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CHANGES OF SELECTED PHYSICAL PROPERTIES AT WHEAT GRAIN DUE TO THERMAL PROCESSING USING INFRA-RED RADIATION

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Key words: moisture content, physical properties, compression strength, wheat grains

The paper addresses the influence of infra-red radiation on moisture content and compressing force of wheat grain (Zawisza cv.). The decrease was observed in moisture content of wheat grains subjected to IR radiation processing. The dependence was described using first-order regression equations. Grain's exposure to IR resulted in a decrease of compressing force recorded directly after heating. After 48 h, values of the measured forces increased considerably and sometimes were higher than those recorded for grains that were not processed with IR.

INTRODUCTION

Nutritional value of raw materials is not constant, but it may vary for various reasons. These changes may lead to deterioration of material quality, *e.g.* due to long-term storage, and even to the loss of nutritional usefulness (*e.g.* due to moulding as a result of storage under elevated humidity conditions), on the other hand, there is an opportunity to apply some procedures that may largely improve the nutritional value. Nevertheless, among plant-originated materials, there are such ones that, besides valuable components, contain different chemicals defined as anti-nutritional agents. The nutritional value and usefulness of some raw materials may be modified due to special processing. There are many processing methods that improve materials, *e.g.* biological-biochemical, chemical, and physical ones, including thermal processes.

Thermal processes lead to the reduction of anti-nutritional agents that can be decomposed due to high temperatures (thermo-labile), including inhibitors of enzymes that decompose proteins. Decrease of a microbial pollution level is another apparent effect of their action. As a result of thermal processes, also physical and chemical changes take place in processed material; which results in the increase of digestibility level of a final product.

Among currently used thermal processes, those using electromagnetic waves find their wide application. Knowledge on their specific interaction to biological materials may contribute to the improvement of known or elaboration of new technologies for processing a wider and wider spectrum of plant-originated materials.

Therefore, the study was aimed at evaluating the influence of thermal processing parameters in the form of IR radiation on selected physical properties (moisture content and compressing strength) at wheat grains.

MATERIAL AND METHODS

Study material. The study object consisted of wheat grains of Zawisza *cv.* A cultivar-uniform material originated from 2006 harvest. Grain moisture content was *ca*. 10.1%. Its general physical properties are given in Table 1.

Study procedure. Raw material of 10.1% moisture content was heated (single layer) using IR radiation at various temperatures (100, 150, and 180°C) and for different periods (30, 60, 90, 120, and 150 sec). Directly after processing, grain moisture content (accordingly to AACC Method 44-15A [AACC, 1975]) as well as compressing strength were measured. Furthermore, compressing tests were performed using grains previously IR-processed and seasoned for 48 h at ambient conditions (temperature of *ca*. 20°C).

Selection of IR radiator. Ceramic IR radiator (ECS-1 type) of 400 W power was selected as a source of IR radiation (Elcer). It is a temperature radiator supplied by electricity (230 V), and having in its spectrum the share of visible radiation at the level of small fraction (dark radiator), and

TABLE 1. General physical properties of wheat grains (Zawisza cv.).

Moisture content (%)	Bulk density (kg/m^3)	Shaken density (kg/m^3)	Weight of 1000 seeds (g)	Angle of repose (°)
10.1	748.7	797.2	37.5	24.0

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uniformly warming all plane points (plane radiator). Average temperature of filament surface is about 500°C, and wavelength λ=2.5-3.0 μm.

Compressing test upon single grains. Most often, studies on the strength of single grains are based on compressing them between two parallel plates. However, there are two study directions: the first refers to applying loads till durable deformation or sample damage, *i.e.* the exceeding of elasticity limit of a given material takes place [Gąska & Kolowca, 1978].

Rheological model is another study direction. There is no elasticity limit exceeding in it. These studies are involved in phenomena occurring in biological materials subjected to loads at their plasticity limit and after removal of those loads [Haman, 1978]. In the reported experiments we accepted the first study model.

The a method used consisted in application of the axial compressing test for single wheat grains between parallel plates in a strength device (Instron 4302). During testing, velocity of the working plate was constant and amounted to 10 mm/min. Single grains were placed on a stationary plate and then compressed using the moving one. The axis of pressing force passed along the grain's transverse section diameter. Measurements were made till the grain's break and registering the compressing force F, at which it happened. Arithmetic mean from 10 replications was accepted as a final result.

