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Infrared drying: A promising technique for bulgur production

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ABSTRACT

Bulgur is a very famous industrially processed ancient wheat product. High nutritional value, long shelf life and low price of bulgur increased the demand in new and developing markets all over the world. Cooking and drying are the most critical steps in bulgur production and should be controlled carefully and adapted with new technologies. Infrared (IR) drying has obtained a great interest in the food industry, due to its advantages over conventional heating. In this study, durum and bread wheat samples were cooked under atmospheric pressure or in autoclave and dried by using infrared at 525, 666 and 814 W powers for 3:30, 2:10 and 1:20 h, respectively. Control samples were either sun-dried for 72 h or dried in oven at 60 °C for 18 h. For the samples cooked in autoclave, amount of bran removed during debranning was lower and cooking loss was slightly higher. IR-dried samples generally gave comparable results with controls in terms of color, particle size, cooking loss, ash, dietary fiber and water absorption values. The ash and cooking loss values of all bulgur samples meet the levels indicated in Bulgur Communiqué. Infrared drying shows great promise in bulgur production by reducing drying time without causing any deterioration in bulgur quality.

1. Introduction

Bulgur is one of the traditional durum wheat products in Turkey and Middle Eastern countries and there is an increasing trend to produce bulgur in developing and developed countries. Annual bulgur production in Turkey is approximately 1 million tons (Caba et al., 2012). Annual consumption in Turkey is about 15 kg per person (Caba et al., 2012) and it is extremely high in the East and South parts of Turkey, Syria, Iran, Iraq, Lebanon, Israel and Arabia (25–35 kg/person) (Yıldırım et al., 2008). The consumption of bulgur is approximately 2.5 and 2.0 times higher than that of pasta and rice in Turkey, respectively. High nutritional value, long shelf life and low price of bulgur increased the demand in new and developing markets all over the world (Bayram and Öner, 2005; Caba et al., 2012; Kadakal et al., 2007; Ozboy and Koksel, 2001). Such a high demand indicates the significance of bulgur in the diet and technological advancements are needed to enhance the quality of bulgur. Therefore, critical steps in bulgur production should be controlled carefully and adapted with new technologies.

The major bulgur production steps are cleaning, cooking, drying, debranning, cracking and classification. Cooking and drying are the most critical steps in bulgur production. Traditionally bulgur is sun-dried but it may cause quality degradation and infestation of the product. Kadakal et al. (2007) investigated the effect of cooking (in beaker at 90, 100 °C or in autoclave at 121 °C) and drying (in hot-air oven at 60, 70, 80 °C or sun-drying in open air) on the water-soluble vitamins (thiamin, niacin, pantothenic acid, pyridoxine, riboflavin) of bulgur. It was reported that the greatest reductions in water-soluble vitamins were observed for the sun-dried bulgur samples followed by the samples hot-air oven dried at 80 °C. In modern bulgur plants, hot air drying is often used due to increased capacity and sanitation benefits (Hayta, 2001; Kahyaoglu et al., 2012). However, more effective drying methods with additional benefits (reduced drying time, higher product quality etc.) must be investigated to encourage bulgur producers. In a study by Hayta (2001), the effects of different drying methods (solar, sun, microwave, tray drying) on quality characteristics of bulgur were investigated. Sun drying resulted in the lowest bulgur yield. It was reported that the drying method affected the protein extractability, water and oil absorption values. Flavor, mouth feel, and appearance of the bulgur samples were found to be similar. Kahyaoglu et al. (2010) compared physical properties of bulgur samples produced using spouted bed and microwave assisted spouted bed drying. Microwave assisted spouted bed drying shortened drying time but resulted in more

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porous microstructure and lower water absorption capacities and the bulgur yield decreased with increasing microwave power. Kahyaoglu et al. (2012) reported that microwave-assisted spouted bed drying at microwave power of 3.5 W/g and 7.5 W/g reduced drying time of parboiled wheat by at least 60% and 85%, respectively, as compared to spouted bed drying.

Infrared treatment may also provide an alternative route for bulgur drying. In recent years, there has been an increasing trend towards the utilization of infrared (IR) as a drying technology for obtaining high quality food. This trend is largely due to the advantages of infrared over conventional heating. As compared to other technologies, infrared has demonstrated many advantages such as higher thermal efficiency and fast heating rate, resulting in reduced drying time (Datta and Almeida, 2005; Sakai and Mao, 2006). Infrared heating has been used in some of the food applications such as drying, frying, roasting, baking, thawing, blanching, pasteurization and sterilization of food products (Erdoğdu et al., 2010; Krishnamurthy et al., 2008; Rastogi, 2011). It has been investigated as a potential method to reduce the moisture content of grains, legumes, fruit and vegetables (Krishnamurthy et al., 2008). It was also used in the production of quick-boiling noodle (Basman and Yalcin, 2011), bread (Olsson et al., 2005), cookies (Heist and Cremer, 1990) and tortillas (Martínez-Bustos et al., 1999). Infrared treatment is an effective method for inactivation of trypsin inhibitor and lipoxygenase in soybeans (Yalcin and Basman, 2015). Infrared reduces cooking time of legumes (Arntfield et al., 1997; Scanlon et al., 1998) and increases starch gelatinization degree.

