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# EFFECT OF VACUUM TREATMENT ON STRENGTH CHARACTERISTICS OF MAIZE KERNEL PREVIOUSLY SUBJECTED TO HYDRO-THERMAL PROCESSING

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Key words. maize kernel, hydro-thermal treatment, vacuum pressure, destructive force and energy, moisture content, horizontal projection area

The effects of applied hydro-thermal treatment of maize kernels and following it vacuum pressure on changes in seed moisture content (dry basis), destructive force, energy to destroy a single kernel, and changes in horizontal projection area of a single kernel, were determined in the studies. Dent maize kernels, used as an experimental material, were subjected to hydro-thermal processing (boiling for 20 and 30 min at a temperature of 100°C), and next to the treatment in vacuum pressure (20 kPa) for 1, 3 and 5 min. In the whole range of applied vacuum pressure treatment durations the higher values of destructive force and energy were observed for the kernel hydro-thermally treated for over 20 min, in comparison to those treated for over 30 min.

## INTRODUCTION

Vacuum treatment is widely used in different branches of the food processing industry, *e.g.* to production of the feed mixtures of high fat content, at packaging of food products for longer storage, in drying and other food processing technologies [Białobrzewski & Misiak, 1997; Chiralt *et al*., 2001; Klimczak & Irzyniec, 1999; McArdle *et al*., 1974; McDonald & Da-Wen Sun, 2000; Zapotoczny & Markowski, 1999].

The quick pressure changes result in temporary deformation of pores in the structure of majority of food products. Such deformation is affected by the rate of pressure drop and increase. Time of changing pressure from vacuum to atmospheric is of special importance as the closing of capillary vessels in plant material and inhibition of hydrodynamic mechanism may occur [Fito *et al*., 1996; Salvatori *et al*., 1998].

## MATERIAL AND METHODS

The studies were carried out to determine the effect of vacuum pressure and its duration, applied after preliminary hydro-thermal processing (boiling), on the strength characteristics of maize kernel thermally treated over various time intervals.

The effects of the applied hydro-thermal treatment and subsequent vacuum pressure on changes in maize seed moisture content (dry basis), destructive force and energy as well as changes in horizontal projection area for single kernel, were determined.

Dent maize kernels, used as the experimental material, were hydro-thermally treated (boiling over 20 and 30 min at 100°C) and next subjected to vacuum pressure (20 kPa) for 1, 3 and 5 min, on the experimental stand presented Figure 1. Before and after processing of seed samples the moisture content (d.b.), changes in destructive force and energy as well as the horizontal projection area of single seed, were determined.

Samples for vacuum treatment were put into perforated plastic container (7) placed in basic tank (3). After putting the sample and closing the basic tank, the ball valves (4, 11) were closed. Then the vacuum pump (1) was activated to generate vacuum pressure in the main tank (2). Sensor of the pressure (5) installed on the console enabled continuous control of vacuum pressure in the system. Next, after required vacuum level had been obtained and stopping vacuum pump (1), the ball valve between main (2) and basic (3) tanks was opened to equalize the pressure.

Moisture content was determined using the oven method at a temperature of 130°C, according to Polish Standard [PN--ISO 712/2002].

Strength parameters of the kernels were measured in an Instron 4302 apparatus using compression test, at 50 mm/min rate. The changes in destructive force and energy as affected by vacuum treatment were determined.

Horizontal projection area for processed kernel was measured on the SVIST stand for computer image analysis [SVIST, 1992], (Figure 2). All the measurements were done in ten replications.

## RESULTS AND DISCUSSION

Figure 3 presents the investigation results concerning kernels processed hydro-thermally over 20 and 30 min, and next subjected to vacuum pressure treatment at the pressure of 20 kPa.