RESULTS AND DISCUSSION

Fast reduction of moisture content, *i.e.* drying, is a result of thermal processing using IR [Grochowicz, 1997]. It changes physical and chemical properties of final products, which is important during transport, storage, breaking, dehulling, agglomerating, *etc.* [Andrejko, 1995]. Thus, studies upon the influence of thermal interaction of IR radiation on wheat grain moisture content were carried out. Figures 1-3 present changes in moisture content at wheat grains subjected to IR processing. The achieved results indicate that IR warming of a single grain layer made material dry, which was the more intensive, the higher was the processing temperature

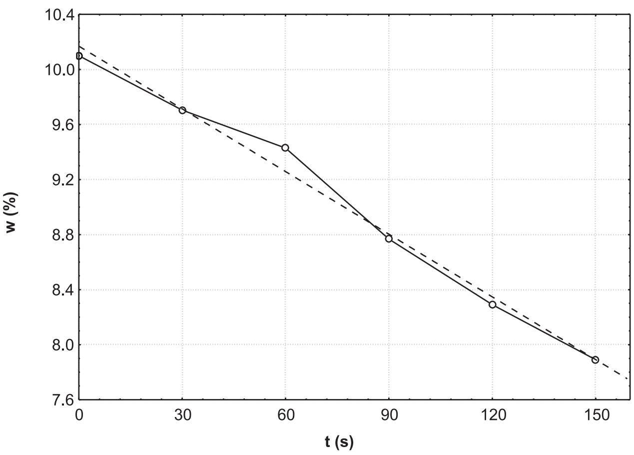

FIGURE 2. Influence of heating duration (t) using IR radiation on moisture content (w) at wheat grains (temperature – 150°C, initial moisture content – about 10.1%).

and longer the time. Exposure of grain to IR action at 100°C caused a relatively slight decrease of moisture content, which amounted to *ca*. 13.3% after 150 sec in relation to initial moisture. an increase of temperature to 180°C was the reason of more intensive grain drying. Under such conditions (180°C, 150 sec) wheat grain moisture content decreased by *ca*. 31.1% as compared to grain before heating.

The above described moisture changes due to thermal operation of IR radiation at wheat grain were presented in mathematical form as first-order regression equations (Table 2). Values of determination coefficients (R^2) near one prove good fitting the mathematical model to experimental data.

Besides factors associated with heating process parameters (temperature and duration), permeability of seed cover, that depends on their structure and physical properties, determines the amount of water evaporated. The increase of moisture content at seed cover, which leads to their thickening [Andrejko, 1995], may cause the decrease of the intensity of mass exchange between raw material and surroundings. Haghighi & Segerlind [1988a, b] as well as Tang & Sokhansanj [1993a, b] also reported on the role of seed cover as a barrier for moisture loss during thermal process-

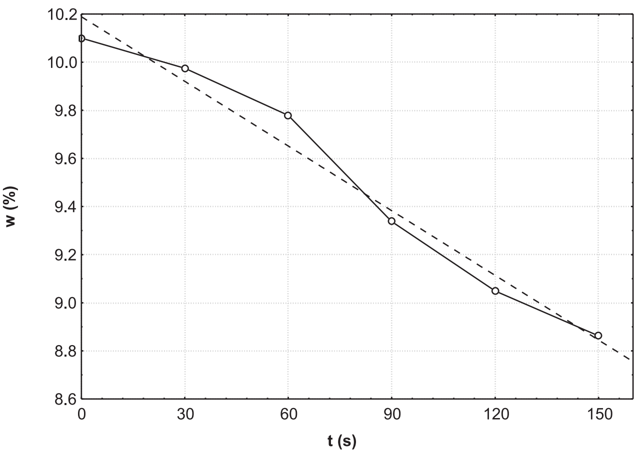

FIGURE 1. Influence of heating duration (t) using IR radiation on moisture content (w) at wheat grains (temperature – 100°C, initial moisture content – about 10.1%).

