DEVELOPMENT OF TECHNOLOGICAL PARAMETERS FOR THE HYDROTERMAL PROCESSING OF SPROUTED WHEAT GRAIN POWDER

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Abstract: The present work is devoted to the development of technological parameters for the hydrothermal processing of powdered sprouted wheat and justification of use of the powder produced as a food additive. Introduction of sprouts into the diet stimulates metabolism and hematopoiesis, boosts immunity, compensates for vitamin and mineral deficiency, normalizes the acid-alkaline balance, promotes the elimination of toxins from the body, stimulates digestion, and slows the aging process. The use of sprouted wheat grains in public catering is very limited due to the short shelf-life of this product. Storage of dried grains provides a solution for this problem; however, it necessitates the development of a technology for the use of dried sprouted wheat grain. The present study was a part of research on the powder produced from sprouted wheat and centered on the process of hydrothermal treatment of dry sprouted wheat powder. Conventional methods were used in the present work for the analysis of physical and chemical parameters. A range of factors, including the protein content of the powder, the degree of mechanical damage of the starch granules, and the pH value of the solution, affects the water absorption capacity of the powder produced from sprouted wheat. Treatment time, temperature, and mash ratio at pH 4.5 and pH 7.0 were varied in experiments performed to determine the optimum operating parameters of the hydrothermal processing. As a result of the study, an energy-efficient technology has been developed for the hydrothermal processing of powdered sprouted wheat grains. The following process parameters were selected: an optimum swelling temperature of 45°C, hydrothermal treatment duration of 60 min at pH 4.5, and an optimum mash ratio of 1:1.25.

Keywords: technological parameters of hydrothermal processing, powdered germinated wheat grains, the degree of powder swelling

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INTRODUCTION

Dormant plant seeds are used as the raw material to prepare a large variety of foods. Sprouted wheat grains are known as a natural organic food, containing a broad range of nutrients in balanced natural amounts and combinations. Introduction of sprouts into the diet stimulates metabolism and hematopoiesis, boosts immunity, compensates for vitamin and mineral deficiency, normalizes the acid-alkaline balance, promotes the elimination of toxins from the body, stimulates digestion, and slows the aging process. Grains with sprouts shorter than 5 mm contain a sufficient amount of antioxidants, which decelerate or prevent oxidative processes when used in low concentrations. Furthermore, enzyme systems of the grain are activated during germination, and complex nutrients are cleaved into smaller molecules easily digestible by the human organism. The use of sprouted wheat grains in public catering is very limited due to the short shelf-life of this product. Storage of dried grains provides a solution for this problem; however, it necessitates the development of a technology for the use of dried germinated wheat. The aim of the present work was to develop technological parameters for the hydrothermal processing of powder produced from sprouted wheat grains.

OBJECTS AND METHODS OF RESEARCH

The powder produced by grinding dried sprouted wheat grains (Technical Specification (TU) 9290-002-50765127-03, OOO SibTar, Novosibirsk) in a Robot Coupe R4 cutter (ROBOT COUPE) was the object of investigation in the present work. The powder had a beige color and a typical smell of wheat flour; particles of 250–300 μm in size constituted 80 ± 0.05% of the powder, and the size of the rest of the particles ranged from 300 to 450 μm; the solids content of the powder was 96.5 ± 0.05%.

Conventional methods were used for the analysis of the physical and chemical characteristics, namely, the content of dry matter was assayed according to GOST (State Standard) R 50189-92 using a moisture analyzer ELVIZ-2C, and active acidity was assayed using a multichannel ion meter Ekspert-001 (3.0.4). The degree and rate of swelling of the sprouted wheat powder were determined according to the procedure developed at the Belarusian branch of VNIMI (All-Union Research Institute of Dairy Industry): namely, 1 g of dry powder obtained from sprouted wheat was placed into a centrifuge tube, and water was added to a ratio of 1:1–1:2. The mixture was incubated in a steamer (Stlf Cooking Center 61) for 60 min at a temperature of 25±1, 45±1, 65±1, or 85±1 °C. The samples were then centrifuged for 5 min at 1000 rpm, the supernatant was decanted, and the moisture content of the residue was measured.

The degree of swelling of the samples was determined according to the formula (1):

$$A = (m - m_0)100/m_0 , \quad (1)$$

where A is the degree of swelling, %; m is powder weight after hydration, g; m_0 is the weight of dry powder, g.

