JANUARY 2017

M. Sc. in Food Engineering

EMRE YİĞİT

GAZIANTEP UNIVERSITY

GRADUATE SCHOOL OF

NATURAL AND APPLIED SCIENCES

THE DEVELOPMENT OF NEW TECHNIQUES TO INCREASE THE PERFORMANCE OF GERMINATION AND NEW PRODUCTS FROM GERMINATED WHEAT AND RED-LENTIL

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SUPERVISOR

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Emre YİĞİT

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Emre YIĞİT

ABSTRACT

THE DEVELOPMENT OF NEW TECHNIQUES TO INCREASE THE PERFORMANCE OF GERMINATION AND NEW PRODUCTS FROM GERMINATED WHEAT AND RED-LENTIL

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In this study, microwave and ultrasound aided germination operation was investigated as a new technique to produce germinated bulgur (as a new developed product) and red-lentil.

During the study, microwave (1, 3 and 5 W/kg of power levels for 1, 3 and 5 mins) and ultrasound (at 40 kHz, 10, 30 and 50 W/kg of power levels for 10, 20 and 30 mins) were carried out during the germination operation (20 hrs at 25 ^{o}C, 95 % RH, non-illuminated condition) by applying at each 6-hours intervals to improve the nutritional value and to increase the germination performance of wheat (*Triticum durum* to produce bulgur) and red-lentil (*Lens culinaris*).

After the germination operation, bulguration (combined cooking and drying operation) was made then milling and sieving were performed to produce bulgur from the germinated wheat. Red-lentil was directly germinated and analyzed. For both final products, yield (%), 1000-kernels weight (g, d.b.), hectolitre-weight (kg/100 L, d.b.), moisture (%, d.b.), ash (%, d.b.), protein (%, d.b.), fat (%, d.b.) and starch (%, d.b.) contents, color values (CIE L*, CIE a*, CIE b* and CIE YI) and water absorption capacities (%, d.b.) were determined. Only for bulgur samples the amount of water-soluble substance (%, g/g) was also determined. For both products, sensory analysis was made.

Ultrasound and microwave operations decreased the fat contents of bulgur ($P \leq 0.05$) and red-lentil ($P \leq 0.01$). Germination increased CIE L* value of bulgur ($P \leq 0.05$); however, it decreased the fat and starch contents of wheat and red-lentil significantly.

Key Words: Germination, microwave, ultrasound, lentil, wheat, bulgur

ÖZET

ÇİMLENDİRİLMİŞ BUĞDAY VE KIRMIZI MERCİMEKTEN YENİ ÜRÜNLERİN VE ÇİMLENDİRME PERFORMANSININ ARTTIRILMASI İÇİN YENİ TEKNİKLERİN GELİŞTİRİLMESİ

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Bu çalışmada, çimlendirilmiş bulgur (yeni geliştirilmiş bir ürün olarak) ve kırmızı-mercimek üretmek için yeni bir teknik olarak mikrodalga ve ultrason destekli çimlendirme işlemi araştırıldı.

Çalışma sırasında, buğdayın (bulgur üretmek için *Triticum durum*) ve kırmızı-mercimeğin (*Lens culinaris*) besin değerini geliştirmek ve çimlenme performansını artırmak için çimlendirme işlemi (20 saat, 25 ^{o}C, % 95 BN ve ışıksız ortam) esnasında 6 saat aralıklarla mikrodalga (1, 3, ve 5 dakika için 1, 3 ve 5 W/kg güç seviyeleri) ve ultrason (40 kHz'te 10, 20 ve 30 dakika için 10, 30 ve 50 W/kg güç seviyeleri) uygulanmıştır.

Çimlendirme işlemini takiben, çimlendirilmiş buğdaydan bulgur üretmek için bulgurasyon (pişirme ve kurutma) yapılmış olup, daha sonra öğütme ve eleme uygulanmıştır. Kırmızı-mercimek doğrudan çimlendirilmiş ve analiz edilmiştir. Her iki son üründe de, randuman (%), 1000-dane ağırlığı (g, k.m.), hectolitre-ağırlığı (kg/100 L, k.m.), nem (%, k.m.), kül (%, k.m.), protein (%, k.m.), yağ (%, k.m.) ve nişasta (%, k.m.) miktarları, renk değerleri (CIE L*, CIE a*, CIE b* ve CIE YI) ve su emme kapasiteleri belirlenmiştir. Ayrıca, sadece bulgur numunelerinde suya geçen madde miktarı (%, g/g) belirlenmiştir. Her iki ürün için duyusal analiz yapılmıştır.

Ultrason ve mikrodalga işlemi bulgur ($P \leq 0.05$) ve kırmızı-mercimeğin ($P \leq 0.01$) yağ miktarlarını düşürmüştür. Çimlendirme ise bulgurun ($P \leq 0.05$) CIE L* değerini arttırırken, buğday ve kırmızı-mercimeğin yağ ve nişasta miktarlarını önemli olarak düşürmüştür.

Anahtar Kelimeler: Çimlenme, mikrodalga, ultrason, mercimek, buğday, bulgur.

To my precious family and beloved fiancé

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CHAPTER 1.

LITERATURE REVIEW

1.1. Bulgur

Bulgur is a whole grain product, which is generally produced from *Triticum durum* using a cleaning, cooking, drying, tempering, peeling, milling, polishing (optional) and classification operations. It is a semi-ready-to-eat food product. However, in some regions, it is also used as a ready-to-eat food product especially in tabbouleh salad (USA, EU and Arabic countries) and kısır (Turkey). It has long shelf-life and high nutritional value. Its price is also lower than bread and pasta. It is easily prepared and resistant to insect, mites, and microorganisms (Bayram, 2000, 2005; Bayram et al., 2004a; Bayram & Öner, 2005; Bayram & Öner, 2007; Yıldırım et al., 2008).

There is a long history about bulgur. It is an ancient wheat product and its history goes back to 4000 BC. Archaeological studies have been made by Valamoti, (2002). Today, there are two basic processing methods to produce bulgur i.e. Antep and Karaman (Mut) methods (Bayram & Öner, 2005). Milling techniques (stone, disc, roll etc.) used in each method affect the significant properties of bulgur i.e. color, shape, size etc. Therefore, studies are generally related to the milling of bulgur (Bayram & Öner, 2005; Bayram & Öner, 2007; Yıldırım et al., 2008).

Bulgur is main ingredient pleasantly used in more than 250 delicious meals. It is also important as a dietary fiber source, having 18.3 g dietary fiber per 100 g. Its dietary fibre content is 3.5, 6.8, 1.1, 1.8, 7.0, 15.3, 9.2, 2.3, 1.3 and 4.3 times higher than rice, wheat flour, barley, oatmeal, spinach, tomato, turnip, whole wheat bread, soybean and pasta, respectively (Dreher, 2001; Yıldırım et al., 2008).

Bulgur is an excellent food source due to its low cost, storability (long shelf-life), ease of preparation, and high nutritional value, which resists mold contamination and attack by insects and mites (Bayram, 2000). Another important property is that all starch is

gelatinized and the kernel is almost cooked. It is more stable than wheat under hot and humid environmental conditions. Biological differences between wheat and bulgur are that wheat has a respiration activity and enzymes are active in the kernel in contrast to bulgur (Bayram et al., 2004b).

Bulgur is also stored for military and human nutritional purposes in some countries because of its resistance to absorbance of radiation (today, bulgur is one of the important wheat products in the U.S., and it is included in the special list of food rations in nuclear fallout shelters), prevent intestinal cancer risk and consumable alone due to its fiber content (formation of fibrous structure, lack of phytic acid due to the processing properties) and good nutritional composition. Additionally, bulgur is a critical food material for Turkish, Arabic, Mediterranean, North-African and East European peoples because of its economical and nutritional values, especially, in Turkey (Bayram et al., 2004b).

The most important factor in the production of high-quality bulgur is the wheat type. Generally, *Triticum durum* (pasta type) is used for its preparation. Hard wheat has a light yellow color and it has more proteins than other wheat types (Bayram, 2000; Bayram et al., 2004c). It has a high resistance to absorption of radiation, and it can be consumed alone as diet (Bayram et al., 2004c; Kadakal et al., 2007).

Cooking and drying are important steps in bulgur processing because of the effects on the color, yield, chemical composition and nutritive quality of the end product (Certel, 1990; Koca & Anıl, 1996; Köksel et al., 1999). Different cooking (atmospheric, pressure, microwave and infrared) and drying (fluidized bed, tray, conduction, infrared and microwave) methods were studied for wheat, triticale, and soy bulgur production by some researchers (Bayram, 2003; Certel, 1990; Singh & Dodda, 1979). Bayram, (2003) found that the optimum cooking operation was pressure cooking because of maximum gelatinization and minimum cooking time, wheat kernel damage, carbohydrate loss and moisture content. Certel, (1990) reported that pressure- and infrared cooking processes increased wheat bulgur yield (Bilgiçli, 2009).

Bulgur processing has been shown to not alter protein content (Ozboy & Koksel, 1998) and to decrease levels of thiamin and riboflavin (Adolph et al., 1955; Pence et al., 1964; Sabry & Tannous, 1961), ash (Ozboy & Koksel, 1998), and mineral (Özkaya et

al., 1996). Nutritional recommendations (Jenkins et al., 1986) increased cereal based product consumption and required developing a wide range of products with excellent sensory properties. Bulgur has been considered as a useful contribution to diet because of its nutritional value (rich in phosphorus, zinc, magnesium, and selenium) and versatility (Hayta et al., 2003; Nouri, 1988; Ranum, 1996).

1.2. Lentil

The Leguminosae (*Fabaceae*) is one of the largest families of flowering plants (over 15000 species), ranging from tiny wild plants to large trees. Members of the family can easily be recognized by (a) the flower with its petals comprising a large upper standard, two lateral wings, and a boat-shaped keel, and (b) the fruit, known as the legume or pod, containing the seeds or beans (Vaughan & Judd, 2006).

Lentil (*Lens culinaris* Medik.) is predominantly grown in South East Asia. The Indian subcontinent is the largest producer but it is also grown in most subtropical and warm temperate countries. On sale as pulses, the seeds are biconvex or lens-shaped (3–9 mm in length) and green, yellow, orange, red, or brown in color. It is commonly consumed as thick soup made from whole grain or split pulse commonly referred to as ‘dhal’. Seeds can be fried and seasoned for consumption; flour is used to make soups, stews purees, and mixed with cereals to make bread and cakes, and as a food for infants (Williams et al., 1988; Zia-Ul-Haq et al., 2011). It is used in culinary dishes in the Indo-Pakistan sub-continent and in the Middle East and incorporated into soups in Europe and North America. In Western countries, lentils may be used in casseroles and as meat substitutes in vegetarian diets. Lentil although called as a ‘poor man's meat’, is equally liked by all socioeconomic groups in South East Asia (Bhatty, 1988; Zia-Ul-Haq et al., 2011).

Lentil is one of the most important crops with 4.4 % protein, 1.8 % oil, 41-50.8 % carbohydrates, 21.4 % fibrous, a high percentage of other mineral nutrients and unsaturated linoleic and oleic acid for human consumption (Karadavut & Genç, 2010). The nutritional importance lentil is that it is a protein/calorie crop packed with nutrients, fiber, complex carbohydrate, folic acid and an important source of iron (Sulieman et al., 2007).

Lentils are an excellent source of protein and also rich in important vitamins, minerals, soluble and insoluble dietary fiber. The unsaponifiable lipid fraction of lentil is a potential source of bioactive components such as phytosterols, squalene, and tocopherols (Ryan et al., 2007). Lentils contain saponins (triterpene glycosides), which have been implicated in hypercholesterolemia in animals (Savage, 1991) and phenolic compounds with high antioxidant activity (Amarowicz et al., 2009; Amarowicz et al., 2010; Amarowicz & Pegg, 2008; Zia-Ul-Haq et al., 2011).

The nutritional value of lentils is gaining considerable interest since its nutritional value/100 g dry weight is as follows; energy, 353 kcal; carbohydrates, 60 g; sugars, 2 g; dietary fibers, 31 g; fat, l g; protein, 26 g; thiamine (B1), 0.87 mg; folate (B9), 479 μg and iron, 7.5 mg (Callaway, 2004). In common with other legumes, lentils contain a number of components called anti-nutritional factors which limit the wider use of crop (Sheshetawy & Faid, 2010).

Turkey is basically an agricultural country and its economy depends on the agricultural sector. Legumes crops take place in agriculture of Turkey. Legumes are cultivated on large areas of Turkey. There are protein-calorie malnutrition problems in Turkey as all over the World. Legumes may be helpful in solving this problem. Legumes crops have richly essential amino acids, particularly lysine. It has been demonstrated that legume protein is the natural protein suitable to complement that present in cereals grains and legumes grains comprise an important part of the human diet (Ribeiro & Melo, 1990). Iqbal et al., (2006) explained that legumes are helpful in enhancing the protein content (Karadavut & Genç, 2010).

Lentil is generally grown in non-irrigation conditions. Different *Lens* varieties showed some genetic variation for plant height, the number of branches, the number of pod per plant, the number of seed per plant, harvest index and biological yield. The chemical composition of *Lens* crops can vary with cultivars, soil and climatic conditions of the area. Karadavut and Palta, (2010) explained that chemical composition varied in different locations (Karadavut & Genç, 2010).

1.3. Germination

Cereal grains and legume seeds are usually submitted to technological processes, such as fermentation and controlled germination, in order to improve the nutritive value of the final products (Bartolomé et al., 1997; Sadowska et al., 1999; Trugo et al., 2000; Yang, 2001). Germination is an economical and simple method for improving the nutritive value, and several studies have reported higher levels of nutrients and lower levels of antinutrients in sprouts compared to the ungerminated seeds (Abdel-Rahman, 1984; Honke et al., 1998; King & Puwastien, 1987; Zieliński et al., 2006).

Germination is a natural biological process of all superior plants by which the seed comes out of its latency stage, once the minimal environmental conditions needed for its growth and development, such as humidity, temperature, nutrients, etc., are given. For the seed to germinate, there are also external factors such as a humid substrate, availability of oxygen for aerobic respiration and an adequate temperature for the different metabolic processes and for the development of the plantlet. The process of germination has been developed in some countries as an alternative to defeat some of the disadvantages associated with untreated grains, such as undesirable tastes and smells, as well as the presence of trypsin inhibitors (Sangronis & Machado, 2007; Suberbie et al., 1981).

The process of germination is an ancient and popular practice in many parts of the world, particularly in Asia. Germinated legumes are often added to diets to increase their acceptability and nutrient contents. Germination involves the breakdown of seed reserves owing to increased enzyme activity. Upon germination, the content of vitamins also increases considerably (Tharanathan & Mahadevamma, 2003; Vijayaraghavan, 1981).

Germination starts with the uptake of water (imbibition) by the quiescent dry seed and terminates with the emergence of the embryonic axis, usually the radicle. It is a time of intense metabolic activity, involving subcellular structural changes, respiration, macromolecular syntheses and, finally, cell elongation. Establishment of the seedling occurs the following germination and its growth is initially supported by metabolites produced by the hydrolysis and conversion of the major stored reserves proteins, carbohydrates, and lipids (Zieliński et al., 2006).

Germination is simple, inexpensive and improves the palatability, digestibility, and availability of certain nutrients. During germination several enzymes become active; vitamins are increased, whereas there is a reduction in phytates and tannins (Mehta & Bedi, 1993). However, the effect of germination depends on the type of legume and on the conditions and duration of the germination process (Savelkoul et al., 1992). Sprouting or controlled germination of legumes increases protein and carbohydrate digestibility, enhance some of their vitamin contents, reduces the anti-nutritional factors and improves their overall nutritional quality (Malleshi & Klopfenstein, 1996). As sprouting proceeds, the ratio of essential to non-essential amino acids changes, providing more of essential amino acids. Sprouted seeds have more of maltose, therefore, improve the digestibility of carbohydrates (Uppal & Bains, 2012).