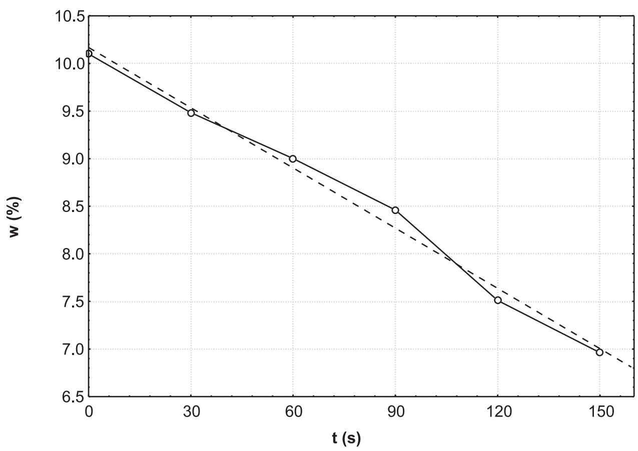

FIGURE 3. Influence of heating duration (t) using IR radiation on moisture content (w) at wheat grains (temperature – 180°C, initial moisture content – about 10.1%).

TABLE 2. Regression equations describing changes of moisture content (w) at wheat grains depending on IR heating duration (t).

Heating temperature (°C)	Regression equation	R^2
100	$w = -0.009 \cdot t + 10.189$	0.9741
150	$w = -0.0152 \cdot t + 10.169$	0.9895
180	$w = -0.0211 \cdot t + 10.168$	0.9899

es. Also grain dimensions, *i.e.* evaporation specific surface area, are important in phenomena associated with the drying processes. Water is evaporated faster from smaller grains than larger ones [Andrejko, 2005].

Resistance of plant-originated materials to compressing due to outer loads plays a major role in many technological processes. Therefore, attempts to determine the changes of mechanical resistance at wheat grains during their compressing as a result of thermal IR processing were undertaken. Data presented in Figures 4-6 indicate that thermal IR action to wheat grains caused a decrease of compressing force (measured directly after heating), which contributed to destruction of a single grain, as compared to not treated grains – values of compressing force for a single wheat grain with 10.1% of initial moisture content and previously not heated amounted to 0.3174 kN. No univocal dependence was observed between recorded compressing force value and temperature and heating duration.

The achieved dependencies are not characteristic for only one type of raw material (wheat grains). Earlier studies [Andrejko & Rydzak, 2000; Andrejko & Grochowicz, 2001] revealed that values of compressing force that damaged the white lupine grains (Wat *cv.*), as well as rye grains (Warko *cv.*) decreased after IR processing. Similar conclusions were drawn by Fasina *et al.* [2001]. After IR treatment of beans, peas, and lentils grains, they found a decrease of forces damaging the grain structure, but those values were different for particular materials, although processed under the same conditions.

The present study revealed that values of measured forces changed depending on the moment the recording had been begun, *i.e.* different values were achieved directly after the start and completing the IR heating. Results from these measurements are presented in Figures 4-6. Regardless the applied experimental factors (duration and temperature), the increase of force value was observed after 48-h seasoning as compared to that measured directly after the processing. Forces were similar to those recorded in the compressing test of grains that were not thermally processed, and even exceeded them. It should be stated that wheat grain resistance to compressing forces action recorded directly after IR treatment was apparently lower as compared to that at non-processed grain. It is an advantageous effect from the point of view of energetic input required for pelleting hot wheat grains.

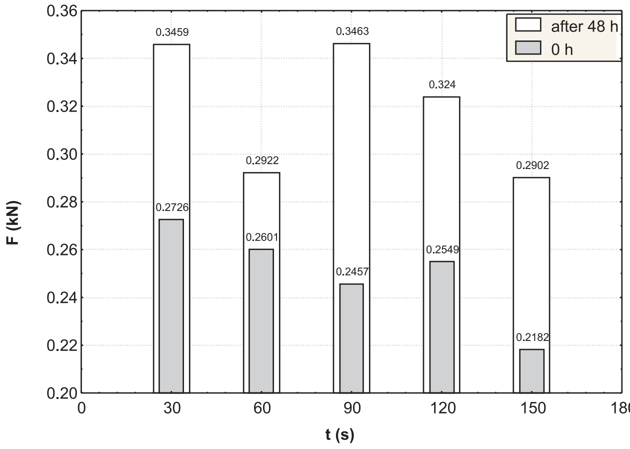

FIGURE 5. Influence of IR heating duration (t) on compressing force value (F) for a single wheat grain (measurements directly after heating – 0 h and 48 h, temperature – 150°C, initial moisture content – about 10.1%.