The mass of the powder after swelling was determined according to the formula (2):

$$m = m_0(100 - B)/(100 - B_1) , \quad (2)$$

where m is mass of the powder after swelling, g; B is the moisture content of dry powder, mass. %; B_1 is the moisture content of hydrated powder, mass. %.

The optimal amount of water required for the swelling of sprouted wheat powder (mash ratio) was determined.

Statistical analysis of the results was performed using nonparametric tests implemented in the software package Statistica 6.0. The difference between values was considered to be significant at a confidence level of 95% ($p < 0.05$), both for the comparison of mean values between two samples and for multiple comparison of means.

RESULTS AND DISCUSSION

The capacity of powdered sprouted wheat to absorb water is an important factor for further industrial use as an additive in foodstuffs, for example, in minced meat and fish. High water absorbing capacity of the powder is a positive feature, since it allows for an increase of the final product yield. A range of factors, the content of protein being the most important of them, affect the water absorption capacity of the powder obtained from sprouted wheat grains. The contact of powder particles with water leads to osmotic binding of the latter; free interstitial protein is the first to bind water, followed by protein surrounding individual starch granules and protein present on large powder particles, that is, intact cells or cell groups of the endosperm [1–3].

The swelling of starch granules depends on the temperature and the degree of mechanical damage to the granules. Binding of water by intact starch grains mainly occurs through adsorption, and therefore the volume of the grains increases only slightly (up to 44% of water can be bound through adsorption). Grinding of the seeds into powder causes disruption of 15–20% of starch grains. The amount of water absorbed by such grains can be as high as 200% of their dry weight [4–6].

Swelling of colloids occurs in two stages. First, water molecules are adsorbed on the surface of the powder particles due to the presence of active and hydrophilic groups in colloids. The hydration process is accompanied by heat release. Thermal motion of the flexible side chains of the proteins enabled by loose packing of protein and starch macromolecules results in the formation of small gaps into which the water molecules penetrate, giving rise to the second stage of swelling, namely, osmotic water binding. The amount of water bound by proteins is approximately twice higher than the weight of the proteins themselves [7–10].

According to earlier reports, maximal hydration of gluten rinsed by phosphate buffer with a pH value ranging from 3.7 to 8.5 is observed at acidic and alkaline pH values, and minimal hydration is observed at a pH of about 6.0–6.5 [10–11].

The changes of the degree of swelling of sprouted wheat grain powder during 60 min of incubation at pH 4.5 or 7.0 and the effect of varying temperature and mash ratio on these changes are illustrated by Figures 1–8.

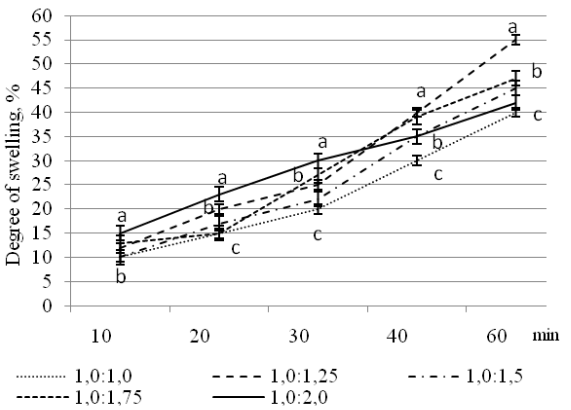

Fig. 1. Changes in the degree of powder swelling during 60 minutes at 25°C, pH 7.0 (different letters denote intra-group difference for multiple comparison of the means, LSD test, $p < 0.05$).

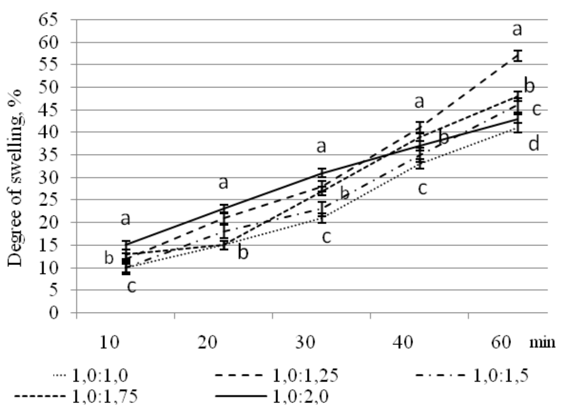

Fig. 2. Changes in the degree of powder swelling during 60 minutes at 25°C, pH 4.5 (different letters denote intra-group difference for multiple comparison of the means, LSD-test, $p < 0.05$).