Germination is generally preceded by soaking seeds in water. Some of the reserve materials of the seeds are degraded and used partly for respiration and partly for the synthesis of new cell constituents of the developing embryo during germination, therefore, this process causes important changes in the biochemical, nutritional and sensory characteristics of legumes. Fats and carbohydrates, which often are at surplus levels in the western diets are broken down and starch digestibility increases (Jyothi & Reddy, 1981; Vidal-Valverde & Frias, 1992). Vitamins and secondary compounds, many of which are considered beneficial as antioxidants, often change dramatically during germination (Kylen & McCready, 1975; Nandi & Banerjee, 1950; Sierra & Vidal-Valverde, 1999). Germinated grains are good sources of ascorbic acid, riboflavin, choline, thiamine, tocopherols and pantothenic acid (Sangronis & Machado, 2007). Phytic acid and dietary fiber both affect the uptake of micronutrients in the digestive tract and these compounds change differently during the germination process (Pawar et al., 1986; Vidal-Valverde & Frias, 1992). α-Galactosides content, oligosaccharides that produce flatulence, and trypsin and chymotrypsin inhibitors, which affect the digestion of proteins, can be reduced during germination (Frias et al., 1995; Urbano et al., 1995; Vidal-Valverde & Frias, 1992; Vidal-Valverde et al., 1994). The in vitro digestibility of proteins increases during germination (Ghorpade & Kadam, 1989) and the emulsifying capacity of legume protein increase (Hsu et al., 1982).

During the germination, there are certain changes that could occur as far as the quantity and type of nutrients within the seed. Those changes can vary depending on the type of vegetable, the variety of the seed and the conditions of germination (Bau et al., 1999; Dhaliwal & Aggarwal, 1999; Vidal-Valverde et al., 2002). In the natural environment, seed sprouts survive during germination by enhancing their defensive responses through phenolics biosynthesis (Randhir et al., 2004). Germination may cause changes in the nutrients, including functional substances, through aerobic respiration and biochemical metabolism (Lin & Lai, 2006).

Germinated grain was used in China not only for food but for medicine 5000 years ago. It was observed that grain sprouts increase bio-disposal of food products i.e. human body can promptly assimilate substances (Lintschinger et al., 1997; Lorenz & Valvano, 1981). Wheat grain sprouts may also scavenge free radicals in a human body, reduce the level of cholesterol and improve immune system (Seibold, 1990). Thus, at present germination is more and more widely used not only for improvement of nutritional grain quality but also as a raw material for healthy food production (Kraujutiene et al., 2010; Lintschinger et al., 1997; Lorenz & D'Appolonia, 1980; Price, 1988; Yang, 2001).

1.3.1. Wheat and Germinated Wheat

Wheat is a basic human food staple supplying significant amounts of dietary carbohydrate and protein and is also a useful source of antioxidant compounds (Andlauer & Furst, 1998; Baublis et al., 2000; Miller et al., 2000). In bread wheat, however, the concentration of carotenoids is low (from 0.1 to 2.4 mg/g dm) but they are more abundant in durum wheat (1.5 to 4.0 mg/g dm) (Panfili et al., 2004; Zandomeneghi et al., 2000) where the yellow colour of the semolina, and the derived pasta, is perceived as an important quality trait. Tocols, in contrast, are abundant both in bread wheat (74.3 mg/g dm) and durum wheat (60.6 mg/g dm) (Hidalgo et al., 2006; Panfili et al., 2003).

The nutritional value of wheat is extremely important as it takes an important place among the few crop species being extensively grown as staple food sources. The importance of wheat is mainly due to the fact that its seed can be ground into flour,

semolina, etc., which form the basic ingredients of bread and other bakery products, as well as pasta, and thus it presents the main source of nutrients to the most of the world population (Šramková et al., 2009).

Epidemiological studies have associated the consumption of whole grain and whole-grain products with reduced incidence of chronic diseases such as cardiovascular disease (Jacobs et al., 1998; Thompson, 1994), diabetes (Meyer et al., 2000), and cancer (Jacobs Jr et al., 1995; Kasum et al., 2002; Nicodemus et al., 2001; Smigel, 1992; Thompson, 1994). These health benefits have been attributed in part to the unique phytochemical content of grains. Morris et al., (1977) presented evidence demonstrating the protective role of cereal grains in the human diet. They observed, in a cohort study of 337 men, a reduced incidence of coronary heart disease (CHD) in those with diets high in cereal fiber. Results from the Health Professional Followup Study suggested that the consumption of high dietary fiber obtained from cereal and grains can substantially reduce the risk of CHD (Adom et al., 2003; Rimm et al., 1996).

Current interest in the health benefits provided by grain consumption has led to an increased focus on the phytochemical content of different grains and grain varieties. For example, there has been some renewed interest in ancient grains by health-conscious groups, as well as the health-food market, which wants to exploit the unique nutraceutical values offered by these ancient grains. Buckwheat, for example, contains rutin and other flavonoids that serve as functional compounds for treating vascular disorders (Adom et al., 2003; Marconi & Carcea, 2001).

In cereal grains, covalently bound phenolic acids are concentrated in the cell walls of the various grain tissues especially the aleurone and the pericarp-seed coat where they are esterified to the arabinose side groups of arabinoxylans (Antoine et al., 2003; Maillard & Berset, 1995; Parker et al., 2005). On the other hand, Goupy et al., (1999) have reported that free and other soluble phenolics, such as phenolic acid esters, are mainly found in the aleurone layer and starchy endosperm of barley. Sosulski et al., (1982) reported the presence of trans-ferulic, syringic and vanillic acids in wheat while Hatcher and Kruger, (1997) reported six phenolic acids, namely sinapic, ferulic, vanillic, syringic, caffeic and p-coumaric acids in wheat (Liyana-Pathirana & Shahidi, 2007).

The European Prospective Investigation into Cancer and Nutrition (EPIC) (Bingham et al., 2003) recommended that people eating low fiber diets could significantly reduce the risk of colorectal cancer, by 40%, by eating more fibre-rich foods. Similarly, the World Cancer Research Fund's report on cancer and diet, physical activity, and weight suggested that foods containing fiber decrease risk of colorectal cancer (Stevenson et al., 2012; WCRF/AICR, 2007).

The amount of dry matters and starch in germinated grain reduces. However, the amounts of amino acids compositions, polyunsaturated fatty acids, B group vitamins, sugar increases and the content of anti-nutritional substances reduces (Chavan et al., 1989; Finney & Friedman, 1978). Germinated grain contains huger quantum of essential amino acids (lysine, methionine etc.), which take part in protein production in a human body (Harmuth-Hoene, 1988; Jahn-Deesbach & Schipper, 1991; Tkachuk, 1979). Besides, dietary fiber in grain bran is not lost (Seibold, 1990). It was established that the longer is the period of germination, the vaster is the content of vitamin C, beta carotene, and other antioxidants (Augustin et al., 1983; Harmuth-Hoene et al., 1987; Heinonen et al., 1989; Yang, 2001). Antioxidant biosynthesis at the time of grain germination depends on temperature, lighting, air and humidity (Kraujutiene et al., 2010; Price, 1988; Sattar et al., 1989; Seibold, 1990).

1.3.2. Lentil and Germinated Lentil

Germination process can be considered as a natural and safe process of enzymatic modification to develop functional, as well as nutritional properties of lentil seeds (Bamdad et al., 2009). Germination of legume seeds has been documented to be an effective treatment to reduce anti-nutritional factors and improve the nutritional quality by increasing the level of some amino acids, vitamins and minerals (Urbano et al., 2005b; Vidal-Valverde et al., 2002). Germination causes important changes in the biochemical, nutritional and sensory characteristics of legume seeds, due mainly to enzyme activity in moist seeds, which is engaged in protein and starch hydrolysis (Sadowska et al., 1999). Increased enzymatic activities in the germinating seeds are usually accompanied by interconversion and production of new compounds (Ahmed et al., 2003; Bamdad et al., 2009; Wanasundara et al., 1999). During germination, the

reserved nutrients (carbohydrates, proteins, and lipids) stored in the cotyledon are degraded by enzymes and used for the respiration and development of the embryo (Bryant, 1985; Joshi et al., 2010).

According to the current state of knowledge, germinated seeds are characterized by higher contents of nutrients, notably amino acids, peptides, vitamins, and minerals, (Frias et al., 2002; Kuo et al., 2004) and lower levels of non-nutrients like trypsin inhibitors, galactosides, tannins, and lectins (Bau et al., 1999; Chang & Harrold, 1988; Frias et al., 1995; Ibrahim et al., 2002; Savelkoul et al., 1992) compared to their ungerminated analogues. Changes in the content of polyphenolic antioxidants for different legumes as a result of germination have also been reported (Bartolomé et al., 1997; López-Amorós et al., 2006; Oomah et al., 2011; Troszyńska et al., 2011; Urbano et al., 2005a).

1.3.3. Other Legumes

Several studies on the effect of germination on legumes found that germination can increase protein content and dietary fiber, reduce tannin and phytic acid content and increase mineral bioavailability (Ghanem & Hussein, 1999; Ghavidel & Prakash, 2007b; Rao & Prabhavathi, 1982). Germination also was reported to be associated with an increase of vitamin concentrations and bioavailability of trace elements and minerals (El-Adawy et al., 2003). Kaushik et al., (2010) found that germination improves calcium, copper, manganese, zinc, riboflavin, niacin and ascorbic acid content. In cereal grains, germination increase oligosaccharides and amino acids concentration as observed in barley (Rimsten et al., 2002), wheat (Yang, 2001), oat (Mikola et al., 2001) and rice (Naing & Pe, 1995). Decomposition of high molecular weight polymers causes generation of bio-functional substances and improvement of organoleptic qualities due to softening of texture and increase of flavor in grains (Beal & Mottram, 1993). In Japan, germination was used to enhance flavor and nutrients in brown rice apart from softened the texture (Megat Rusydi et al., 2011; Ohtsubo et al., 2005).

The effect of germination on the chemical and biochemical constituents of seeds vary greatly with plant species, seed varieties and the germination conditions such as

temperature, light, moisture and the time of germination (Bau et al., 1999; Kuo et al., 2004; Megat Rusydi et al., 2011; Sattar et al., 1989).

Germination also affects the anti-nutritional factors of the legume, although there is some disagreement as to the ultimate consequences because the effect depends on the type of legume and on the conditions and duration of the germinating process (Savelkoul et al., 1992). Thus, various authors (Ibrahim et al., 2002; Mbithi et al., 2001) have found significant reductions in trypsin inhibitor activity (TIA) content, while others (Chang & Harrold, 1988; Frias et al., 1995) found no substantial variations in TIA levels in beans and lentils after germination periods of up to 6 days (Urbano et al., 2005a).

With regard to the functionality of the nutrients, Nnanna et al., (1990), Bau et al., (2000), and Uwaegbute et al., (2000) reported that long germination periods have a negative effect on the organoleptic properties of legume seeds. Mbithi-Mwikya et al., (2000) reported that germination for periods exceeding 48 h produces considerable losses of dry matter through respiration (Urbano et al., 2005a)

Heat processing in general, improves the nutritive value of legume proteins, by inactivating trypsin and growth inhibitors and hemagglutinin (Swaminathan, 1974; Tharanathan & Mahadevamma, 2003).

Germination has an important effect on the water-soluble vitamin composition of legumes, and sprouted legumes usually contain different levels of some vitamins (ascorbic acid, thiamine, riboflavin, niacin, vitamin B6, total folacin and total pantothenic acid) compared to levels in the corresponding dry seeds (Augustin & Klein, 1989; Kavas & El, 1992; Nnanna & Phillips, 1989; Sattar et al., 1989). Despite the fact that there are some reports about the effect of germination on the vitamin content in legumes, most of the studies cited here were performed with soybeans or chickpeas, using a single set of germination conditions, and the results in terms of vitamin content are sometimes contradictory, and dependent on the variety of the legume (Finney et al., 1983; Prodanov et al., 1997).

1.4. Ultrasound Processing

Ultrasound, in its most basic definition, refers to pressure waves with a frequency of 20 kHz or more (Butz & Tauscher, 2002). Generally, ultrasound equipment uses frequencies from 20 kHz to 10 MHz. Higher-power ultrasound at lower frequencies (20 to 100 kHz), which is referred to as ‘‘power ultrasound’’, has the ability to cause cavitation, which has uses in food processing to inactivate microbes. Types of transducers that can accomplish the generation of ultrasonic waves, equipment, and their functions are given in details by Povey and Mason, (1998).

Ultrasound has been successfully used by the food industry for: the measurement of thickness of pipes, chocolate layers, fat, lean tissues in meat, canned liquids and shell eggs; detection of contaminants such as pieces of metal, glass or wood in foods; measurement of flow rates through pipes; determination of food composition; and measurement of particle size distribution in dispersed systems. However, further research is required before ultrasound becomes an alternative method of food preservation (Piyasena et al., 2003).

Ultrasound has been used physically or chemically in many aspects of food processing and preservation, for example pasteurization, sterilization, generation of emulsions, disruption of cells, promotion of chemical reactions, inhibition of enzymes, tenderizing meat and modification of crystallization (Chemat & Hoarau, 2004; Mason et al., 1996; Yıldırım et al., 2013).

Ultrasound has been used to enhance mass transfer in solid/liquid food systems (Gallego-Juárez & Fuente, 2004; Riera et al., 2004). Ultrasound applications were reported to promote the leaching of oligosaccharides in legumes (Han & Baik, 2006) and to reduce cooking time of rice (Wambura et al., 2008; Yıldırım et al., 2011).

In recent years, ultrasound (US) in the food industry has been the subject of research and development. There is a great interest in ultrasound due to the fact that industries can be provided with practical and reliable ultrasound equipment. Nowadays, its emergence as green novel technology has also attracted the attention to its role in the environment sustainability. Ultrasound applications are based on three different methods; direct application to the product, coupling with the device, and submergence in an ultrasonic bath (Chemat et al., 2011).

Ultrasound treatment to stimulate germination has been investigated in many seed types including carrot, radish, maize, barley, rice and sunflower (Aladjadjiyan, 2002; Carbonell et al., 2000; Florez et al., 2007; Hebling & da Silva, 1995; Miyoshi & Mii, 1988; Shimomura, 1998; Yaldagard et al., 2008a, 2008c). Results of these investigations indicated that the effects of ultrasound on seed germination depend on frequency and exposure time and appear to vary widely between the different species and cultivars (Goussous et al., 2010).

The application of ultrasonic stimulation for rising seed germination and early stages plant development has been investigated for different cultures: chickpea, wheat, pepper, and watermelon (Goussous et al., 2010), corn (Hebling & da Silva, 1995), rice cells (Oryza sativa Nipponbare) (Liu et al., 2003), pepper, tomatoes and cucumbers (Markov et al., 1987), fodder beans, radish (Shimomura, 1990), carrot (Aladjadjiyan, 2002), ornamental trees (Aladjadjiyan, 2003). Ultrasonic treatment of seeds was used also for industrial purposes like oil extraction and malts preparation (Kobus, 2008; Yaldagard et al., 2008a; Yaldagard et al., 2008b; Yaldagard et al., 2008c) since cell destruction under the shock of the ultrasonic wave with high intensity facilitates extraction (Aladjadjiyan, 2011).

1.5. Microwave Operation

Microwaves are electromagnetic waves whose frequency varies within 300 MHz to 300 GHz. Domestic microwave appliances operate generally at a frequency of 2.45 GHz, while industrial microwave systems operate at frequencies of 915 MHz and 2.45 GHz (Chandrasekaran et al., 2013; Datta, 2001). Microwaves (300 MHz to 300 GHz) produces changes in the cell membrane's permeability and cell growth rate as well as interference with ions and organic molecules, like proteins (Ragha et al., 2011; Ungureanu et al., 2009).