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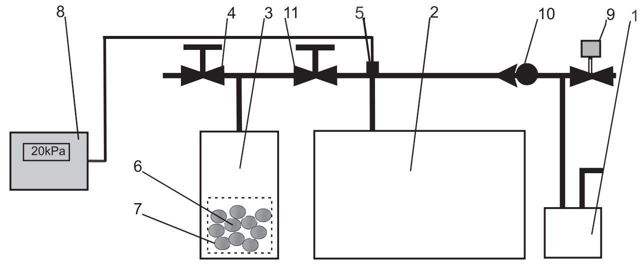


FIGURE 1. Schematic diagram of the experimental stand: 1 – vacuum pump, 2 – main tank, 3 – basic tank, 4 – ball valve, 5 – sensor of the pressure, 6 – sample treated by vacuum pressure, 7 – mesh preventing the sample ingestion, 8 – vacuum pressure gauge, 9 – electro valve, 10 – check valve, 11 – valve.

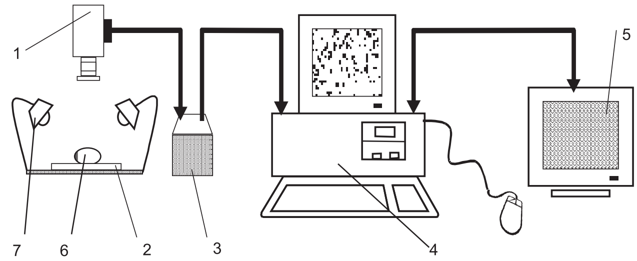


FIGURE 2. Scheme of the SVIST system for computer image analysis: 1 – digital camera, 2 – subject table, 3 – converter, 4 – personal computer, 5 – screen, 6 – sample, 7 – source of light.

Application of 20 min hydro-thermal treatment resulted in almost four-fold increase of moisture content (d.b.) in the samples, while in the samples treated for over 30 min – more than four-fold increase of that value.

In maize samples boiled for 20 min and subjected to 20 kPa pressure, the moisture content (d.b.) decreased by 0.04 kg/kg d.m. in relation to the material not treated with vacuum pressure, achieving the level of 0.384 kg/kg d.m. (after 5-min vacuum pressure treatment).

In the case of samples boiled for 30 min after analogous vacuum pressure treatment, that value decreased – likewise as at 20 min hydro-thermal treatment – by 0.04 kg/kg d.m., achieving the level of 0.43 kg/kg d.m. (after 5-min vacuum pressure treatment).

Figure 4 illustrates the changes in destructive force for maize kernels hydro-thermally treated for 20 and 30 min and subjected to vacuum pressure of 20 kPa.

Application of 20 min hydro-thermal treatment reduced the value of destructive force by over 65%. As a result of hydro-thermal treatment prolonged from 20 to 30 min the destructive force was reduced by about 75%.

In seed samples boiled for over 20 min, after 1-min vacuum pressure treatment an increase of destructive force by about 55 N was observed; its maximum value reached 280 N. Further prolongation of the vacuum pressure treatment reduced gradually destructive force down to 244 N (after 5-min treatment).

In the case of 30 min hydro-thermal processing of maize seeds the application of vacuum pressure gradually increased destructive force from 170 N (for boiled material without vacuum pressure treatment) to 212 N (5-min vacuum pressure treatment).

The changes in destructive energy for maize seeds hydro-thermally processed for over 20 and 30 min, and vacuum pressure treated at 20 kPa, are presented in Figure 5.

The applied 20-min hydro-thermal processing increased the energy necessary to destroy the single seeds, from 0.138 J to 0.178 J; in the case of 30-min hydro-thermal processing no changes of energy value were observed.

In the case of maize seeds boiled for 20 min, prolonged duration of vacuum treatment up to 3 min, increased destructive energy to the maximum value of 0.212 J; further vacuum treatment prolongation reduced that value to the level of 0.162 J.

The seeds boiled for 30 min, as the vacuum treatment duration increased, showed a rise of energy necessary to destroy the seeds from 0.130 J (for material not subjected to vacuum pressure) to 0.165 J (for material kept under vacuum pressure for 5 min).

Figure 6 illustrates the changes in horizontal projection area of the maize seeds (as a result of swelling), subjected to 20 and 30 min hydro-thermal processing and vacuum pressure treatment at 20 kPa.

The applied hydro-thermal processing decreased the horizontal projection area for single maize seeds, in the case of 20 min duration by 1.3 $mm^2$, whereas for 30 min duration by 3.4 $mm^2$ on average.

