NOTE

Effect of Microwave Energy on Drying Wheat

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ABSTRACT

This is the first report of a study undertaken to determine the ability of microwave energy to dry wheat. The first step included measuring the temperature that can safely be reached by the grain without damaging effects on germination and protein. In microwave drying, the measurement of total protein content was not affected by heating up to 91° C, but germination and wet gluten content were progressively affected by temperatures exceeding 60 and 66° C, respectively.

In the northern part of the wheat-growing area of Argentina, the practice during recent years has been to sow soybeans immediately after the wheat harvest. A week's delay in planting date can be critical to obtaining good yields of soybeans. Therefore, the harvesting of wheat needs to be completed as early as possible despite high moisture content of the grain. Consequently, it is usually necessary to dry the crop before storage.

It is common to use hot air to dry grain, but low thermal conductivity of grains and case hardening of kernels hinder the efficiency of the process (Fanslow and Saul 1971). In a conventional dryer, heat flows from outside to inside the grain by conduction, with a gradual increase in temperature within the product, but frequently with undesirable overheating of peripheral zones. Case hardening of kernels appears to be caused when peripheral layers dry first and become less permeable to water vapor as they dry (Fanslow and Saul 1971). Consequently, evaporation takes a long time.

Heat treatment may cause a reduction in baking quality of wheat flour. This becomes more pronounced as the temperature of the drying air increases. Except in extreme situations, it is very difficult to visually detect this heat damage (Mounfield et al 1944). In Argentina this is an important problem for both milling and export industries, because such a high percentage of the crop is artificially dried; during the 1983–1984 crop year this amounted to 33% of the wheat produced. Also, during conventional drying the grain becomes contaminated with combustion gases (Fritz 1974, Tosi 1983). As an alternative, microwave energy used to dry grains would have the advantage that neither normal rate-limiting factors nor contamination were present.

Its permanent dipole moment causes water to interact with electromagnetic waves, and this energy is converted into heat. This heat is internally generated and tends to be selectively higher in regions of higher moisture contents. Thus, the vapor pressure will be the highest in these moist regions, and diffusion will be toward the surface of kernels, especially when the outer humidity is removed by airflow or by vacuum.

Microwave energy has been used to dry or to heat corn (Fanslow and Saul 1971, Nofsinger et al 1980) and to condition wheat and wheat flour (Doty and Baker 1977, MacArthur and D'Appolonia 1981). However, no detailed report of the effects of this technique on drying wheat has been published. In particular, it is important to know the upper temperature limit, when heating with microwaves, that can be attained without damaging the quality of wheat. The present research was undertaken to develop more information about the effects of microwave energy at 2,450 MHz on drying wheat. In this paper, we report preliminary results on germination, total protein content, and wet gluten content.

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MATERIALS AND METHODS

The sample used in these experiments was a hard wheat mix with an initial moisture content of 13.9%. It was divided in two parts, rewetted to 17 and 19%, respectively, and held 24 hr before treatment.

The microwave oven was a White-Westinghouse model KM 50 V (240 V, 6.5 A), with an operating frequency of 2,450 MHz. No forced airflow was used; the grain was exposed only to microwave energy.

For each test, 200 and 400 g of grain were weighed, placed on a Pyrex glass tray, and irradiated with microwave energy. Grain temperatures were measured immediately after irradiation with a mercury-in-glass thermometer. The temperature of the grain was recorded as an average of four readings. Hot spots from nonuniform heating were observed in all cases. Temperature differences between hot spots and other locations were usually 3–4° C. After measuring the temperature, the grain was hand mixed to allow the moisture to evaporate and the sample to cool. In several cases the total time of irradiation was divided into three or more periods in order to maintain the temperature limit below a prefixed value. In all tests the final moisture content was about 14%, calculated from weight difference during and at the end of the experiment with a Brabender semiautomatic moisture tester (Rochelle Park, NJ).

The germination test was done in an environmental cabinet at 23° C, recording germinated seeds on the third and seventh days.

For protein and wet gluten analysis, the wheat was milled on a Brabender Quadrumat Junior laboratory mill. Total protein of the flour was estimated using the Udy dye method (method 46-14A, AACC 1976) with a Udy model S protein analyzer (Udy Corp., Boulder, CO). Values for wet gluten contents of the flours were obtained according to the gluten machine-washing method (AACC method 38-11). The mechanical determination of the wet gluten content was done according to ICC standard 137 (ICC 1982), with Glutomatic equipment manufactured by Falling Number AB (Stockholm, Sweden). Dough-mixing times of 30 sec and dough-washing times of 8 min were used.