Banik et al., (2003) reviewed the bioeffects of the microwave, mostly on animal and human health. In their paper, the most popular opinion has been outlined, that the effect of the microwave is attributed mainly to the heating. Nevertheless, it has been mentioned that there are also non–thermal microwave effects in terms of energy required to produce molecular transformations (Aladjadjiyan, 2010).

It has been accepted, (Buffler, 1993), that the thermal effect of the microwave is related to the interaction with charged particles and polar molecules. Microwave fields are a form of electromagnetic energy and its interaction with charged particles and polar molecules lead to their agitation which is defined as heat. Biological material placed in such radiation absorbs an amount of energy which depends on the dielectric characteristics of the material (Aladjadjiyan, 2010).

Reddy et al., (1995) and Reddy et al., (1998) used successfully the treatment with electromagnetic radiation from the radio- (10–40 MHz) and microwave diapason (2.45 GHz) on seeds of mustard, wheat, soybean, peas and rice seeking to eliminate the microorganisms *(Fusarium graminearum*) before seed storage (Aladjadjiyan, 2010).

Some authors have investigated the influence of microwave treatment on different properties of seeds. Yoshida et al., (2000) treated soybean seeds with microwave radiation (2.45 GHz) for 6 to 12 min with the aim to improve the distribution of triglycerides in the seed coat. Oprica, (2008) has studied microwave treatment with power density under 1 mW/cm^3 on rapeseeds (*Brassica napus*) and concluded that the microwaves determined variations of catalase and peroxidase activities depending on the age of the plants, time of exposure and state of seeds (germinated and non-germinated) exposed to microwave (Aladjadjiyan, 2010).

Low-intensity microwave radiation on the germination of cereals (winter and spring wheat, spring barley, and oats) causes an increasing of germination for all the treated seeds (Aladjadjiyan, 2010).

Cooking of chickpea by microwave shown that it reduces anti-nutritive agents in soybean (Rajkó et al., 1997) and have positive effects on protein digestibility (Khatoon & Prakash, 2004) in eight whole legumes (Alajaji & El-Adawy, 2006).

The microwave drying helps remove the moisture content from the food products without the problem of case hardening (Schiffmann, 1986). The microwaves have the distinct advantage in drying and thawing of foods as the heat is generated within the food material by reorientation of the dipoles which in turn cause molecular friction and generate heat (Datta, 1990; Decareau, 1985). Doty and Baker, (1976) studied microwave conditioning of durum and HRS wheat by taking 200 g samples with moisture contents of 15, 15.5 and 16 % at 22–100 ^{o}C. The microwave energy

significantly affected all the physical and biochemical properties of wheat. Campana et al., (1986) and Campana et al., (1993) reported that the total protein content was not affected even by heating to 91 ^{o}C in microwave dryer, but germination and wet gluten content were progressively affected by temperatures above 60 and 66 ^{o}C respectively. The functionality of gluten altered gradually with increase in time of exposure of microwave drying. The grain temperature is more critical than that of drying air, and it should not be above 60 ^{o}C (Okazaki & Ishihara, 1980; Walde et al., 2002).

1.6. The Aim of This Study

The aim of this thesis is to investigate the germination operation; to develop a new germinated product (germinated bulgur and germinated lentil product), to develop new techniques such as microwave and ultrasound aided germination methods to enhance germination yield.

CHAPTER 2.

MICROWAVE AND ULTRASOUND AIDED GERMINATION TO PRODUCE GERMINATED BULGUR AS A NEW PRODUCT

In this chapter, microwave and ultrasound were used to improve the nutritional values and increase the germination performance of durum wheat (*Triticum durum*). Microwave and ultrasound applications were carried out at each 6 hours intervals during 20 hours (25 ^{o}C, 95 % RH, and non-illuminated condition). At microwave practice, at each 6-hour time intervals, the samples were subjected to microwave for 1, 3 and 5 minutes. Three different power levels were used at 1, 3 and 5 W/kg during the applications.

At ultrasound (40 kHz) practice, again at each 6-hour time intervals, the samples were subjected to ultrasound for 10, 20 and 30 minutes. Power levels were 10, 30 and 50 W/kg.

After germination process, bulguration (combined cooking and drying operation) of germinated wheat were done, and then bulgur was produced by milling and sieving. At final products; yield (%), 1000-kernels weight (g, d.b.), hectoliter-weight (kg/100 L), moisture (%, d.b.), ash (%, d.b.), protein (%, d.b.), fat (%, d.b.) and starch contents (%, d.b.), color (CIE L*, a*, b, YI), water absorption capacity (%, d.b.), water-soluble substance (%, g/g), and sensory analyses were done for wheat and bulgur.

Ultrasound and microwave operations decreased the protein content of wheat and fat content of bulgur significantly ($P \leq 0.05$). Also, germination decreased the fat and starch contents of wheat ($P \leq 0.05$). However, increase in exposure power of treatments increased the protein content of bulgur ($P \leq 0.05$). In addition, germination, ultrasound and microwave operations increased CIE L* of wheat and bulgur, also CIE b* of wheat increased significantly.

Key Words: Germination, microwave, ultrasound, wheat, bulgur

2.1. Introduction

As a whole grain food, bulgur is popular in the health food sector, and its pleasant flavor lends itself to inclusion in vegetarian meals (Bayram, 2000; Bayram et al., 2004a; Bayram & Öner, 1996, 2002; Bayram et al., 1996; Bayram & Öner, 2005; Bayram et al., 2004c; Bayram et al., 2004d).

It is more stable than wheat due to the restriction of respiration, enzymatic and microbial activities during the cooking operation in hot and humid environmental conditions (Bayram, 2006; Bayram & Öner, 1996; Bayram et al., 1996).

In poor countries, intake of protein is expensive due to the high price of meat. Cereals, legumes, and their products play an important role in the protein supply in these countries. To solve some nutritional problems in poor countries, protein rich foods are needed. In spite of the fact that bulgur has a high nutritional value, like everything else bulgur is needed to be upgraded in the globalized world. In recent years, with the aim of improving the nutritive value of cereals and legumes, preparation techniques such as germination and fermentation have been developed.

The germination of seeds is a method that has been in existence for centuries, having been particularly developed using traditional procedures in the countries of the Far East and India (Deshpande & Deshpande, 1991). During germination, the seeds are transformed from the dormant state into a metabolically active state. This process involves intensive mobilization of the stored reserves, which results in a rapid increase in respiration, the synthesis of proteins and nucleic acids, and the elongation and division of cells (Górecki et al., 2000; Kadlec et al., 2008).

A number of studies have performed to investigate the influence of germination on wheat (Hung et al., 2012; Ijarotimi, 2012; Kraujutiene et al., 2010; Morad & Rubenthaler, 1983). It has been reported that protein (Ijarotimi, 2012; Kraujutiene et al., 2010), ash (Hung et al., 2012), moisture (Ijarotimi, 2012; Morad & Rubenthaler, 1983), and hectoliter-weight increased; however, fat and starch content (Ijarotimi, 2012) decreased during germination of wheat grain.

In addition to these, germination has also benefits in terms of health. Wheat grain sprouts may also scavenge free radicals in a human body, reduce the level of

cholesterol and improve immune system (Seibold, 1990). Thus, at present germination is more and more widely used not only for improvement of nutritional grain quality but also as a raw material for healthy food production (Kraujutiene et al., 2010; Lintschinger et al., 1997; Lorenz & D'Appolonia, 1980; Price, 1988; Yang, 2001).

However, no research has focused on the application of ultrasound and microwave during germination. Also, there is no study about bulgur which is made from germinated wheat in spite of nutritional improvement and health benefit effects of germination. The aim of this study was to investigate a) the effect of germination on *Triticum durum* wheat, b) the effect of germinated wheat used for bulgur production, c) the production of new bulgur named as germinated bulgur, d) the effect of the application of ultrasound and microwave techniques **during germination** instead of **before** germination, and e) the acceptability of germinated bulgur by consumers.

2.2. Materials and Methods

2.2.1. Sample Preparation

Wheat (*Triticum durum*) harvested in 2013 were obtained from a local bulgur factory in Gaziantep. The properties of wheat used in this study were shown in Table 2.1. Wheat was cleaned by using 2.5 mm sieve and germinated for 20 hours between two coarse filter papers in a climate cabinet (25 ^{o}C, 95 % RH, and non-illuminated condition) (Nüve ID 501, Ankara, Turkey) with adding water continuously to prevent the dehydration of the samples. Germination system and germinated wheat were shown in Figure 2.1. Microwave and ultrasound applications were made for 6-hours intervals for 20 hours of germination operation. At the microwave operation, which was made in a microwave oven (Bosch HMT84G421, Stuttgart, Germany); at each 6-hours intervals, the samples were subjected to the microwave for 1, 3 and 5 minutes at 1, 3 and 5 W/kg. At the ultrasound (40 kHz) application, which was made in an ultrasonic water bath (100 W/cm^3, 4 L, Modified Minisonik, Min 18, Intersonik, Istanbul, Turkey); again at each 6-hours intervals, the samples were subjected to the ultrasound application for 10, 20 and 30 minutes. The power levels used during the applications were 10, 30 and 50 W/kg. The volume of water in the ultrasonic water bath needed to obtain desired power level was calculated according to the density of

each sample and also power (100 W/cm3) and wash volume (4 L) of the ultrasonic water bath. After 20 hours germination process, the germinated wheat grains were dried in a packed bed dryer (MK II, Sherwood Scientific, Cambridge, UK) at 90 ^{o}C. After that, bulguration (combined cooking and drying operation) (Bayram, 2007) of germinated wheat were made and bulgur was produced by a hammer mill (Armfield Co., England). Then, the sieving was made to separate flour. After sieving, the product between 1.6 – 2.8 mm sieves were taken as bulgur sample. Wheat samples after drying and bulgur samples after the bulguration process were stored at + 4 ^{o}C for the further analysis. The sample nomenclature was given in Table 2.2. Also, experimental set-up of germination process and bulgur process were illustrated in Figures 2.2. and 2.3.

Table 2.1. The properties of wheat used in the experiments

Properties		Wheat
	Protein content (%, d.b.)	9.91 (±0.03)
	Fat content (%, d.b.)	1.89 (±0.01)
	Starch content (%, d.b.)	70.38 (±0.49)
	Moisture content (%, d.b.)	8.03 (±0.47)
	Ash content (%, d.b.)	1.46 (±0.09)
	Water Absorption Capacity (%, d.b.)	31.90 (±0.17)
	Hectoliter-Weight (kg/100 L)	85.14 (±0.00)
	1000-kernels weight (g, d.b.)	43.56 (±0.00)
Color	CIE L*	51.00 (±0.11)
	CIE a*	9.50 (±0.19)
	CIE b*	25.62 (±0.33)
	CIE YI	76.56 (±0.41)

± means the standard deviation of measurements.
CIE L*: Lightness, CIE a*: Redness, CIE b*: Yellowness, CIE YI: Yellowness Index.

Figure 2.1. Germination system (left) and germinated wheat (right)

Table 2.2. Description of the samples

Wheat Samples	Germination (yes/no)	Process	Applied Power (W/kg)	Duration (min)	Bulgur Samples
WO (control)	No	No	0	0	BO (control)
WGO (control)	Yes	No	0	0	BGO (control)
WM11	Yes	Microwave	1	1	BM11
WM13	Yes	Microwave	1	3	BM13
WM15	Yes	Microwave	1	5	BM15
WM31	Yes	Microwave	3	1	BM31
WM33	Yes	Microwave	3	3	BM33
WM35	Yes	Microwave	3	5	BM35
WM51	Yes	Microwave	5	1	BM51
WM53	Yes	Microwave	5	3	BM53
WM55	Yes	Microwave	5	5	BM55
WU1010	Yes	Ultrasound	10	10	BU1010
WU1020	Yes	Ultrasound	10	20	BU1020
WU1030	Yes	Ultrasound	10	30	BU1030
WU3010	Yes	Ultrasound	30	10	BU3010
WU3020	Yes	Ultrasound	30	20	BU3020
WU3030	Yes	Ultrasound	30	30	BU3030
WU5010	Yes	Ultrasound	50	10	BU5010
WU5020	Yes	Ultrasound	50	20	BU5020
WU5030	Yes	Ultrasound	50	30	BU5030

W: Wheat, B: Bulgur, G: Germinated, O: Control, M: Microwave, U: Ultrasound.