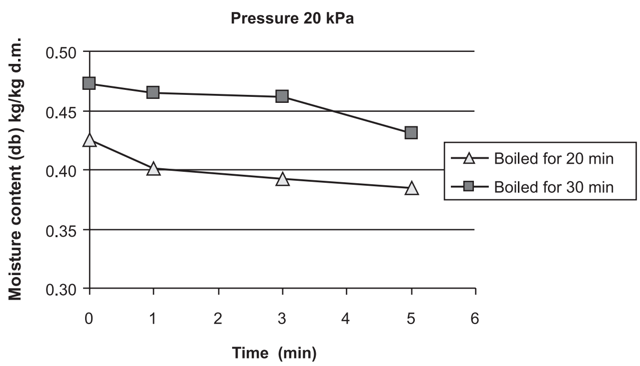


FIGURE. 3. Changes in the moisture content (dry basis) of raw materials subjected to 20 and 30 min hydro-thermal treatment and next to the vacuum pressure of 20 kPa.

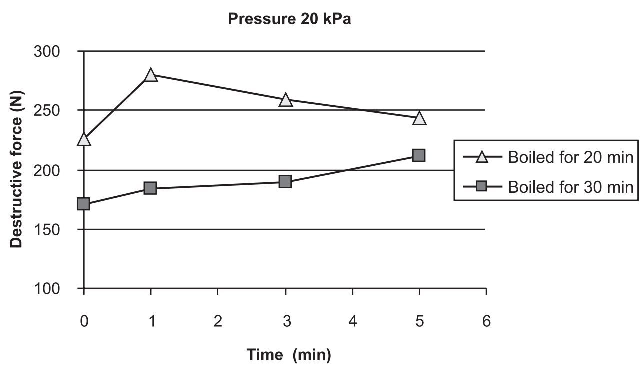


FIGURE. 4. Changes of destructive force for maize seed samples subjected to 20 and 30 min hydro-thermal treatment and vacuum pressure of 20 kPa.

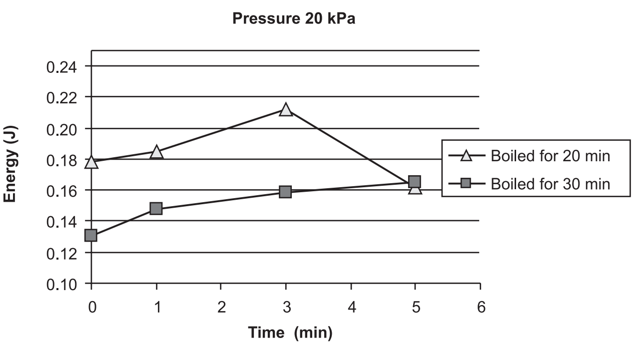


FIGURE. 5. Changes of destructive energy for maize seeds after 20 and 30 min hydro-thermal processing, subjected to vacuum pressure 20 kPa.

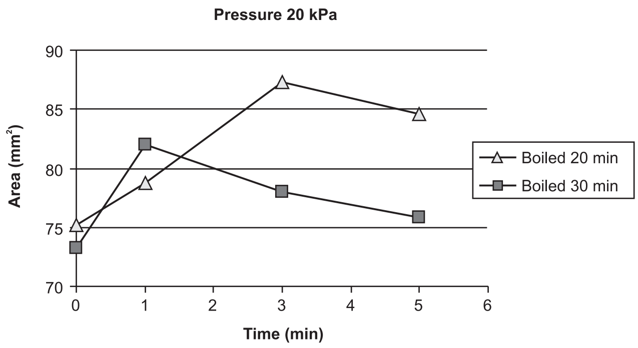


FIGURE. 6. Changes in horizontal projection area for maize seeds in samples hydro-thermally treated for 20 and 30 min and subjected to 20 kPa vacuum pressure.

For maize seeds boiled for 20 min, the vacuum pressure duration extended to 3 min increased the horizontal projection area of single seeds to the maximum value of 87.35 $mm^2$; further prolongation of vacuum pressure treatment reduced that value to the level of 75.13 $mm^2$.

The maize seeds boiled for 30 min showed the maximum value of horizontal projection area for single seeds after 1-min vacuum pressure treatment (reaching above double increase in relation to the material not subjected to vacuum pressure). Further prolongation of vacuum treatment gradually decreased that value to the level of 75.6 $mm^2$ (for material kept under pressure for over 5 min).