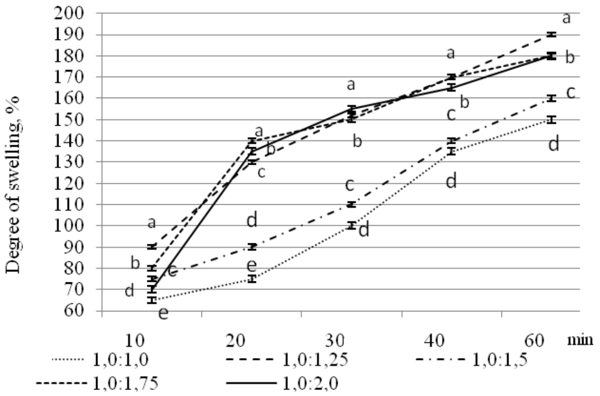

Fig. 3. Changes in the degree of powder swelling during 60 minutes at 45°C, pH 7.0 (different letters denote intra-group difference for multiple comparison of the means, LSD test, $p < 0.05$).

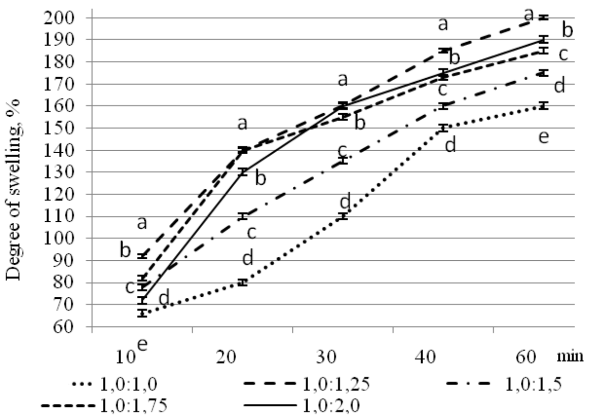

Fig. 4. Changes in the degree of powder swelling during 60 minutes at 45°C, pH 4.5 (different letters denote intra-group differences for multiple comparison of the means, LSD test, $p < 0.05$).

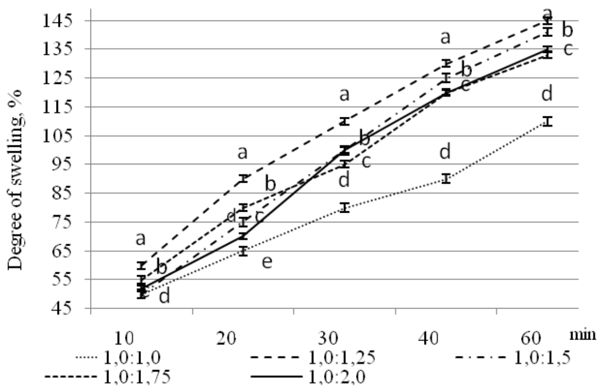

Fig. 5. Changes in the degree of powder swelling during 60 minutes at 65°C, pH 7.0 (different letters denote intra-group difference for multiple comparison of the means, LSD test, $p < 0.05$).

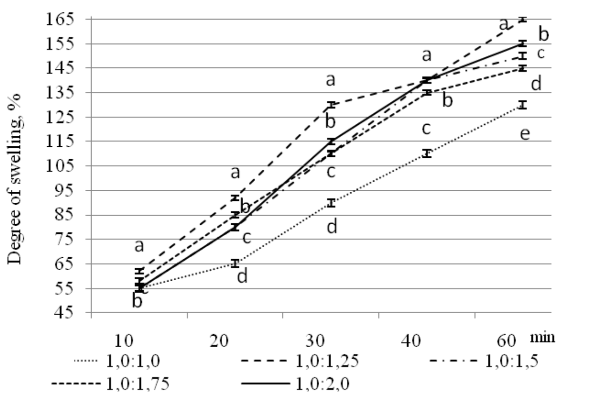

Fig. 6. Changes in the degree of powder swelling during 60 minutes at 65°C, pH 4.5 (different letters denote intra-group difference for multiple comparison of the means, LSD test, $p < 0.05$).