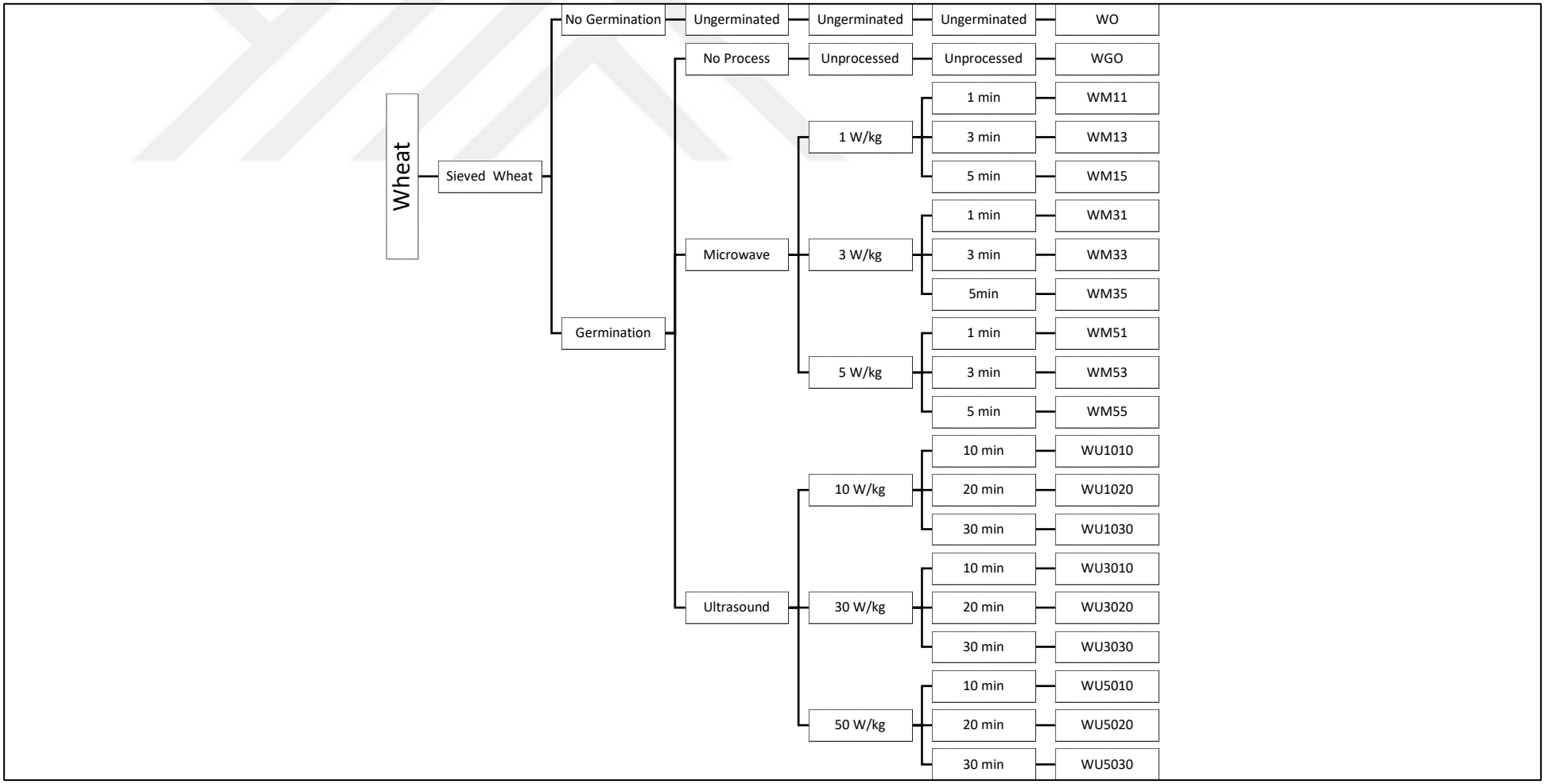


Figure 2.2. Experimental design of germination process of wheat samples

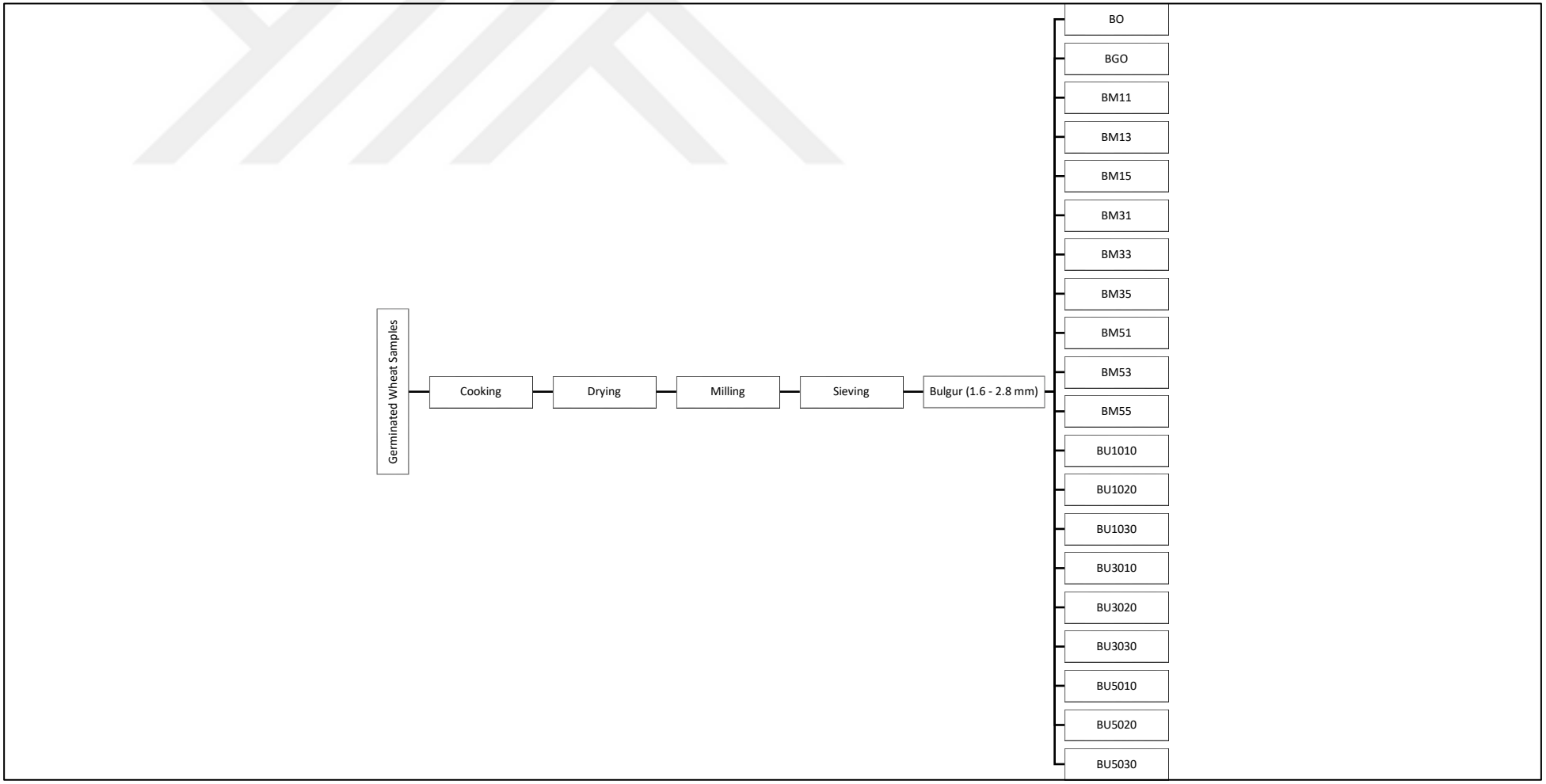


Figure 2.3. Experimental design of bulgur production

2.2.2. Chemicals

The chemicals used in protein, fat and starch contents analyses were obtained from Merck (Darmstadt, Germany).

2.2.3. Analyses

2.2.3.1. Physical and Chemical Analyses

Moisture (%, d.b.), ash (%, d.b.), protein (%, d.b.) and fat (%, d.b.) contents were measured by using the standard of AOAC methods (AOAC, 1990). For bulgur yield (%), the weight of unprocessed wheat and weight of final product bulgur was considered. 1000-kernels weight (g, d.b.) was calculated according to the method of Turkish Standards (TS 1136; TSE, 2007). Hectoliter-weight (kg/100 L) was determined according to the method of Turkish Standards (TS EN ISO 7971-1; TSE, 2012). The color was measured as CIE L*, a*, b*, and YI with HunterLab colorimeter (Colorflex 45/0, HunterLAB, USA). Before each of the color measurement, black and white standard tiles were used to calibrate colorimeter (L=93.01, a=-1.11, b=1.30). The color measurements were performed at room temperature (25 ± 2 °C). Analysis of starch content (%, d.b.) was carried out according to ISO 10520 (ISO, 1998). Analysis of water-soluble substances (%, g/g) for the bulgur samples was calculated according to the percentage change during the cooking of wheat. Analysis of water absorption capacity (%, d.b.) was carried out according to weight difference after and before immersion at 20 ^{o}C for 60 minutes (Joshi et al., 2010).

2.2.3.2. Sensory Analysis

Bulgur pilaf was made from 3 bulgur samples which were control sample (1) and the best bulgur from the ultrasound (2) and microwave (3) applications according to nutritional values. The best bulgur samples were chosen according to the highest protein, lowest fat and starch contents. Sensory analysis was done with a scoring test by 15 panelists in Sensory Analysis Laboratory, Gaziantep University.

The panelists were scored according to flavor, odor, texture, appearance and overall effect of the pilaf samples.

2.2.4. Statistical Analyses

The analysis was carried out in 2 replicates for all determinations. The mean and standard deviation of means were calculated. The data were analyzed by one-way analysis of variance (ANOVA) ($P<0.05$). Duncan test were applied to determine difference between the measurements. A multiple comparison procedure of the treatment means was performed by Pearson correlation test. Statistical Analyses were carried out by using IBM SPSS Statistics (v22.0.0, 2014, IBM Corporation, New York, USA).

In the text of the results and discussion section, the numbers in the parentheses are the Pearson correlation coefficients.

2.3. Results and Discussion

2.3.1. The Changes in Protein, Fat and Starch Contents of Wheat Samples

The protein, fat and starch contents of wheat samples after germination and treatments (microwave and ultrasound) were presented in Table 2.3. Also, Pearson test results of wheat samples were given in Table A.4. (Appendix).

According to the result, the germination process caused decrease in protein content (WGO).

In general, the protein content of the samples decreased by using ultrasound and microwave treatments ($P\leq0.05$) (-0.345). The treatments e.g. microwave, ultrasound, increase in exposure power and exposure time of microwave and ultrasound treatment have resulted in a decrement in protein content. However, it has been reported that the protein content increased during the germination of wheat grain (Ijarotimi, 2012; Kraujutiene et al., 2010). The highest value of protein content (10.78 %) was obtained for WM51 which wheat was germinated and exposed to the microwave for 1 min at 5

W/kg. Also, there was an increase in protein content, from 9.91 to 10.66 % was obtained from WM11 which was microwave treated germinated wheat for 1 min and 1 W/kg. In some treatments, microwave treatment is the major factor for increasing protein content. Because microwave treatment was increased the protein content of WM51 from 9.91 to 10.78 %, WM11 from 9.91 to 10.66 %, WM15 from 9.91 to 10.46 % and WM33 from 9.91 to 10.24 %.

The fat content of wheat samples was decreased during germination ($P \leq 0.01$) (-0.421), which the treatments, increasing exposure time and power for ultrasound and microwave. The results in this study are corresponding to the results in the literature, which the fat content decreased during germination of wheat grain (Ijarotimi, 2012). The lowest value obtained was 1.18 % for WU5030 sample, which was ultrasound treated germinated wheat for 30 min and 50 W/kg, and WU3010 sample, which was ultrasound treated germinated wheat for 10 min and 30 W/kg (the initial value of 1.89 %). Also, there was a decrease in fat content, from 1.89 to 1.24 % was obtained from WM35, which was microwave treated germinated wheat for 5 min and 3 W/kg. Germination and increasing exposure time and power of treatments decrease the fat content of wheat. The major decrement of fat content was provided by germination from 1.89 to 1.36 %. In this study, if it is desired, fat content can be decreased by using these treatments.

Starch content was decreased during germination ($P \leq 0.05$) (-0.395). Also, it decreased due to the treatment of ultrasound and microwave and increasing the exposure time of the treatments during the germination operation. Starch content decreased during the germination of wheat grain (Ijarotimi, 2012). The initial value of the wheat samples was 70.38 %. The lowest value was obtained as 61.95 % for WU3020, which was ultrasound treated during germination at 30 W/kg for 20 min. Also, there was a decrease in starch content, from 70.38 to 61.97 %, was obtained from WGO which was germinated wheat. In this research, it was founded that germination, treatments and increasing the exposure time decreased the starch content of wheat samples.

Table 2.3. The protein, fat and starch contents of the samples after the germination and treatments

Sample	PC	FC	SC
WO (control)	9.91^{cdef} (± 0.03)	1.89^{j} (± 0.01)	70.38^{c} (± 0.49)
WGO (control)	9.60^{bcde} (± 0.19)	1.36^{cdef} (± 0.00)	61.97^{a} (± 0.24)
WM11	10.66^{gh} (± 0.17)	1.28^{abcd} (± 0.09)	63.57^{ab} (± 2.24)
WM13	9.88^{cdef} (± 0.03)	1.26^{abc} (± 0.06)	62.29^{a} (± 1.01)
WM15	10.46^{fgh} (± 0.20)	1.72^{i} (± 0.01)	69.11^{bc} (± 3.35)
WM31	10.13^{defgh} (± 0.23)	1.29^{abcd} (± 0.03)	65.01^{abc} (± 3.07)
WM33	10.24^{efgh} (± 0.37)	1.25^{ab} (± 0.07)	64.59^{abc} (± 2.13)
WM35	9.91^{cdef} (± 0.14)	1.24^{ab} (± 0.02)	62.67^{a} (± 0.41)
WM51	10.78^{h} (± 0.03)	1.42^{efgh} (± 0.02)	64.78^{abc} (± 1.30)
WM53	9.97^{cdefg} (± 0.63)	1.31^{bcde} (± 0.09)	67.21^{abc} (± 4.16)
WM55	8.85^{a} (± 0.37)	1.50^{h} (± 0.00)	66.77^{abc} (± 2.49)
WU1010	9.35^{abc} (± 0.32)	1.47^{fgh} (± 0.07)	66.32^{abc} (± 3.21)
WU1020	9.72^{cdef} (± 0.19)	1.99^{j} (± 0.03)	64.93^{abc} (± 3.60)
WU1030	9.45^{abcd} (± 0.13)	1.52^{h} (± 0.00)	63.17^{ab} (± 2.02)
WU3010	8.92^{ab} (± 0.59)	1.18^{a} (± 0.07)	67.10^{abc} (± 2.71)
WU3020	9.30^{abc} (± 0.22)	1.48^{gh} (± 0.00)	61.95^{a} (± 0.08)
WU3030	9.28^{abc} (± 0.19)	1.36^{cdef} (± 0.02)	65.47^{abc} (± 0.89)
WU5010	9.78^{cdef} (± 0.10)	1.91^{j} (± 0.10)	67.34^{abc} (± 4.43)
WU5020	9.42^{abcd} (± 0.29)	1.39^{defg} (± 0.05)	64.82^{abc} (± 4.31)
WU5030	10.30^{efgh} (± 0.61)	1.18^{a} (± 0.02)	67.29^{abc} (± 1.21)
n	3	3	3
min	8.85	1.18	61.95
max	10.78	1.99	70.38
Av.	9.80	1.45	65.34

n means the number of a run for each data.
± means the standard deviation of "n" number of measurements.
PC: Protein Content (%, d.b.), FC: Fat Content (%, d.b.), SC: Starch Content (%, d.b.).
a, b, c etc. show Duncan Test homogeneous groups ($P<0.05$).

2.3.2. The Changes in Color Values of Wheat Samples

Bulgur should have a light yellow, homogeneous color (Bayram et al., 2003). The main purpose of polishing operation during production is to increase CIE L* and CIE b* values while to decrease CIE a* and CIE YI values according to Bayram, (2005). Therefore, durum wheat will be used for bulgur production should meet these properties. Color values of wheat samples after germination and the treatments were presented in Table 2.4. Also, Pearson test results of wheat samples were given in Table A.4. (Appendix).

The CIE L* value shows the darkness (0) and lightness (+100). CIE L* value increased with the germination operation (0.656) and the microwave and ultrasound treatments (0.563) ($P \leq 0.01$). The increase in exposure power and exposure time of microwave and ultrasound treatments resulted in an increase in CIE L* value. The highest value of CIE L* (55.99) was obtained for WU3020 which wheat was germinated and exposed to the ultrasound (40kHz) for 20 min at 30 W/kg. Also, there was an increase in CIE L* value, from 51.00 to 55.80, was obtained for WU3030, which was ultrasound treated germinated wheat for 30 min and 30 W/kg. The germination is the major factor for increasing CIE L* value. Because the germination increased the CIE L* value of wheat from 51.00 to 54.62. Considering a higher increment in CIE L* value is desired, wheat should be germinated and treated with ultrasound at higher power and time.

The CIE a* value shows the redness (+) and greenness (-). The CIE a* value decreased during the germination ($P \leq 0.01$) (-0.530), and increasing exposure time and power for ultrasound and microwave. The lowest value obtained was 8.36 for WGO sample with the germination operation (the initial value of 9.50). Also, there was a decrease in CIE a* value, from 9.50 to 8.55, was obtained for WU3020, which was ultrasound treated germinated wheat for 20 min and 30 W/kg. Germination and increasing exposure time and power of the treatments decrease the redness of wheat. The major decrement of CIE a* value was provided by the germination.