TABLE 1. Regression equation and determination coefficient $R^2$ describing moisture content (dry basis) variability in maize seeds boiled and vacuum pressure treated for 1, 3 and 5 min (τ- time of treatment).

| Treatment | Regression equation | $R^2$ |
|---|---|---|
| Boiled 20 min, pressure 20 kPa | $u = -0.007\tau + 0.42$ | 0.84 |
| Boiled 30 min, pressure 20 kPa | $u = -0.008\tau + 0.47$ | 0.86 |

TABLE 2. Regression equations and determination coefficients $R^2$ describing variability of destructive force for maize seeds boiled and vacuum pressure treated over (τ- time of treatment).

| Treatment | Regression equation | $R^2$ |
|---|---|---|
| Boiled 20 min, pressure 20 kPa | $F = -15.63\tau2 + 28.79\tau + 236.49$ | 0.74 |
| Boiled 30 min, pressure 20 kPa | $F = 7.51\tau + 171.95$ | 0.94 |

TABLE 3. Regression equations and determination coefficients $R^2$ describing variability of destructive energy for maize seeds boiled and vacuum pressure treated over 1, 3 and 5 min (τ- time of treatment).

| Treatment | Regression equation | $R^2$ |
|---|---|---|
| Boiled 20 min, pressure 20 kPa | $E = -0.006\tau2 + 0.029\tau + 0.17$ | 0.83 |
| Boiled 30 min, pressure 20 kPa | $E = 0.002\tau2 + 0.014\tau + 0.132$ | 0.97 |

TABLE 4. Regression equations and determination coefficients $R^2$ describing variability of horizontal projection area for maize seeds boiled and vacuum pressure treated over 1, 3 and 5 min (τ- time of treatment).

| Treatment | Regression equation | $R^2$ |
|---|---|---|
| Boiled 20 min, pressure 20 kPa | $P = -0.938\tau2 + 6.79\tau + 74.41$ | 0.96 |
| Boiled 30 min, pressure 20 kPa | $P = -0.872\tau2 + 4.37\tau + 75.05$ | 0.69 |

On the basis of investigation results the regression equations were derived and the determination coefficients were appointed, as presented in Tables 1 – 4.

High value of determination coefficient for all derived equations indicated very good fitting of the equations to the results obtained.

## CONCLUSIONS

1. Prolongation of vacuum pressure (20 kPa) treatment within the range of 1 – 5 min resulted in drop of maize seed moisture content (dry basis) for both applied durations of the previous hydro-thermal treatment.
2. Maize seeds boiled for over 20 min within the tested range showed the maximum value of destructive force after 1-min vacuum pressure treatment.
3. Maximum destructive energy was found for seed samples hydro-thermally treated for over 20 min and subjected to vacuum pressure for 3 min.
4. Within the whole range of vacuum pressure (20 kPa) durations higher values of destructive forces and energy were observed for maize seeds hydro-thermally treated for over 20 min, as compared to those treated for over 30 min.

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## WPŁYW OBRÓBKI PODCIŚNIENIOWEJ NA WŁAŚCIWOŚCI WYTRZYMAŁOŚCIOWE NASION KUKURYDZY PODDANYCH OBRÓBCE HYDROTERMICZNEJ

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W pracy określono wpływ zastosowanej obróbki hydrotermicznej i następującym po nim oddziaływaniu podciśnienia na zmiany zawartości wody, siły niszczącej, energii koniecznej do zniszczenia pojedynczych ziaren, oraz zmian pola powierzchni rzutu poziomego pojedynczych ziaren. Materiałem wykorzystanym do badań była kukurydza paszowa. Materiał badawczy został poddany obróbce hydrotermicznej (gotowanie przez 20 i 30 minut w temperaturze 100°C) i następnie poddana oddziaływaniu obniżonego ciśnienia (20 kPa) przez 1, 3 i 5 minut. W całym zakresie stosowanych czasów oddziaływania podciśnienia 20 kPa zaobserwowano wyższe wartości sił niszczących i energii niszczącej dla surowca obrabianego hydrotermicznie 20 minut w stosunku do obrabianego 30 minut.