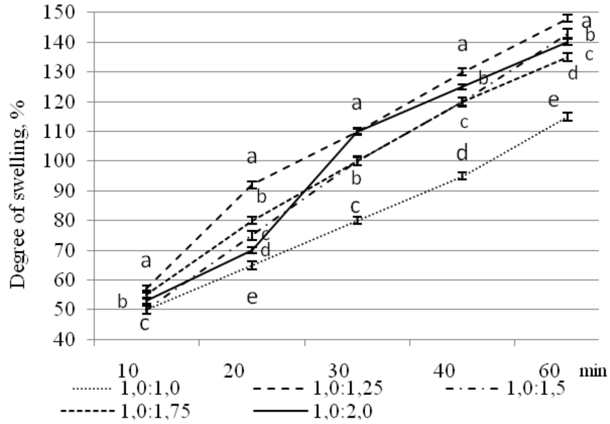

Fig. 7. Changes in the degree of powder swelling during 60 minutes at 85°C, pH 7.0 (different letters denote intra-group difference for multiple comparison of the means, LSD test, $p < 0.05$).

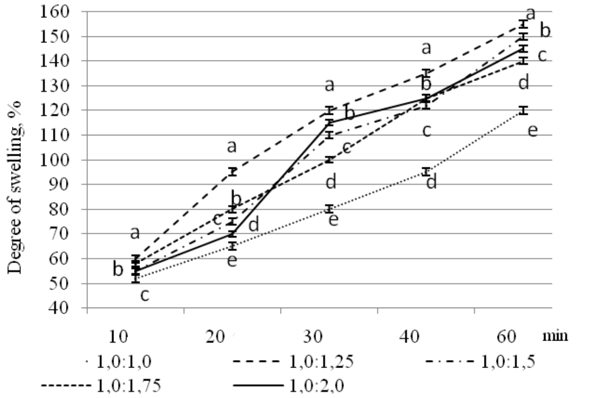

Fig. 8. Changes in the degree of powder swelling during 60 minutes at 85°C, pH 4.5 (different letters denote intra-group difference for multiple comparison of the means, LSD test, $p < 0.05$).

Changes in the amount of moisture retained by the powder at the beginning of the hydrothermal processing were slight at all the temperatures tested. Further penetration of moisture retained by surface tension resulted in intense absorption of water. The effect of temperature was more pronounced at this stage, with the rate of water absorption being higher at 45–65°C than at 25°C. Maximal swelling of gluten proteins is known to occur at 30°C, while maximal swelling of starch grains occurs at 50°C. This difference in the optimal swelling temperatures for proteins and starch in the powder is due to differences in the molecular weight and structure of these substances. Analysis of the data concerning the swelling of powder produced from sprouted wheat grains showed that the maximal degree of powder swelling (201%) was observed at the following parameters of hydration: mash ratio of 1:1.25, temperature of 45 °C, and treatment duration of 60 min at pH 4.5. These parameters were considered optimal. The development of an energy-efficient technology for the hydrothermal processing of sprouted grain powder was addressed in an experiment which involved a change in the mode of steam convector operation: namely, the convector was switched on and off for 10–15 min (T cycl), and the results were compared to those obtained at constant heating (T const). The degree of swelling of the powder was measured (Fig. 9).

The experiment did not reveal a statistically significant difference between the values of the degree of swelling of dried sprouted wheat powder attained at T cost and T cycl. Thus, we have developed an energy-saving technology for the hydrothermal processing of powdered sprouted wheat intended for use as a food additive. The parameters of the process were the following: temperature of 45°C, mash ratio of 1:1.25, and hydrothermal treatment duration of 60 min at pH 4.5.

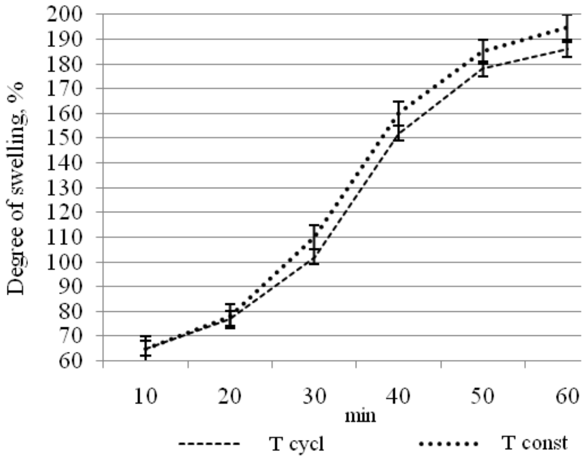

Fig. 9. Changes in the degree of powder swelling at different steamer operation modes.

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