	240	6.83 D ± 0.3	244 E ± 2	46.7 E ± 0.5	0.0082 E ± 0.0002
9	33	45	55	360	7.45 CBD ± 0.5	273 D ± 8	59.4 DC ± 0.3	0.008 E ± 0.0003

Explanatory notes: WSI – water solubility index; WAI – water absorption index; % DG – degree of starch gelatinisation; I – temperature of pre-dryer No. 1; II – temperature of pre-dryer No. 2.; Apparent viscosity of 10% (w/w) instant pasta dispersion; Means in the same column with the same letters are not significantly different (Duncan; $p \leq 0.05$)

Increase of dough moisture caused a significant reduction of the effect of steaming time on DG. In the case of pasta produced from dough with moisture of 35% the extensiof steaming time from 120 to 360 s caused DG increase by only 7%. According to Hou *et al.* (2010), the temperature of steaming has a decisive effect on DG. According to those authors, steaming temperature above 98°C permits the obtainment of a product with gelatinisation degree of 80-85% during 2-3 min. Depending on dough moisture level applied, an increase of WAI within the range of 15-17% was observed with the extension of streaming time from 120 to 360 s. A slightly higher increase of WAI was observable in the case of application of dough with moisture of 35%.

Statistical analysof the results obtained indicated a high correlation (R = 0.93, Tab. 2) between water absorption (WAI) and the degree of starch gelatinisation. In this case the variability of DG can be explained in ca. 87% by the WAI ($R^2 = 0.87$; Fig 1). The observed correlations are in conformance with literature data presented for extruded products of snacks type (Ding *et al*., 2005, Gat and Ananthanarayan 2015). A significant correlation ($p < 0.01$) was also noted between DG and apparent viscosity of dispersions of ground pasta (R = 0.85, Tab. 2) The variability of DG can be explained in ca. 74% by the apparent viscosity ($R^2 = 0.74$; Fig. 2). The viscosity of the dispersions was also positively correlated with WAI (Tab. 2, Fig. 3). Whereas, no significant linear correlation was noted between DG and WSI, between WAI and WSI, and between WSI and viscosity of the dispersions (Tab. 2).

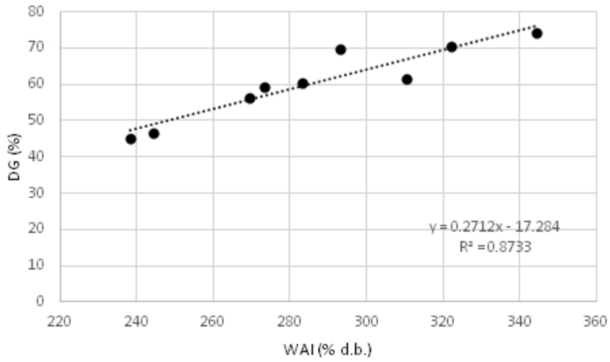

Fig 1. Correlation between water absorption index (WAI) and degree of starch gelatinisation (DG)

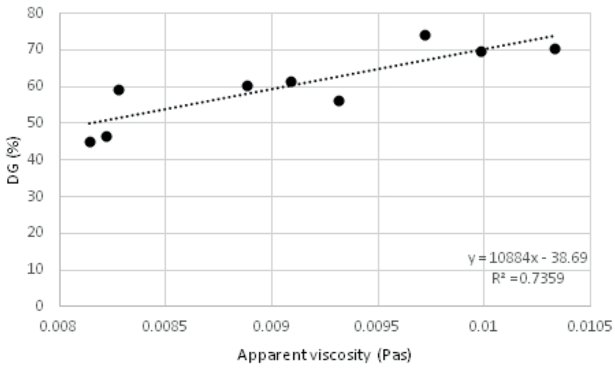

Fig 2. Correlation between apparent viscosity of pasta suspension (10% w/w) and degree of starch gelatinisation (DG)

Table 2. Correlations matrix among instant pasta properties

	% DG	WSI	WAI	Apparent viscosity
% DG	1.00000	0.00048; p = 0.9990	0.93452**; p = 0.0002	0.85784**, p = 0.0031
WSI		1.00000	–0.03588; p = 0.9270	–0.10425; p = 0.7895
WAI			1.00000	0.78592*; p = 0.0120
Apparent viscosity				1.00000

Explanatory notes: WSI – water solubility index; WAI – water absorption index; % DG – degree of starch gelatinization; Apparent viscosity of 10% (w/w) instant pasta dispersion; *Correlation coefficient statistically significant at $p \le 0.05$; **Correlation coefficient statistically significant at $p \le 0.05$.

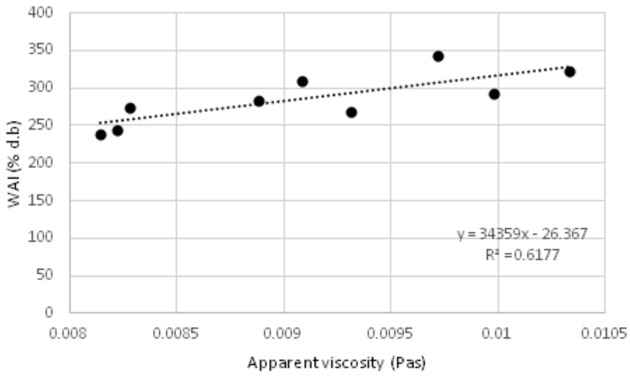

Fig 3. Correlation between apparent viscosity of pasta suspension (10% w/w) and water absorption index (WAI)

CONCLUSION

The results obtained indicate a possibility of rapid estimation of changes in the degree of starch gelatinisation in instant pastas on the baof measurement of the WAI and viscosity of dispersions.

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OKREŚLENIE STOPNIA SKLEIKOWANIA SKROBI W MAKARONACH BŁYSKAWICZNYCH NA PODSTAWIE POMIARÓW LEPKOŚCI I WODOCHŁONNOŚCI WODNYCH DYSPERSJI ROZDROBNIONYCH MAKARONÓW

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S t r e s z c z e n i e. Celem przeprowadzonych badań była ocena możliwości określenia stopnia skleikowania skrobi w makaronach typu instant na podstawie pomiarów właściwości fizycznych tych makaronów. Badania pilotażowe pozwoliły na określenie zastosowanych parametrów produkcji tj. wilgotności ciasta (33-35%), temperatury wstępnego suszenia (35-55°C) oraz czasu parowania (120-360 s, temp. 95°C). Parametry te pozwoliły na uzyskanie makaronów błyskawicznych o zróżnicowanym stopniu skleikowania skrobi. W badaniach określono takie właściwości fizyczne makaronów błyskawicznych jak rozpuszczalność (WSI), wodochłonność (WAI), lepkość pozorną dyspersji próbek rozdrobnionego makaronu oraz stopień skleikowania skrobi (DG). Na podstawie uzyskanych wyników stwierdzono, że najwyższe wartości współczynników korelacji występują pomiędzy DG a WSI oraz DG a lepkością ($p < 0,01$). Zmienność DG może być wyjaśniona w około 87% przez WAI ($R^2 = 0,87$) i w około 74% za pomocą lepkości pozornej dyspersji rozdrobnionych makaronów ($R^2 = 0,74$). Nie odnotowano istotnej korelacji pomiędzy DG a WSI. Wykazano, że pomiary lepkości pozornej wodnych dyspersji oraz WAI makaronów błyskawicznych mogą być wykorzystane do szybkiej oceny stopnia skleikowania skrobi w tych produktach.

S ł o w a k l u c z o w e: rozpuszczalność, parowanie makaronu, dyspersje makaronu