Table 2.4. Color values of the samples

Sample	CIE L*	CIE a*	CIE b*	CIE YI
WO (control)	51.00^{a} (± 0.11)	9.50^{f} (± 0.19)	25.62^{a} (± 0.33)	76.56^{b} (± 0.41)
WGO (control)	54.62^{cdefgh} (± 0.59)	8.36^{a} (± 0.08)	28.63^{cd} (± 0.61)	76.92^{bc} (± 0.41)
WM11	55.07^{defgh} (± 0.15)	8.69^{abc} (± 0.02)	28.88^{cde} (± 0.04)	77.41^{bcd} (± 0.24)
WM13	55.02^{cdefgh} (± 0.93)	8.63^{ab} (± 0.36)	29.27^{cdef} (± 0.04)	78.02^{bcde} (± 1.34)
WM15	54.44^{bcdefgh} (± 0.33)	8.76^{abcd} (± 0.17)	29.23^{cdef} (± 0.59)	78.60^{cde} (± 0.92)
WM31	54.08^{bcdef} (± 0.45)	8.86^{bcde} (± 0.20)	29.22^{cdef} (± 0.19)	79.06^{de} (± 0.99)
WM33	53.00^{b} (± 0.39)	8.93^{bcde} (± 0.16)	28.73^{cde} (± 0.41)	79.26^{de} (± 1.23)
WM35	53.85^{bcde} (± 1.59)	8.82^{bcde} (± 0.22)	29.08^{cdef} (± 1.33)	78.97^{de} (± 0.47)
WM51	53.99^{bcdef} (± 0.07)	9.10^{cde} (± 0.13)	29.46^{cdef} (± 0.34)	79.60^{e} (± 1.00)
WM53	54.39^{bcdefgh} (± 0.24)	8.69^{abc} (± 0.13)	29.36^{cdef} (± 0.81)	78.73^{cde} (± 1.25)
WM55	53.43^{bc} (± 0.39)	8.94^{bcde} (± 0.24)	28.99^{cde} (± 0.31)	79.35^{de} (± 1.18)
WU1010	54.24^{bcdefg} (± 0.38)	9.14^{def} (± 0.16)	29.49^{cdef} (± 0.76)	79.75^{e} (± 1.11)
WU1020	53.76^{bcd} (± 0.51)	9.22^{ef} (± 0.24)	30.39^{f} (± 0.00)	81.71^{f} (± 0.79)
WU1030	54.73^{cdefgh} (± 0.16)	8.74^{abcd} (± 0.17)	29.54^{cdef} (± 0.03)	78.85^{cde} (± 0.32)
WU3010	55.03^{cdefgh} (± 0.84)	8.77^{bcd} (± 0.06)	29.07^{cdef} (± 0.77)	77.72^{bcde} (± 0.26)
WU3020	55.99^{h} (± 0.78)	8.55^{ab} (± 0.15)	27.39^{b} (± 0.29)	74.04^{a} (± 1.32)
WU3030	55.80^{gh} (± 0.43)	9.07^{cde} (± 0.06)	30.01^{ef} (± 0.59)	79.13^{de} (± 0.48)
WU5010	55.44^{efgh} (± 0.80)	8.88^{bcde} (± 0.14)	29.81^{def} (± 0.39)	78.84^{cde} (± 0.26)
WU5020	55.58^{fgh} (± 1.20)	8.75^{abcd} (± 0.02)	28.28^{bc} (± 0.87)	76.11^{b} (± 0.45)
WU5030	54.64^{cdefgh} (± 0.63)	8.90^{bcde} (± 0.11)	29.44^{cdef} (± 0.34)	79.00^{de} (± 0.14)
n	4	4	4	4
min	51.00	8.36	25.62	74.04
max	55.99	9.50	30.39	81.71
Av.	54.40	8.86	28.99	78.38

n means the number of a run for each data.
± means the standard deviation of "n" number of measurements.
CIE L*: Lightness, CIE a*: Redness, CIE b*: Yellowness, CIE YI: Yellowness Index.
a, b, c etc. show Duncan Test homogeneous groups (P<0.05).

The CIE b* value shows the yellowness (+) and blueness (-). The CIE b* value increased with the germination (0.727), and the microwave and ultrasound treatments (0.446) (P≤0.01). Also, it increased with the increasing exposure time of the treatments

during the germination operation (0.376) ($P \leq 0.05$) and with increasing exposure power of the treatments during the germination operation. The initial value of the wheat sample was 25.62. The highest value was obtained as 30.39 with WU1020, which was ultrasound treated during germination at 10 W/kg for 20 min. Also, there was an increase in CIE b* value, from 25.62 to 30.01, was obtained for WU3030, which was ultrasound treated germinated wheat for 30 min and 30 W/kg. It is desired that CIE b* value of wheat should be higher for bulgur production. The germination operation and the treatments increase the yellowness of wheat.

Yellowness Index (CIE YI) is a measure of the color on the yellow scale that describes the change in color of a sample from clear or white toward yellow (Balcı, 2015). The CIE YI value increased not significantly ($P > 0.05$) with germination and all treatments. The initial value of the wheat sample was 76.56. The lowest value was obtained as 74.04 for WU3020, which was ultrasound treated during germination at 30 W/kg for 20 min. Also, there was a decrease in CIE YI value, from 76.56 to 76.11, was obtained for WU5020, which was ultrasound treated germinated wheat for 20 min and 50 W/kg.

2.3.3. The Changes in Ash and Moisture Contents, Water Absorption Capacity, Hectoliter-Weight, and 1000-Kernels Weight of Wheat Samples

The changes in ash and moisture content, water absorption capacity, hectoliter-weight, and 1000-kernels weight of wheat samples after germination and treatments were presented in Table 2.5. Also, Pearson test results of wheat samples were given in Table A.4. (Appendix).

Ash content of the wheat samples decreased with germination (-0.350) ($P \leq 0.05$). However, according to the results in the study of Hung et al., (2012) the ash content of wheat grain increased during germination. The initial ash content of control sample (WO sample) of wheat was 1.46 %. The highest ash content after the treatments was obtained as 1.43 % for WU5020, which was ultrasound treated germinated wheat for 20 min and 50 W/kg. Also, another high ash content after the operations was obtained as 1.39 % for WU1020, which was ultrasound treated germinated wheat for 20 min and 10 W/kg. Germination decreased the ash content of the wheat samples from 1.46

to 1.24 %. Considering a higher increment in the ash content is desired, wheat should be treated with ultrasound.

Table 2.5. The ash and moisture contents, water absorption capacity, hectoliter-weight, and 1000-kernels weight of the samples

Sample	AC	MC	WAC	HW	TKW
WO (control)	1.46^{g} (± 0.09)	8.03^{c} (± 0.47)	31.90^{de} (± 0.17)	85.14 (± 0.00)	43.56 (± 0.00)
WGO (control)	1.24^{bcd} (± 0.02)	15.98^{l} (± 0.22)	32.43^{e} (± 0.12)	68.22 (± 0.00)	42.06 (± 0.00)
WM11	1.31^{bcdef} (± 0.07)	12.13^{hij} (± 0.73)	30.51^{cde} (± 2.11)	70.92 (± 0.00)	41.00 (± 0.00)
WM13	1.29^{bcde} (± 0.01)	11.84^{ghi} (± 0.51)	31.18^{cde} (± 1.88)	76.94 (± 0.00)	42.08 (± 0.00)
WM15	1.27^{bcde} (± 0.06)	15.36^{l} (± 0.04)	26.33^{a} (± 1.39)	69.30 (± 0.00)	40.55 (± 0.00)
WM31	1.06^{a} (± 0.01)	12.42^{ijk} (± 0.07)	26.91^{ab} (± 1.79)	73.98 (± 0.00)	42.87 (± 0.00)
WM33	1.21^{b} (± 0.03)	11.27^{fg} (± 0.14)	30.03^{bcde} (± 2.05)	69.64 (± 0.00)	40.62 (± 0.00)
WM35	1.31^{bcdef} (± 0.05)	11.47^{fgh} (± 0.61)	26.85^{ab} (± 0.80)	68.02 (± 0.00)	44.58 (± 0.00)
WM51	1.27^{bcde} (± 0.06)	12.53^{ijk} (± 0.23)	32.62^{e} (± 0.38)	71.16 (± 0.00)	41.09 (± 0.00)
WM53	1.37^{defg} (± 0.02)	12.72^{jk} (± 0.37)	31.54^{de} (± 0.94)	69.82 (± 0.00)	43.54 (± 0.00)
WM55	1.33^{bcdefg} (± 0.01)	12.92^{k} (± 0.12)	30.25^{cde} (± 0.80)	69.58 (± 0.00)	42.68 (± 0.00)
WU1010	1.33^{bcdefg} (± 0.07)	9.48^{de} (± 0.66)	32.48^{e} (± 0.96)	69.90 (± 0.00)	39.50 (± 0.00)
WU1020	1.39^{efg} (± 0.01)	7.70^{bc} (± 0.21)	31.90^{de} (± 1.48)	75.24 (± 0.00)	39.72 (± 0.00)
WU1030	1.26^{bcde} (± 0.03)	10.81^{f} (± 0.04)	29.75^{bcde} (± 1.93)	70.80 (± 0.00)	39.24 (± 0.00)
WU3010	1.22^{bc} (± 0.07)	11.37^{fg} (± 0.04)	30.96^{cde} (± 2.04)	74.10 (± 0.00)	41.52 (± 0.00)
WU3020	1.35^{cdefg} (± 0.07)	10.75^{f} (± 0.26)	28.96^{abcd} (± 1.85)	76.06 (± 0.00)	42.74 (± 0.00)
WU3030	1.37^{defg} (± 0.09)	6.53^{a} (± 0.11)	28.80^{abcd} (± 0.36)	74.50 (± 0.00)	42.19 (± 0.00)
WU5010	1.36^{defg} (± 0.03)	10.03^{e} (± 0.08)	28.77^{abcd} (± 1.63)	71.82 (± 0.00)	41.08 (± 0.00)
WU5020	1.43^{fg} (± 0.04)	7.20^{ab} (± 0.05)	28.16^{abc} (± 0.43)	74.66 (± 0.00)	42.89 (± 0.00)
WU5030	1.38^{efg} (± 0.10)	8.87^{d} (± 0.03)	32.70^{e} (± 0.32)	73.98 (± 0.00)	40.15 (± 0.00)
n	3	3	3	1	1
min	1.06	6.53	26.33	68.02	39.24
max	1.46	15.98	32.70	85.14	44.58
Av.	1.31	10.97	30.15	72.69	41.68

n means the number of a run for each data.
± means the standard deviation of "n" number of measurements.
AC: Ash Content (%, d.b.), MC: Moisture Content (%, d.b.), WAC: Water Absorption Capacity (%, d.b.), HW: Hectoliter-Weight (kg/100 L), TKW: 1000-Kernels Weight (g, d.b.).
a, b, c etc. show Duncan Test homogeneous groups ($P<0.05$).

The moisture contents of wheat samples were decreased with ultrasound and microwave treatments (-0.563) ($P \leq 0.01$), increasing exposure time and power for ultrasound and microwave treatments. The lowest value obtained was 6.53 % for WU3030, sample which was ultrasound treated germinated wheat for 30 min and 30 W/kg (the control value of 8.03 %). Also, there was a decrease in moisture content from 8.03 to 7.20 % was obtained for WU5020, which was ultrasound treated germinated wheat for 20 min and 50 W/kg. Ultrasound and microwave treatments, increasing exposure time and increasing exposure power of treatments decrease the moisture content of wheat. Major decrease in the moisture content was provided by the ultrasound treatments.

The water absorption capacity of wheat samples decreased with increasing exposure time of treatments during germination ($P \leq 0.05$) (-0.362), ultrasound and microwave treatments, and increasing exposure power of treatments during germination of wheat samples. The water absorption capacity of control wheat sample was 31.90 %. The lowest value was obtained as 26.33 % for WM15, which was microwave treated wheat during germination at 1 W/kg for 5 min. Also, there was a decrease in water absorption capacity, from 31.90 to 26.85 %, was obtained for WM35, which was microwave treated germinated wheat for 5 min and 3 W/kg. The results show that major decrement provided by increasing the exposure time of the microwave and ultrasound treatments.

The hectoliter-weights of the wheat samples decreased during the germination operation ($P \leq 0.01$) (-0.736). Also, it decreased with microwave and ultrasound treatments, increasing exposure time and the power of the treatments during the germination operation. However, it decreased during the germination of wheat grain according to the study of Ijarotimi, (2012). Initial value for the wheat sample was 85.14 kg/100 L. The lowest value was obtained as 68.02 kg/100 L with WM35, which was microwave treated during germination at 3 W/kg for 5 min. Also, there was a decrement in hectoliter-weight, from 85.14 to 68.22 kg/100 L, was obtained from LGO, which was germinated wheat.

The 1000-kernels weight decreased significantly with germination, the ultrasound and microwave treatments ($P \leq 0.01$) (-0.445), and increasing the exposure time of treatments during the germination of the samples. The 1000-kernels weight of control value of wheat sample was 43.56 g. The lowest value was obtained as 39.24 g for

WU1030, which was ultrasound treated wheat during germination at 10 W/kg for 30 min. Also, there was a decrease in 1000-kernels weight, from 43.56 to 39.50 g was obtained for WU1010, which was ultrasound treated germinated wheat for 10 mins and 10 W/kg. The results show that significant decrement provided by the microwave and ultrasound treatments.

2.3.4. Relationship Between Parameters of Wheat Samples

Pearson test results of wheat samples were given in Table A.4. (Appendix).

There are positive significant correlations between fat content of the samples and the starch (0.336) and ash contents (0.382) of the samples at level $P \leq 0.05$. Also, a positive significant correlation has been observed between fat content and CIE a* value of the samples at level $P \leq 0.01$ (0.434). However, there is a negative significant correlation between fat content and hectoliter-weight (-0.325) of the samples at level $P \leq 0.05$. Therefore, the results showed that whenever the fat content of wheat samples decreased; the starch and ash contents, and CIE a* value of the samples decreased.

While there is a negative significant correlation between CIE L* and CIE a* values of the samples at level $P \leq 0.01$ (-0.628); a positive significant correlation has been observed between CIE L* and CIE b* values of the samples at level $P \leq 0.01$ (0.484). As CIE L* value of the samples increased; CIE a* and b* values decreased.

There are positive correlations between CIE a* and CIE YI values (0.484) and the hectoliter-weight (0.427) of the samples at level $P \leq 0.01$. Also, there is a positive correlation between CIE a* value and the ash content at level $P \leq 0.05$ (0.330). However, it has been observed that there is a negative correlation between CIE a* value and the moisture content of the samples at level $P \leq 0.01$ (-0.551). As the CIE a* value of the samples increases, a decrement observed in terms of CIE YI value, hectoliter-weight and ash content. However, the increment in the CIE a* value of the samples has resulted in an increment in terms of the moisture content.

Additionally, there is a positive significant correlation between CIE b* value and CIE YI value at level $P \leq 0.01$ (0.722). Negative significant correlation has been observed between CIE b* value and hectoliter-weight (-0.540) and 1000-kernels weight (-0.447)

of the samples at level P≤0.01. It has been observed that the CIE b* value increases as CIE YI value increases and hectoliter-weight and 1000-kernels weight of wheat samples decreases.

There is a positive significant correlation between the hectoliter-weight and the ash content of the samples at level P≤0.05 (0.356). But a negative significant correlation has been observed between hectoliter-weight and moisture content of wheat samples at level P≤0.01 (-0.570). As the hectoliter-weight of wheat samples increases, an increment in terms of ash content and a decrement in terms of the moisture content was observed.

Besides, it observed that there was a negative significant correlation between the ash and moisture contents of the samples at level P≤0.01 (-0.556). Therefore, the moisture content decreases as the ash content increases.

2.3.5. Bulgur Yield

Bulgur was produced from microwave and ultrasound aided germinated wheat in order to determine the yield.

Whole processes were initiated with 250 g of wheat. Therefore, it was investigated that how many grams of bulgur (between 1.6 – 2.8 mm sieve) were produced from 250 g treated with microwave and ultrasound, and germinated wheat. The yield during bulgur process was given in Table 2.6.

According to Table 2.6., the highest bulgur yield was obtained for WU5010; however, the lowest bulgur yield was obtained from WM53.

During the bulgur production, cooking of the wheat samples were controlled according to the cutting method (Bayram, 2006). This method was applied to examine for the opaque white centers of the endosperms of the cooked kernels, which were cut with a razor blade. Uniform gelatinization of starch throughout the kernel endosperm was required. It was obtained the differences between the cooking times. It is probably due to the application of microwave and ultrasound with different time and power was caused by changes in the structure and starch content of wheat.