RESULTS AND DISCUSSION

Results obtained from three replications for germination, wet gluten, and total protein as functions of drying temperature are

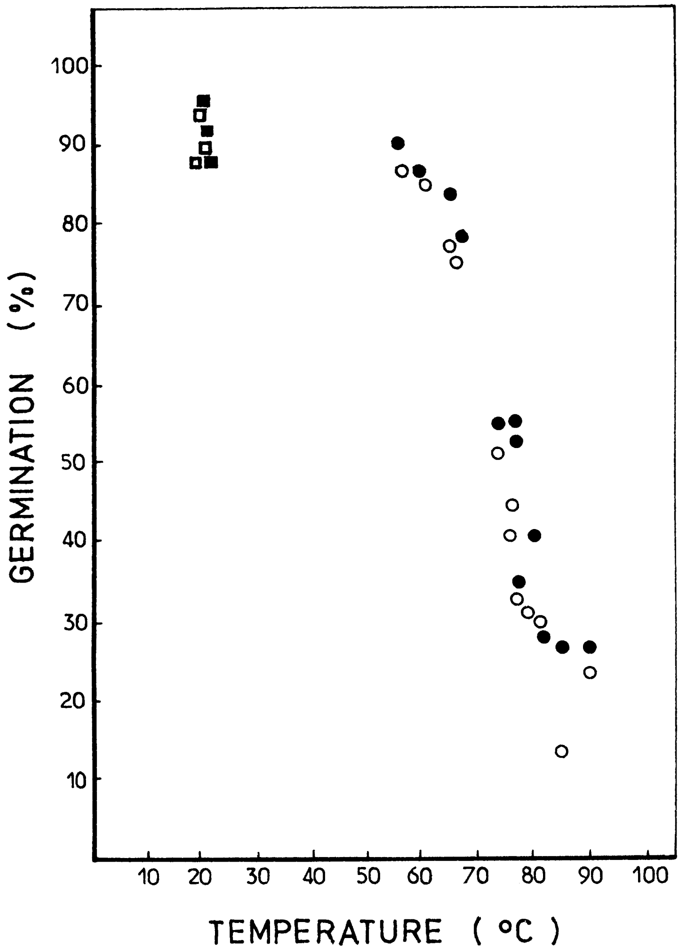

Fig. 1. Effect of temperature on wheat germinability when drying with microwave energy at 2,450 MHz. Germination as recorded for control samples on the third day (□) and seventh day (■); dried samples germinated on the third day (o) and seventh day (•).

shown in Figures 1–3. The critical temperature for gluten damage was different from that for germination capacity. Germination was reduced by exposure to temperatures over 60° C, but gluten was not damaged until temperatures exceeded 66° C.

When Hutchinson (1944) studied the effect of temperature on germination of wheat, he found that wheat at 2–3% moisture content exposed to 110° C for 1 hr still gave 80% germination, but this percentage could not be attained with wheat containing 24% moisture and exposed for 1 hr to a temperature exceeding 60° C. In wheat grain with 17–19% moisture, the critical temperature affecting germination capacity was 58–62° C, which is in agreement with our results. Moreover, for conventional heating he found that for wheat of 14% moisture content heated for 36 min, gluten was progressively damaged in the range of 70–85° C, whereas the corresponding range of temperatures affecting germination capacity was 64–72° C.

Doty and Baker (1977) have reported that gluten quality decreased between 52 and 66° C and was nearly destroyed after reaching 66° C when heating wheat with microwaves. Their temperature limit for gluten damage was a little lower than that observed in this study.

In mechanical determination of the wet gluten content, samples heated up to 66° C formed gluten normally. In those samples heated to 68 and 75°, 10 sec longer mixing was necessary to obtain gluten, and it did not form in samples heated above 76° C.

In contrast, the analysis showed total protein content (Fig. 3) not to be affected by microwave heating, although temperatures up to 91° C were recorded. In an early study, Finney et al (1962) dried wheat with 16.5, 19.4, and 27% moisture content by eight heat treatments, reaching temperatures between 90 and 280° F (32.2 and 137.8° C). Protein content was nearly equal in all samples, but as drying temperature increased, the mixing time became longer and the loaf volume decreased, indicating partial destruction of gluten functionality.