CONCLUSIONS

1. Temperature and duration the wheat grains are exposed in IR radiation are factors that significantly affect the amount of evaporated water. Increasing the temperature from 100 to 180°C and elongating the heating time from 30 to 150 sec

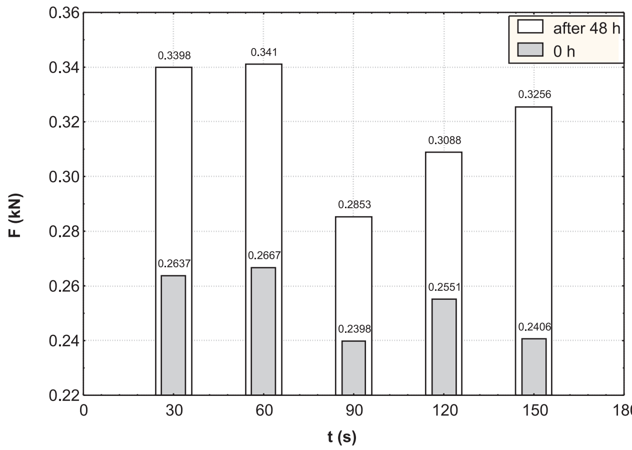

FIGURE 4. Influence of IR heating duration (t) on compressing force value (F) for a single wheat grain (measurements directly after heating – 0 h and 48 h, temperature – 100°C, initial moisture content – about 10.1%.

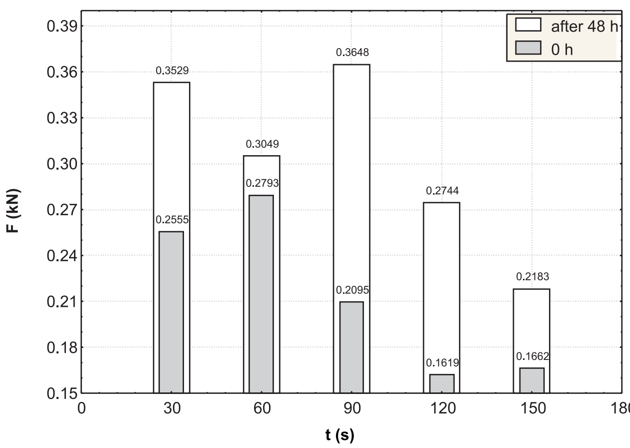

FIGURE 6. Influence of IR heating duration (t) on compressing force value (F) for a single wheat grain (measurements directly after heating – 0 h and 48 h, temperature – 180°C, initial moisture content – about 10.1%.

evoked an increase of evaporate moisture (about 31.1% in relation to initial moisture content at grains).

2. Dependencies of wheat grain moisture content on heating duration are quite well described by first-order regression equations.

3. Wheat grains subjected to IR processing are characterised by lower resistance to compression.

4. Seasoning of thermally-treated grains is the reason of their intensive drying, which in consequence leads to the increase of their resistance to compression.

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ZMIANY WYBRANYCH WŁAŚCIWOŚCI FIZYCZNYCH ZIARNA PSZENICY POD WPŁYWYM CIEPLNEGO ODDZIAŁYWANIA PROMIENIOWANIA PODCZERWONEGO

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W pracy zaprezentowano wpływ cieplnego oddziaływania promieni podczerwonych na wilgotność i siłę ściskającą ziarna pszenicy odmiany Zawisza. Na podstawie uzyskanych wyników stwierdzono spadek wilgotności ziaren pszenicy poddanych obróbce promieniami podczerwonymi. Zależności te opisano równaniami regresji pierwszego stopnia. Ekspozycja ziaren na działanie promieniowania podczerwonego była przyczyną zmniejszenia wartości siły ściskającej rejestrowanej bezpośrednio po ogrzewaniu. Po 48 godzinach wartości mierzonych sił znacznie wzrastały i niejednokrotnie były wyższe od wartości uzyskanych dla ziaren wstępnie nieogrzanych.