Table 2.6. Bulgur yield data

Sample	Wheat (g)	Cleaned (2.5 mm) (g)	Germinated (g)	Germinated and Dried (g)	Start for Bulgur Production (g)	Cooking Time (min)	Cooked (g)	Dried (g)	Dehulled (g)	< 0.50 mm (g)	0.5-1.6 mm (g)	1.6-2.8 mm (g)	2.8-3.55 mm (g)	> 3.55 mm (g)
WO	250	231.79	NO	NO	231.88	55	390	241.25	232.17	4.40	16.4	93.95	91.31	17.52
WGO	250	229.75	345	237.86	182.70	49	282	181.05	171.25	4.00	18.15	97.64	42.95	4.95
WM11	250	232.71	358	243.10	185.18	60	311	184.77	175.77	6.00	17.5	86.35	51.72	8.20
WM13	250	236.34	361	246.60	187.90	63	320	186.00	177.32	5.96	22.6	90.77	45.75	5.66
WM15	250	236.61	345	245.37	187.28	53	305	186.00	177.36	3.78	18.11	87.52	55.16	7.09
WM31	250	238.37	365	249.68	190.53	48	299	185.00	179.38	4.00	19.34	101.65	41.28	4.53
WM33	250	234.19	362	240.17	184.32	54	303	183.00	175.48	4.18	16.33	90.40	49.84	7.17
WM35	250	236.85	365	244.43	189.00	66	310	187.00	179.71	3.17	16.09	85.15	57.63	13.69
WM51	250	237.06	358	245.75	189.00	53	302	188.00	180.48	2.98	12.37	78.35	66.96	13.97
WM53	250	233.03	345	244.49	185.82	54	300	183.00	177.15	2.65	10.57	73.35	69.16	16.75
WM55	250	228.20	340	237.16	180.80	55	290	179.00	172.73	1.93	10.44	73.73	66.00	14.30
WU1010	250	237.75	357	239.13	183.79	57	303	182.00	175.45	2.58	26.13	104.35	28.92	7.17
WU1020	250	236.55	359	231.78	176.20	47	289	175.00	165.56	15.20	40.2	92.10	8.96	1.00
WU1030	250	234.59	360	228.10	172.72	51	290	169.00	160.50	11.50	46.52	89.04	6.77	0.50
WU3010	250	237.13	358	234.28	178.90	63	306	177.00	170.30	10.49	35.88	98.95	17.11	1.59
WU3020	250	237.05	356	233.51	177.10	65	302	176.00	169.21	9.38	29.88	102.33	18.40	2.18
WU3030	250	236.01	357	228.07	172.66	46	277	172.00	155.32	29.47	51.4	64.29	2.72	0.56
WU5010	250	238.75	363	232.83	177.37	53	239	172.00	168.25	4.16	8.28	110.11	31.62	3.79
WU5020	250	234.24	357	229.46	173.80	42	301	172.00	163.56	18.72	51.28	77.55	6.47	0.60
WU5030	250	231.60	348	228.04	172.20	35	297	171.00	173.55	8.97	31.54	97.20	22.33	5.40

The mesh sizes for the cleaning and classification are according to Turkish Standards (TS 2284:2009).

2.3.6. Water-Soluble Substances Amount

The determination of water-soluble substances for the bulgur samples was calculated according to the percent change during the cooking of wheat while bulguration was carried out. The percentage of water-soluble substances was given in Table 2.7. Table 2.7. showed that WU1030 and WGO samples lost most in water-soluble substances. However, WM53 sample was the best sample according to less loss.

Table 2.7. The percentage of water-soluble substances of the samples

Sample	Percentage of water-soluble substances (%, g/g)
WO	2.96
WGO	4.40
WM11	3.72
WM13	1.14
WM15	2.34
WM31	2.70
WM33	1.55
WM35	1.47
WM51	3.63
WM53	0.32
WM55	2.53
WU1010	3.32
WU1020	1.78
WU1030	4.42
WU3010	2.25
WU3020	3.07
WU3030	3.83
WU5010	2.70
WU5020	1.40
WU5030	1.78

2.3.7. The Changes in Protein, Fat, and Starch Content of Bulgur Samples

The protein, fat and starch contents of bulgur samples after the germination and treatments were presented in Table 2.8. Also, Pearson test results of bulgur samples were given in Table A.5. (Appendix).

Table 2.8. The changes in protein, fat, and starch content of bulgur samples

Sample	PC	FC	SC
BO (control)	10.14^{a} (± 0.56)	0.73^{de} (± 0.05)	67.36^{cd} (± 0.04)
BGO (control)	9.89^{a} (± 0.33)	0.79^{efg} (± 0.06)	61.08^{ab} (± 1.48)
BM11	10.26^{a} (± 0.61)	1.22^{k} (± 0.00)	63.78^{abcd} (± 1.51)
BM13	10.17^{a} (± 0.02)	0.71^{de} (± 0.04)	62.02^{abc} (± 0.44)
BM15	10.44^{ab} (± 0.07)	0.89^{hi} (± 0.05)	68.60^{d} (± 0.75)
BM31	10.04^{a} (± 0.18)	1.22^{k} (± 0.09)	64.54^{abcd} (± 0.67)
BM33	10.00^{a} (± 0.63)	0.78^{efg} (± 0.01)	64.56^{abcd} (± 2.47)
BM35	10.12^{a} (± 0.16)	0.76^{def} (± 0.04)	60.81^{a} (± 2.12)
BM51	10.60^{a} (± 0.04)	0.84^{fgh} (± 0.05)	64.65^{abcd} (± 2.71)
BM53	10.04^{a} (± 0.50)	0.93^{i} (± 0.03)	66.60^{cd} (± 2.95)
BM55	10.38^{ab} (± 0.28)	0.85^{gh} (± 0.02)	66.16^{abcd} (± 3.74)
BU1010	10.17^{a} (± 0.16)	0.62^{bc} (± 0.03)	66.41^{bcd} (± 3.14)
BU1020	10.31^{a} (± 0.05)	0.60^{ab} (± 0.02)	63.88^{abcd} (± 2.24)
BU1030	10.24^{a} (± 0.37)	0.57^{ab} (± 0.02)	63.39^{abcd} (± 2.65)
BU3010	10.27^{a} (± 0.23)	0.70^{cd} (± 0.05)	67.02^{cd} (± 3.22)
BU3020	10.43^{ab} (± 0.11)	0.85^{gh} (± 0.01)	61.10^{ab} (± 0.50)
BU3030	9.97^{a} (± 0.01)	0.52^{a} (± 0.02)	64.64^{abcd} (± 1.49)
BU5010	11.15^{b} (± 0.72)	1.04^{j} (± 0.04)	67.33^{cd} (± 3.56)
BU5020	10.39^{ab} (± 0.23)	0.57^{ab} (± 0.01)	64.56^{abcd} (± 0.69)
BU5030	10.32^{a} (± 0.09)	0.86^{ghi} (± 0.02)	66.87^{cd} (± 2.19)
n	3	3	3
min	9.89	0.52	60.81
max	11.15	1.22	68.60
Av.	10.27	0.80	64.77

n means the number of a run for each data.
± means the standard deviation of "n" number of measurements.
PC: Protein Content (%, d.b.), FC: Fat Content (%, d.b.), SC: Starch Content (%, d.b.).
a, b, c etc. show Duncan Test homogeneous groups (P<0.05).

The protein content of bulgur samples increased with increase in exposure power (P≤0.05) (0.321). Additionally, germination and ultrasound and microwave treatments of wheat used for bulgur production have resulted in an increment in protein content

of bulgur samples. The highest value of protein content (11.15 %) was obtained for BU5010, which bulgur was produced from germinated wheat and exposed to the ultrasound (40kHz) for 10 min at 50 W/kg. Also, there was an increase in protein content, from 10.14 to 10.60 % was obtained for BM51, which was microwave treated germinated wheat for 1 min and 5 W/kg. Ultrasound treatment is the major factor for increasing protein content. Because ultrasound treatment increased the protein content of BU5010 from 10.14 to 11.15 %, BU3020 from 10.14 to 10.43 %, BU5020 from 10.14 to 10.39 % and BU5030 from 10.14 to 10.32 %. Considering a higher increment in the protein content is desired, bulgur should be produced from germinated and treated with ultrasound at higher power.

The fat content of bulgur samples decreased with ultrasound and microwave treatments ($P \leq 0.05$) (-0.319) and increasing exposure time for ultrasound and microwave. The lowest value obtained was 0.52 % for BU3030 sample, which bulgur was produced from ultrasound treated germinated wheat for 30 min and 30 W/kg (control value of 0.73 %). Also, there was a decrease in fat content, from 0.73 to 0.57 %, was obtained from BU5020, which bulgur was produced from ultrasound treated germinated wheat for 20 min and 50 W/kg and BU1030, which bulgur was produced from ultrasound treated germinated wheat for 30 min and 10 W/kg. Ultrasound and microwave treatments and increasing exposure time decrease the fat content of bulgur.

Starch content decreased with germination and increasing the exposure time of treatments during germination. The starch content of control bulgur sample was 67.36 %. The lowest value was obtained as 60.81 % with BM35 which bulgur was produced from microwave treated wheat during germination at 3 W/kg for 5 min. Also, there was a decrement in starch content, from 67.36 to 61.08 %, was obtained from BGO, which bulgur produced from germinated wheat. The major decrement of starch content was provided by germination from 67.36 to 61.08 %. Germination and increasing the exposure time decrease the starch content of bulgur samples.

2.3.8. The Changes in Color Values of Bulgur Samples

Color values of bulgur samples were presented in Table 2.9. Pearson test results of bulgur samples were given in Table A.5. (Appendix).

Table 2.9. The changes in color values of bulgur samples

Sample	CIE L*	CIE a*	CIE b*	CIE YI
BO (control)	56.57^{a} (± 0.04)	8.19^{k} (± 0.05)	30.00^{cd} (± 0.35)	77.35^{h} (± 0.65)
BGO (control)	57.29^{ab} (± 0.83)	7.55^{hij} (± 0.16)	29.64^{bcd} (± 0.43)	75.27^{fg} (± 0.28)
BM11	57.63^{bc} (± 0.47)	7.47^{efghij} (± 0.05)	29.44^{bcd} (± 0.07)	74.69^{efg} (± 0.33)
BM13	58.23^{bcdef} (± 0.44)	7.50^{ghij} (± 0.19)	30.23^{d} (± 0.21)	75.50^{g} (± 0.89)
BM15	57.83^{bcd} (± 0.47)	7.67^{j} (± 0.16)	29.79^{cd} (± 0.30)	75.34^{fg} (± 0.11)
BM31	58.95^{ef} (± 0.14)	7.27^{bcdefgh} (± 0.20)	29.84^{cd} (± 0.08)	74.03^{def} (± 0.24)
BM33	57.37^{ab} (± 0.05)	7.55^{hij} (± 0.12)	29.74^{cd} (± 0.16)	75.45^{fg} (± 0.47)
BM35	58.10^{bcde} (± 0.10)	7.40^{defghij} (± 0.09)	29.14^{abc} (± 0.16)	73.73^{cde} (± 0.45)
BM51	58.02^{bcde} (± 0.12)	7.54^{hij} (± 0.08)	29.91^{cd} (± 0.24)	75.20^{fg} (± 0.37)
BM53	58.20^{bcdef} (± 0.06)	7.60^{ij} (± 0.04)	29.92^{cd} (± 0.42)	75.18^{fg} (± 0.65)
BM55	58.42^{cdef} (± 0.18)	7.50^{fghij} (± 0.08)	29.64^{bcd} (± 0.18)	74.43^{efg} (± 0.26)
BU1010	60.10^{g} (± 0.48)	7.01^{abc} (± 0.09)	29.13^{abc} (± 0.77)	71.74^{a} (± 0.74)
BU1020	60.40^{g} (± 0.10)	7.07^{abc} (± 0.09)	29.73^{cd} (± 0.27)	72.54^{abc} (± 0.60)
BU1030	60.39^{g} (± 0.56)	6.93^{a} (± 0.11)	29.20^{abcd} (± 0.08)	71.57^{a} (± 0.66)
BU3010	58.97^{ef} (± 0.20)	7.15^{abcd} (± 0.01)	29.49^{bcd} (± 0.84)	73.34^{bcde} (± 1.22)
BU3020	58.77^{def} (± 0.34)	7.19^{abcde} (± 0.06)	29.15^{abcd} (± 0.11)	72.99^{abcd} (± 0.15)
BU3030	60.67^{g} (± 0.80)	6.97^{ab} (± 0.12)	29.53^{bcd} (± 1.00)	71.94^{ab} (± 0.82)
BU5010	58.92^{ef} (± 0.46)	7.31^{cdefghi} (± 0.00)	28.59^{ab} (± 0.10)	72.18^{ab} (± 0.22)
BU5020	59.13^{f} (± 0.66)	7.20^{abcdef} (± 0.30)	29.39^{abcd} (± 0.45)	73.00^{abcd} (± 0.04)
BU5030	57.46^{abc} (± 0.29)	7.23^{abcdefg} (± 0.06)	28.36^{a} (± 0.76)	72.77^{abcd} (± 1.09)
n	4	4	4	4
min	56.57	6.93	28.36	71.57
max	60.67	8.19	30.23	77.35
Av.	58.57	7.36	29.49	73.91

n means the number of a run for each data.
± means the standard deviation of "n" number of measurements.
CIE L*: Lightness, CIE a*: Redness, CIE b*: Yellowness, CIE YI: Yellowness Index.
a, b, c etc. show Duncan Test homogeneous groups (P<0.05).

CIE L* value of bulgur was increased with germination (P≤0.05) (0.398) and the treatments (P≤0.01) (0.728). The increase in the exposure power and the exposure time of microwave and ultrasound treatments caused an increase in CIE L* value. The

highest value of CIE L* (60.67) was obtained for BU3030, which bulgur produced by using wheat germinated and exposed to the ultrasound (40kHz) for 30 min at 30 W/kg. Also, there was an increase in CIE L* value, from 56.57 to 60.40 was obtained for BU1020, which bulgur produced by using ultrasound treated germinated wheat for 20 min and 10 W/kg. Germination is the major factor for increasing CIE L* value. Because germination increased the CIE L* value of bulgur from 56.57 to 57.29. Considering a higher increment in CIE L* value is desired, bulgur should be produced from germinated and treated wheat with ultrasound at higher power and higher time.

The CIE a* value of bulgur decreased with germination (-0.628) and the treatments (-0.819) ($P \leq 0.01$) by increasing exposure power ($P \leq 0.05$) (-0.354) and time for the ultrasound and microwave operations. The lowest value obtained was 6.93 for BU1030 sample which bulgur produced from germinated and ultrasound treated wheat for 30 min at 10 W/kg (control value of 8.19). Also, there was a decrease in CIE a* value, from 8.19 to 6.97 for BU3030, which bulgur produced from ultrasound treated germinated wheat for 30 min and 30 W/kg. Germination, the treatments by increasing exposure time and power decreased the redness of wheat. The major decrement of CIE a* value was provided by the ultrasound operation. As a note, it is desired that CIE a* value for bulgur should be closer to 0.00 value.

The CIE b* value of bulgur decreased during the microwave and ultrasound treatments ($P \leq 0.01$) (-0.488). Also, it decreased with germination and increasing exposure time and power of treatments. Control value for bulgur samples was obtained as 30.00. The highest value was obtained as 30.23 for BM13 which was microwave treated during germination at 1 W/kg for 3 min. As a note, it is desired that CIE b* value for bulgur should be higher.

It is desired that CIE YI value for bulgur should be closer to 0.00 value. The CIE YI value decreased with germination (-0.496) and the treatments (-0.861) ($P \leq 0.01$) by increasing exposure time ($P \leq 0.05$) (-0.353) and power for the ultrasound and microwave operations. It was found that the control value for the bulgur samples was 77.35. The lowest value was obtained as 71.57 for BU1030, which bulgur sample produced from ultrasound treated during germination at 10 W/kg for 30 min. Also, there was a decrease in CIE YI value, from 77.35 to 71.74, that obtained for BU1010,

which bulgur sample produced from the ultrasound treated germinated wheat for 10 min and 10 W/kg.

2.3.9. The Changes in Ash and Moisture Contents, Water Absorption Capacity, Hectoliter-Weight, and 1000-Kernels Weight Bulgur Samples

The changes in ash and moisture contents, water absorption capacity, hectoliter-weight, and 1000-kernels weight of bulgur samples after the germination and the treatments were presented in Table 2.10. Also, Pearson test results of bulgur samples were given in Table A.5. (Appendix).

The ash content of bulgur samples increased during the germination operation. The highest value of ash content (1.23 %) was obtained for BM11, which bulgur produced from the microwave treated germinated wheat for 1 min and 1 W/kg. Also, another higher ash content after the operations was obtained as 1.18 % for BU5020, which bulgur produced from ultrasound treated germinated wheat for 20 min and 50 W/kg. Germination was increased the ash content of bulgur sample from 0.96 to 1.09 %.