Increasing concern for product quality, minimized food processing and energy costs have led to more detailed studies investigating the effects of different drying techniques on food quality. To the best of our knowledge, infrared was not used in bulgur production at the drying stage and its effect on product quality has not yet been studied. Therefore, in this study, infrared at different powers was used at the drying stage of bulgur production and quality characteristics of the bulgur samples were investigated. Because of rapid heating in the infrared equipment, drying can be rather troublesome. However, undesirable structural changes encountered during drying were eliminated by selection of appropriate IR powers.

2. Materials and methods

2.1. Materials

Two durum wheat cultivars (cvs. Mirzabey and Altın) and two bread wheat cultivars (cvs. Bayraktar and İkizce) used in the study were obtained from Field Crops Improvement Center, Ankara, Turkey. Altın and Mirzabey are the durum wheat cultivars that possess good quality characteristics. Mirzabey is one of the mostly grown durum wheat cultivars in Turkey because of its higher yield and climate requirements. Bayraktar is the soft white bread wheat cultivar and İkizce is the hard red bread wheat cultivar.

2.2. Physical and chemical properties

Moisture, ash (db) and protein (Nx5.7, db) contents of the wheat samples were determined according to Approved Methods of American Association of Cereal Chemists (AACC International, 2000). The thousand-kernel weight was determined by counting the number of seeds in 20 g of grain and reported on a dry basis. Vitreousness was determined according to Williams et al. (1986). All of the tests on the grain samples were performed in duplicate.

2.3. Bulgur production

2.3.1. Cooking

The wheat samples were cooked under atmospheric pressure or in autoclave. For atmospheric pressure cooking, the wheat samples were cooked in boiling water at wheat to water ratio of 1: 2.5 (w/w) for 70 min. For cooking in autoclave, the wheat samples were soaked in water (wheat: water ratio of 1: 1.3, w/w) at 60 °C for 3 h in order to increase the moisture content to about 45% (Özboy Özbaş and Köksel, 2002). Then the soaked grain (deep in water) was cooked in an autoclave (Webeco, Germany) under a steam pressure of 1.1 bar at 121 °C for 17 min. Cooked wheat samples were kept at room temperature for half an hour in order to evaporate surface moisture before drying.

2.3.2. Drying

Control samples were sun-dried for 72 h in September (~22 °C, 42% RH) in Ankara (altitude: 850 m), Turkey or oven-dried at 60 °C for 18 h.

Laboratory scale infrared equipment (Biasis Ltd. Sti., Ankara, Turkey) used in the study was designed as a closed system, including a drying chamber fitted with twelve 150 W halogen lamps (Philips, Infrared, R125 IR, Holland). The equipment contains two aeration channels (12 V each) and a dimmer was used in order to arrange infrared power between 310 W and 1595 W. Aluminum reflectors were used on the walls of the equipment to prevent absorption of the light (Ismailoglu and Basman, 2015). The distance between the lamp system and sample tray can be adjusted from 5 cm to 39 cm and it was set to 20 cm for this study.

In our preliminary studies, it was observed that IR-drying at higher powers (≥1003 W) causes some voids in the samples probably due to the high amount of water evaporation from the samples in a very short time due to rapid drying. These samples had limited strength to withstand the debranning process and the bulgur samples generally had lower particle size due to breakage. Therefore, in this study, as low IR powers as possible were used during drying in order to eliminate the undesirable structural changes. For this purpose, infrared powers and drying times for the bulgur samples were selected as follows; at 525 W for 3:30 h, at 666 W for 2:10 h, at 814 W for 1:20 h. The drying times were determined in order to obtain a final moisture content less than 10%. The temperatures detected by an IR thermometer (Raytek MX6 Infrared Thermometer) at the surface of the samples treated at 525 W, 666 W and 814 W were found to be 84, 91 and 122 °C, respectively.

2.3.3. Tempering, debranning and cracking

Cooked and dried bulgur samples were tempered prior to debranning in order to facilitate bran separation. The samples were tempered to 11% moisture content, rested for 24 h and then tempered to 12% moisture content and rested for 30 min (Özboy Özbaş and Köksel, 2002). Bran separation in the tempered wheat was performed by a debranner (Poyraz Muhendislik, Konya, Turkey) for 5 min. The debranned samples were cracked in a laboratory scale specialized hammer mill designed by a bulgur production company (Duru Degirmen Makinaları, Karaman, Turkey).

2.4. Analysis of bulgur samples

The following analyses were performed on the bulgur samples produced by using different cooking and drying methods.

2.4.1. Amount of bran removed

The percentage of bran removed during the debranning step was calculated as the ratio of bran weight to the total sample