The three control samples maintained at 21–22° C (one at 13.9% moisture and the other two rewetted to 17 and 19% moisture, respectively, and finally dried at ambient temperature) were similar with reference to germination, wet gluten content, and total protein content.

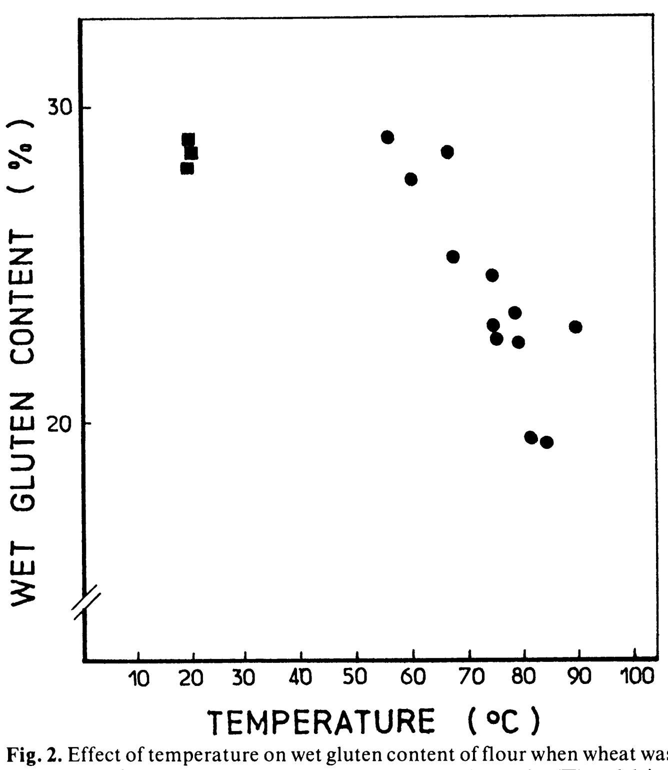

Fig. 2. Effect of temperature on wet gluten content of flour when wheat was dried with microwave energy at 2,450 MHz. Control samples (■) and dried samples (•).

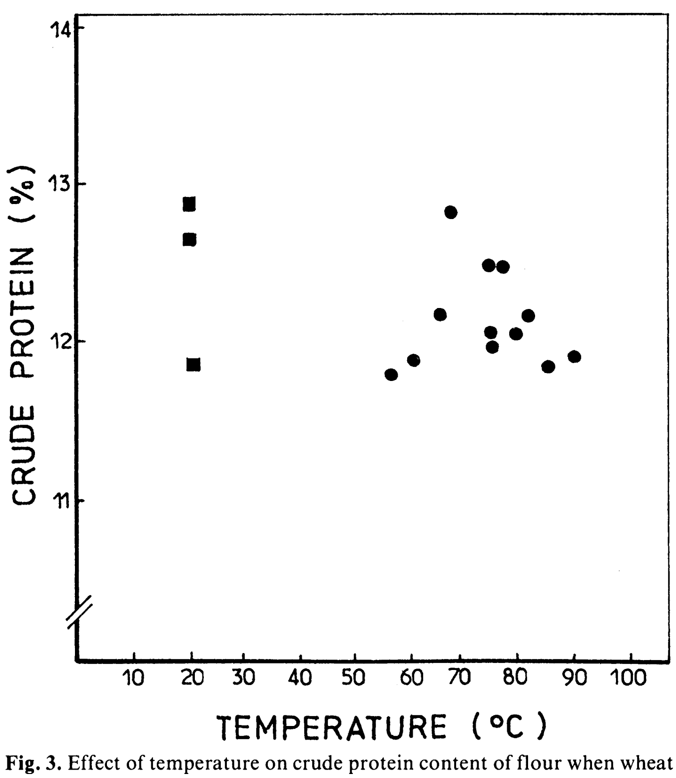

Fig. 3. Effect of temperature on crude protein content of flour when wheat was dried with microwave energy at 2,450 MHz. Control samples (■) and dried samples (•).

In conclusion, microwave energy can be used to dry wheat without appreciable damage if the temperature of the grains does not exceed the limit of about 60–65°C. This is the same temperature limit as for conventional heating techniques.

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