The moisture content of bulgur samples decreased with the ultrasound and microwave treatments ($P \leq 0.01$) (-0.511) and increasing exposure time for the ultrasound and microwave treatments during the germination operation ($P \leq 0.05$) (-0.344). The lowest value was 10.49 % for BU1030 sample, which bulgur produced from the ultrasound treated germinated wheat for 30 min and 10 W/kg (the control value of 14.35 %). Also, there was a decrease in the moisture content from 14.35 to 10.72 % obtained from BU5020, which bulgur produced from the ultrasound treated germinated wheat for 20 min and 50 W/kg. The ultrasound and microwave treatments, germination and increasing exposure time of the treatments decrease the moisture content of bulgur samples. The major decrements of the moisture content were provided by the ultrasound treatments.

Table 2.10. The changes in ash and moisture contents, water absorption capacity, hectoliter-weight, and 1000-kernels weight of bulgur samples

Sample	AC	MC	WAC	HW	TKW
BO (control)	0.96^{ab} (± 0.02)	14.35^{e} (± 0.50)	122.26^{abc} (± 5.43)	62.68 (± 0.00)	5.64 (± 0.00)
BGO (control)	1.09^{defg} (± 0.00)	15.10^{gh} (± 0.00)	117.58^{abc} (± 3.17)	62.98 (± 0.00)	6.58 (± 0.00)
BM11	1.23^{h} (± 0.01)	15.40^{hi} (± 0.18)	116.32^{abc} (± 5.28)	63.94 (± 0.00)	5.37 (± 0.00)
BM13	1.09^{defg} (± 0.01)	14.35^{e} (± 0.21)	110.98^{ab} (± 5.09)	56.98 (± 0.00)	4.87 (± 0.00)
BM15	1.15^{fgh} (± 0.04)	14.86^{fg} (± 0.00)	119.14^{abc} (± 5.84)	60.42 (± 0.00)	5.34 (± 0.00)
BM31	1.12^{efg} (± 0.08)	13.98^{de} (± 0.29)	113.04^{abc} (± 0.81)	55.64 (± 0.00)	7.13 (± 0.00)
BM33	1.00^{abcd} (± 0.07)	13.80^{d} (± 0.07)	112.99^{abc} (± 1.39)	63.36 (± 0.00)	6.19 (± 0.00)
BM35	1.03^{abcd} (± 0.01)	14.42^{ef} (± 0.11)	111.07^{ab} (± 5.13)	65.24 (± 0.00)	4.65 (± 0.00)
BM51	1.05^{bcde} (± 0.05)	15.69^{i} (± 0.20)	124.07^{bc} (± 6.41)	55.62 (± 0.00)	5.40 (± 0.00)
BM53	1.00^{abcd} (± 0.03)	14.96^{gh} (± 0.03)	110.06^{a} (± 6.28)	58.82 (± 0.00)	5.61 (± 0.00)
BM55	0.96^{ab} (± 0.06)	15.62^{i} (± 0.02)	121.98^{abc} (± 8.35)	63.08 (± 0.00)	5.58 (± 0.00)
BU1010	1.05^{bcdef} (± 0.05)	13.58^{d} (± 0.09)	116.94^{abc} (± 7.83)	58.68 (± 0.00)	4.52 (± 0.00)
BU1020	1.06^{cdef} (± 0.02)	11.90^{b} (± 0.12)	124.69^{c} (± 5.49)	62.12 (± 0.00)	3.53 (± 0.00)
BU1030	1.01^{abcd} (± 0.01)	10.49^{a} (± 0.29)	114.88^{abc} (± 7.65)	56.60 (± 0.00)	3.35 (± 0.00)
BU3010	0.98^{abc} (± 0.02)	12.59^{c} (± 0.02)	125.73^{c} (± 1.61)	59.36 (± 0.00)	4.67 (± 0.00)
BU3020	1.05^{bcdef} (± 0.02)	12.18^{bc} (± 0.11)	115.04^{abc} (± 2.05)	65.50 (± 0.00)	5.44 (± 0.00)
BU3030	1.01^{abcd} (± 0.03)	10.74^{a} (± 0.07)	115.43^{abc} (± 7.64)	60.86 (± 0.00)	4.86 (± 0.00)
BU5010	0.94^{a} (± 0.01)	17.70^{j} (± 0.09)	109.28^{a} (± 7.32)	59.00 (± 0.00)	6.03 (± 0.00)
BU5020	1.18^{gh} (± 0.07)	10.72^{a} (± 0.04)	113.58^{abc} (± 0.80)	61.00 (± 0.00)	4.56 (± 0.00)
BU5030	0.98^{abc} (± 0.05)	13.96^{de} (± 0.65)	121.52^{abc} (± 5.72)	59.84 (± 0.00)	4.62 (± 0.00)
n	3	3	3	1	1
min	0.94	10.49	109.28	55.62	3.35
max	1.23	17.70	125.73	65.50	7.13
Av.	1.05	13.82	116.83	60.59	5.20

n means the number of a run for each data.
± means the standard deviation of "n" number of measurements.
AC: Ash Content (%, d.b.), MC: Moisture Content (%, d.b.),
WAC: Water Absorption Capacity (%, d.b.), HW: Hectoliter-Weight (kg/100 L), TKW: 1000-Kernels Weight (g, d.b.).
a, b, c etc. show Duncan Test homogeneous groups (P<0.05).

The water absorption capacity of bulgur samples decreased for all operations. Control value for bulgur samples was obtained as 122.26 %. The lowest value was obtained as

109.28 % for BU5010, which bulgur produced from the ultrasound treated wheat during germination at 50 W/kg for 10 min. Also, there was a decrease in water absorption capacity, from 122.26 to 110.06 %, which was obtained for BM53 which bulgur produced from the microwave treated germinated wheat for 3 min and 5 W/kg. The results show that the major decrement provided by the germination.

The hectoliter-weight of bulgur samples decreased during the germination, microwave, and ultrasound treatments, by increasing exposure power of treatments during the germination operation. The initial value of bulgur samples was 62.68 kg/100 L. The lowest value was obtained as 55.62 kg/100 L for BM51 which bulgur produced from the microwave treated during germination at 5 W/kg for 1 min. Also, there was a decrement in hectoliter-weight, from 62.68 to 55.64 kg/100 L, was obtained for BM31, which bulgur produced from the microwave treated during germination at 3 W/kg for 1 min. The major decrease was obtained by using the microwave treatments.

The 1000-kernels weight decreased significantly ($P \leq 0.01$) for the ultrasound and microwave treatments (-0.597) and increasing the exposure time of treatments during germination (-0.475) ($P \leq 0.01$). The control value of the bulgur samples was 5.64 g. The lowest value was obtained as 3.35 g for BU1030, which bulgur produced from the ultrasound treated wheat during the germination operation at 10 W/kg for 30 min. Also, there was a decrease in 1000-kernels weight from 5.64 to 3.53 g for BU1020, which bulgur produced from the ultrasound treated wheat during the germination operation at 10 W/kg for 20 min. The results show that major decrement provided by the ultrasound treatments.

2.3.10. Relationship Between Parameters of Bulgur Samples

Pearson test results of bulgur samples were given in Table A.5. (Appendix).

There is a negative significant correlation between fat content and CIE L* value of bulgur samples at level $P \leq 0.01$ (-0.448). However, there are positive significant correlations between fat content and CIE a* value ($P \leq 0.05$) (0.325), 1000-kernels weight (0.668), and moisture content (0.673) ($P \leq 0.01$). It has been observed that CIE a* value, 1000-kernels weight and moisture content of bulgur samples increases as the

fat content increases. While fat content increases, CIE L* value of bulgur samples decreases.

Also, there are negative significant correlations between CIE L* value of bulgur samples and CIE a* (-0.848), CIE YI (-0.774), 1000-kernels weight (-0.536), and moisture content (-0.587) ($P \leq 0.01$). So, an increment in CIE L* value of bulgur samples, results decrements in CIE a*, CIE YI, 1000-kernels weight and moisture content.

It has been observed that there are positive correlations between CIE a* and CIE b* values ($P \leq 0.05$) (0.349), and CIE YI (0.897), 1000-kernels weight (0.493), and moisture content (0.555) ($P \leq 0.01$). As CIE a* value of bulgur samples decreases, CIE b*, CIE YI, 1000-kernels weight and moisture content decreases.

Besides, between CIE b* and CIE YI values of bulgur samples, there is a positive significant correlation at level $P \leq 0.01$ (0.659). As CIE b* value increases, CIE YI value of bulgur samples increases.

There are positive significant correlations between CIE YI and 1000-kernels weight (0.513) and moisture content (0.448) ($P \leq 0.01$). So, as CIE YI of bulgur samples increases, the increments in 1000-kernels weight and moisture content were observed.

Also, there is a positive significant correlation between 1000-kernels weight and moisture content of bulgur samples at level $P \leq 0.01$ (0.593). It has been observed that 1000-kernels weight increases as the moisture content of bulgur samples increases.

2.3.11. Sensory Analysis of Bulgur Pilaf Samples

Results are given in Table 2.11 as the average of points which are given according to the quality criterions by the panelists.

Bulgur-1 sample was BO, which was produced from the ungerminated and untreated wheat (control).

Bulgur-2 sample was BM13, which was produced from the microwave treated wheat during the germination operation in every 6 hours for 3 min and 1 W/kg.

Bulgur-3 sample was BU5020, which was produced from the ultrasound treated wheat during the germination operation in every 6 hours for 20 min and 50 W/kg at 40 kHz.

Table 2.11. The average of sensory analysis results of bulgur pilaf samples

Quality Criterions	Sample Codes – Score Out of 5		
	Bulgur-1	Bulgur-2	Bulgur-3
Flavor	3.27^{b} (± 0.70)	2.27^{a} (± 1.03)	3.13^{b} (± 1.25)
Odor	3.73^{b} (± 0.46)	2.73^{a} (± 1.03)	3.73^{b} (± 0.46)
Texture	2.27^{a} (± 1.16)	2.87^{ab} (± 0.64)	3.27^{b} (± 1.03)
Appearance	3.73^{a} (± 0.70)	3.13^{a} (± 0.35)	3.27^{a} (± 1.49)
Overall Effect	3.60^{b} (± 0.74)	2.13^{a} (± 1.12)	3.00^{b} (± 1.31)
Average	3.32 (± 0.55)	2.62 (± 0.37)	3.28 (± 0.36)

± means the standard deviation measurements
a, b, c etc. show Duncan Test homogeneous groups ($P<0.05$).

As the flavor, the best bulgur pilaf was BO sample which was dominated according to the others.

According to odor, BO, and BU5020 bulgur pilaf samples were same and the best ones.

The texture of the pilaf samples as compared, BU5020 bulgur pilaf was better than the other bulgur pilaf samples.

In terms of appearance, BO bulgur pilaf sample was scored better than the other samples.

According to the answer to overall effect asked the panelists, BO pilaf sample was better than the others.

Finally, according to all criteria, BO pilaf sample was the highest score. Likewise, BU5020 was not bad according to the panelists. A score of BO pilaf and BU5020 pilaf samples are close to each other.

CHAPTER 3.

MICROWAVE AND ULTRASOUND AIDED GERMINATION OF RED-LENTIL

In this part of the study, the microwave and ultrasound were used during germination to determine their effects on nutritional values and increasing the germination performance of red-lentil (*Lens culinaris*). The microwave and ultrasound applications were performed at each 6-hours intervals.

During the microwave operation, three different microwave power levels were used such as 1, 3 and 5 W/kg. The samples were applied for 1, 3 and 5 minutes at each 6-hours intervals.

During the ultrasound (40 kHz) operation, the samples were subjected to ultrasound operation for 10, 20 and 30 minutes at each 6-hours intervals. Power levels used during the ultrasound applications were 10, 30 and 50 W/kg.

During both applications, the samples were placed in the germination chamber for 20 hours (25 ^{o}C, 95 % RH, and non-illuminated condition). After the germination process, yield (%), 1000-kernels weight (g, d.b.), hectoliter-weight (kg/100 L), moisture (%, d.b.), ash (%, d.b.), protein (%, d.b.), fat (%, d.b.) and starch contents (%, d.b.), color (CIE L*, a*, b, YI), and sensory analysis were made for red-lentil.

The fat content of the samples was decreased with treatments of ultrasound, microwave and by increasing exposure time ($P \leq 0.05$). Also, germination decreased the starch content of the samples ($P \leq 0.01$). Ultrasound and microwave operations decreased CIE YI value ($P \leq 0.01$). In addition; germination, ultrasound and microwave operations decreased hectoliter-weight and 1000-kernels weight of the samples; however, these operations increased CIE L* value of the samples ($P \leq 0.01$).

Key Words: Germination, microwave, ultrasound, lentil

3.1. Introduction

Lentil (*Lens culinaris* Medik.) is predominantly grown in South East Asia. The Indian subcontinent is the largest producer but it is also grown in most subtropical and warm temperate countries. On sale as pulses, the seeds are biconvex or lens-shaped (3–9mm in length) and green, yellow, orange, red, or brown in color. It is commonly consumed as thick soup made from whole grain or split pulse commonly referred to as 'dhal'. Seeds can be fried and seasoned for consumption; flour is used to make soups, stews purees, and mixed with cereals to make bread and cakes, and as a food for infants (Williams et al., 1988; Zia-Ul-Haq et al., 2011). It is used in culinary dishes in the Indo-Pakistan sub-continent and in the Middle East and incorporated into soups in Europe and North America. In Western countries, lentils may be used in casseroles and as meat substitutes in vegetarian diets. Lentil although called as a 'poor man's meat', is equally liked by all socioeconomic groups in South East Asia (Bhatty, 1988; Zia-Ul-Haq et al., 2011).

The nutritional value of lentils is gaining considerable interest since its nutritional value/100 g dry weight is as follows; energy, 353 kcal; carbohydrates, 60 g; sugars, 2 g; dietary fibers, 31 g; fat, l g; protein, 26 g; thiamine (B1), 0.87 mg; folate (B9), 479 μg and iron, 7.5 mg (Callaway, 2004). In common with other legumes, lentils contain a number of components called anti-nutritional factors which limit the wider use of crop (Sheshetawy & Faid, 2010).

In poor countries, intake of protein is expensive due to the high price of meat. Cereals, legumes, and their products play an important role in the protein supply in these countries. To solve some nutritional problems in poor countries, protein rich foods are needed. In spite of the fact that lentil has a high nutritional value, like everything else lentil is needed to be upgraded in the globalized world. In recent years, with the aim of improving the nutritive value of cereals and legumes, preparation techniques such as germination and fermentation have been developed.

Germination appears to be an inexpensive and effective method of achieving desirable changes in nutritious crops and germinated seeds have become a widely accepted food item. Germination causes important changes in the biochemical, nutritional and sensory characteristics of legume seeds (Kuo et al., 2004). It can be considered as a

procedure for improving legume digestibility and reducing flatulence properties (Vidal-Valverde & Frias, 1992), which are some of the factors that limit consumption. In other words, germination improved the quality of legumes by enhancing the bioavailability and digestibility of nutrients and reducing the antinutrients (Ghavidel & Prakash, 2007a), It induces the release of hydrolytic enzymes, which produce changes in the physical properties and functionality of seed components. Vidal-Valverde and Frias, (1992) demonstrated that the nutritive value of lentils may increase with germination processes (Sheshetawy & Faid, 2010).

A number of studies have performed to investigate the influence of germination on lentil (El-Adawy et al., 2003; Ghavidel & Prakash, 2007a; Morad et al., 1980; Sulieman et al., 2007). It has been reported that protein (Ghavidel & Prakash, 2007a; Morad et al., 1980; Sulieman et al., 2007), and ash (El-Adawy et al., 2003; Morad et al., 1980) increased; however, starch (Morad et al., 1980), fat (El-Adawy et al., 2003; Ghavidel & Prakash, 2007a), moisture (El-Adawy et al., 2003; Ghavidel & Prakash, 2007a; Morad et al., 1980; Sulieman et al., 2007), and ash (Ghavidel & Prakash, 2007a; Sulieman et al., 2007) decreased.

In recent years, a combination of processes such as ultrasound, microwave cooking, soaking or germination is being applied on cereals and legumes to improve nutritional quality.

Ultrasound is a novel physical method that involves the application of sound frequencies in the inaudible range (20 - 100 kHz) to interact with the materials (Goussous et al., 2010). Ultrasound treatment to stimulate germination (before the germination operation) has been investigated in many seed types including carrot, radish, maize, barley, rice and sunflower (Aladjadjiyan, 2002; Carbonell et al., 2000; Florez et al., 2007; Hebling & da Silva, 1995; Miyoshi & Mii, 1988; Shimomura, 1998; Yaldagard et al., 2008a, 2008c). Results of these investigations indicated that the effects of ultrasound on seed germination depend on frequency and exposure time and appear to vary widely between the different species and cultivars (Goussous et al., 2010).

Microwaves are electromagnetic waves whose frequency varies within 300 MHz to 300 GHz. Domestic microwave appliances operate generally at a frequency of 2.45

GHz, while industrial microwave systems operate at frequencies of 915 MHz and 2.45 GHz (Chandrasekaran et al., 2013; Datta, 2001). There is some evidence that microwaves produces changes in the cell membrane's permeability and cell growth rate as well as interference with ions and organic molecules, like proteins (Ragha et al., 2011; Ungureanu et al., 2009)

However, no research has focused on the application of ultrasound and microwave during germination. The aim of this study was to investigate a) the effect of germination on red lentil (*Lens culinaris*), b) the effect of the application of ultrasound and microwave techniques **during** germination instead of **before** germination, and c) the acceptability of germinated red lentil as soup by consumers.

3.2. Materials and Methods

3.2.1. Sample Preparation

Red-lentils (*Lens culinaris*) harvested in 2013 were obtained from a local legume factory in Gaziantep. The properties of red-lentil used in this study were shown in Table 3.1. Lentils were cleaned with 3.0 mm sieve and germinated for 20 hours between two coarse filter papers in climate cabinet (25 ^{o}C, 95 % RH, and non-illuminated condition) (Nüve ID 501, Ankara, Turkey) with adding water continuously. Germination system and germinated red-lentil were shown in Figure 3.1. The microwave and ultrasound applications were made at each 6-hours intervals for 20 hours of the germination operation. At the microwave application, which was made in a microwave oven (Bosch HMT84G421, Stuttgart, Germany); at each 6-hours intervals, the samples were subjected to microwave for 1, 3 and 5 minutes at 1, 3 and 5 W/kg. At the ultrasound (40 kHz) application, which was made in an ultrasonic water bath (100 W/cm^3, 4 L, Minisonik, Min 18, Intersonik, Istanbul, Turkey); again at each 6-hours intervals, the samples were subjected to ultrasound application for 10, 20 and 30 minutes. The power levels were 10, 30 and 50 W/kg. The volume of water in the ultrasonic water bath needed to obtain desired power level was calculated according to the density of each sample and also power (100 W/cm3) and wash volume (4 L) of the ultrasonic water bath. After 20 hours microwave/ultrasound aided germination process, the germinated lentil seed was dried in a packed bed dryer (MK II, Sherwood

Scientific, Cambridge, UK) at 90 ºC and stored at + 4 ºC for the further analysis. The sample nomenclature was given in Table 3.2. Also, the experimental set-up was illustrated in Figure 3.2.

Figure 3.1. Germination system (left) and germinated red-lentil (right)

Table 3.1. The properties of red-lentil used in the experiments

Properties		Red-Lentil
	Protein content (%, d.b.)	18.55 (±0.29)
	Fat content (%, d.b.)	1.28 (±0.05)
	Starch content (%, d.b.)	50.95 (±0.70)
	Moisture content (%, d.b.)	11.67 (±0.27)
	Ash content (%, d.b.)	5.35 (±0.32)
	Hectoliter-weight (kg/100 L)	81.90 (±0.00)
	1000-kernels weight (g, d.b.)	34.44 (±0.00)
Color	CIE L*	44.02 (±0.37)
	CIE a*	11.20 (±0.94)
	CIE b*	18.42 (±0.53)
	CIE YI	71.47 (±2.59)

± means the standard deviation of measurements.
CIE L*: Lightness, CIE a*: Redness, CIE b*: Yellowness, CIE YI: Yellowness Index.

Table 3.2. Description of samples

Samples	Germination (yes/no)	Process	Applied Power (W/kg)	Duration (min)
LO (control)	No	No	0	0
LGO (control)	Yes	No	0	0
LM11	Yes	Microwave	1	1
LM13	Yes	Microwave	1	3
LM15	Yes	Microwave	1	5
LM31	Yes	Microwave	3	1
LM33	Yes	Microwave	3	3
LM35	Yes	Microwave	3	5
LM51	Yes	Microwave	5	1
LM53	Yes	Microwave	5	3
LM55	Yes	Microwave	5	5
LU1010	Yes	Ultrasound	10	10
LU1020	Yes	Ultrasound	10	20
LU1030	Yes	Ultrasound	10	30
LU3010	Yes	Ultrasound	30	10
LU3020	Yes	Ultrasound	30	20
LU3030	Yes	Ultrasound	30	30
LU5010	Yes	Ultrasound	50	10
LU5020	Yes	Ultrasound	50	20
LU5030	Yes	Ultrasound	50	30

L: Red-Lentil, G: Germinated, O: Control, M: Microwave, U: Ultrasound.

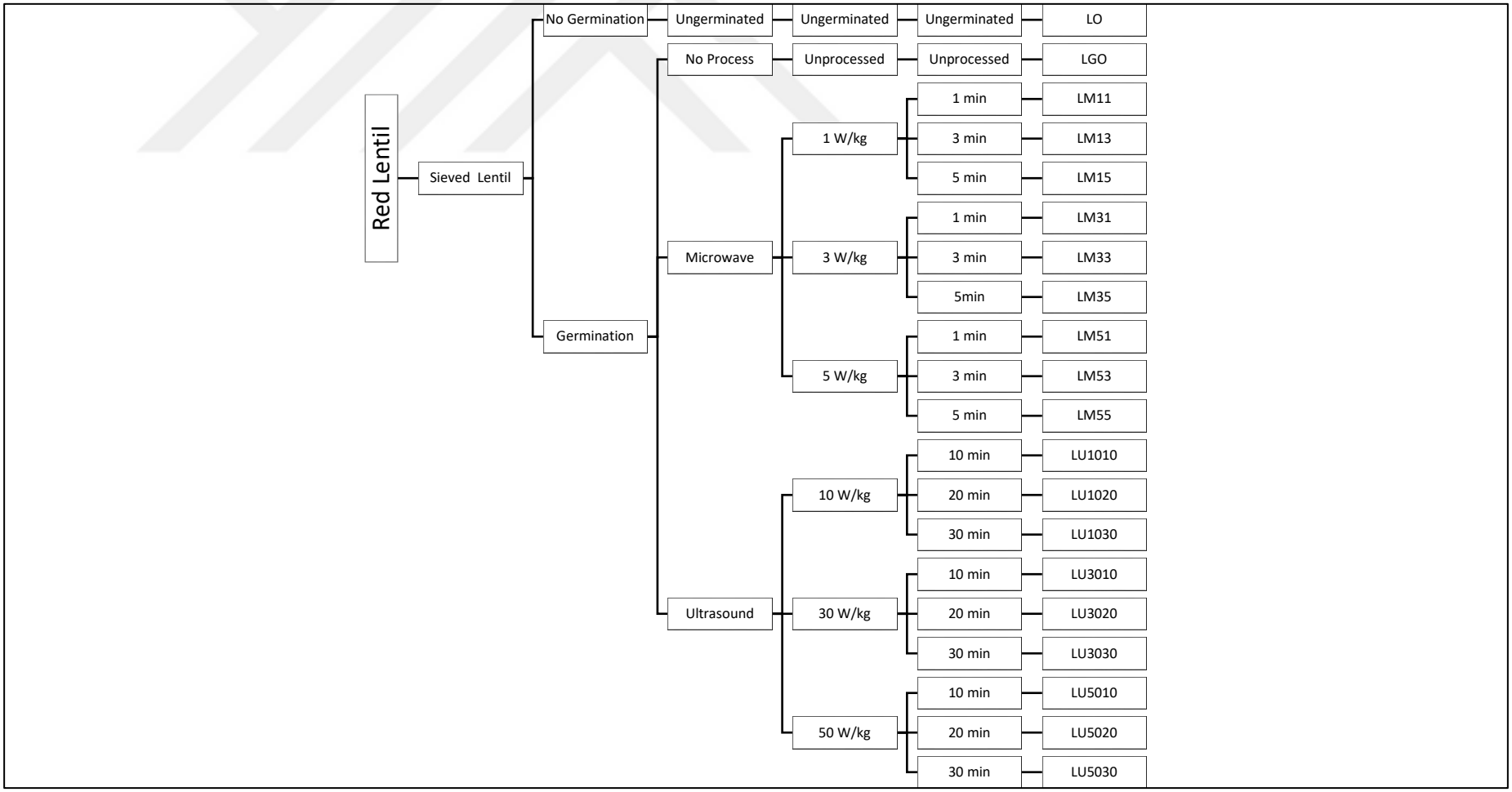


Figure 3.2. Experimental design of germination process of red-lentil samples

3.2.2. Chemicals

The chemicals used in protein, fat and starch contents analyses were obtained from Merck (Darmstadt, Germany).

3.2.3. Analyses

3.2.3.1. Physical and Chemical Analyses

Moisture (%, d.b.), ash (%, d.b.), protein (%, d.b.) and fat (%, d.b.) contents were measured by using the standard of AOAC methods (AOAC, 1990). For yield (%), the weight of unprocessed lentil and weight of the final product was considered. 1000-kernels weight (g, d.b.) was calculated according to the method of Turkish Standards (TS 1136; TSE, 2007). Hectoliter-weight (kg/100 L) was determined according to the method of Turkish Standards (TS EN ISO 7971-1; TSE, 2012). The color was measured as CIE L*, a*, b*, and YI with HunterLab colorimeter (Colorflex 45/0, HunterLAB, USA). Before each of the color measurement, black and white standard tiles were used to calibrate colorimeter (L=93.01, a=-1.11, b=1.30). The color measurements were performed at room temperature (25 ± 2 °C). Analysis of starch content (%, d.b.) was carried out according to ISO 10520 (ISO, 1998).

3.2.3.2. Sensory Analysis

The soup was made from 3 lentil samples which were control sample (1) and best lentil from the ultrasound (2) and microwave (3) applications according to nutritional values. The best lentil samples were chosen according to the highest protein, lowest fat and starch contents. Sensory analysis was done with a scoring test by 15 panelists in Sensory Analysis Laboratory, Gaziantep University. The panelists were scored according to flavor, odor, texture, appearance and overall effect of the soup samples.

3.2.3.3. Statistical Analysis

The analysis was carried out in 2 replicates for all determinations. The mean and standard deviation of means were calculated. The data were analyzed by one-way analysis of variance (ANOVA) ($P<0.05$). Duncan test were applied to determine difference between the measurements. A multiple comparison procedure of the treatment means was performed by Pearson correlation test. Statistical Analyses were carried out by using IBM SPSS Statistics (v22.0.0, 2014, IBM Corporation, New York, USA).

In the text of the results and discussion section, the numbers in parentheses are the Pearson correlation coefficients.

3.3. Results and discussion

3.3.1. The Changes in Protein, Fat, and Starch Content of Red-Lentil Samples

The changes in protein, fat and starch contents of red-lentil samples after the germination operation and the treatments e.g. microwave and ultrasound, were presented in Table 3.3. Also, Pearson test results of red-lentil samples were given in Table A.6. (Appendix).

The protein content of red-lentil increased during germination and by the increasing exposure powers of the microwave and ultrasound treatments. Also, it has been reported that the protein content of lentil seeds increased during the germination according to the literature (Ghavidel & Prakash, 2007a; Morad et al., 1980; Sulieman et al., 2007). The highest value of protein content (20.16 %) was obtained for LM31, which red-lentil germinated and exposed to the microwave for 1 min at 3 W/kg. Also, there was an increase in protein content from 18.55 to 20.07 %, which obtained for LM15 (microwave treated germinated red-lentil for 5 min and 1 W/kg). Germination is the major factor for increasing protein content. Because germination increased the protein content of red-lentil samples as LGO from 18.55 to 19.95 %. In this study, it is desired to increase the protein content with the operations. Considering a higher increment in protein content is desired, red-lentil should be germinated and treated with ultrasound at high power.

Table 3.3. The changes in protein, fat and starch contents of red-lentil samples

Sample	PC	FC	SC
LO (control)	18.55^{ab} (± 0.29)	1.28^{k} (± 0.05)	50.95^{d} (± 0.70)
LGO (control)	19.95^{c} (± 0.40)	0.40^{g} (± 0.00)	48.61^{abc} (± 1.16)
LM11	19.90^{bc} (± 0.11)	0.38^{fg} (± 0.02)	48.22^{abc} (± 0.25)
LM13	19.91^{bc} (± 1.00)	0.27^{cd} (± 0.01)	48.24^{abc} (± 0.73)
LM15	20.07^{c} (± 0.11)	0.38^{fg} (± 0.01)	48.90^{abc} (± 1.27)
LM31	20.16^{c} (± 0.34)	0.54^{h} (± 0.03)	48.70^{abc} (± 0.47)
LM33	19.82^{abc} (± 0.37)	1.20^{j} (± 0.01)	48.07^{ab} (± 0.28)
LM35	19.68^{abc} (± 0.06)	0.52^{h} (± 0.01)	48.28^{abc} (± 0.64)
LM51	19.94^{c} (± 0.92)	0.34^{ef} (± 0.00)	47.93^{a} (± 0.26)
LM53	19.75^{abc} (± 0.12)	1.22^{j} (± 0.01)	48.95^{abc} (± 0.42)
LM55	19.29^{abc} (± 0.73)	0.24^{bc} (± 0.00)	49.64^{c} (± 0.20)
LU1010	19.05^{abc} (± 0.16)	0.24^{bcd} (± 0.00)	49.09^{abc} (± 0.73)
LU1020	19.73^{abc} (± 0.81)	0.15^{a} (± 0.01)	48.50^{abc} (± 0.24)
LU1030	18.44^{a} (± 0.68)	0.29^{de} (± 0.00)	48.56^{abc} (± 0.85)
LU3010	18.51^{a} (± 0.84)	0.29^{cd} (± 0.01)	49.38^{abc} (± 0.06)
LU3020	19.01^{abc} (± 0.45)	0.21^{b} (± 0.00)	48.13^{ab} (± 0.07)
LU3030	19.62^{abc} (± 0.14)	0.20^{b} (± 0.00)	48.08^{ab} (± 0.24)
LU5010	19.79^{abc} (± 0.50)	1.06^{i} (± 0.07)	48.85^{abc} (± 0.37)
LU5020	18.50^{a} (± 0.94)	0.24^{bcd} (± 0.01)	49.48^{bc} (± 0.14)
LU5030	19.41^{abc} (± 0.57)	0.15^{a} (± 0.00)	49.11^{abc} (± 0.82)
n	3	3	3
min	18.44	0.15	47.93
max	20.16	1.28	50.95
Av.	19.45	0.48	48.78

n means the number of a run for each data.
± means the standard deviation of "n" number of measurements.
PC: Protein Content (%, d.b.), FC: Fat Content (%, d.b.), SC: Starch Content (%, d.b.).
a, b, c etc. show Duncan Test homogeneous groups (P<0.05).

The fat content of red-lentil decreased during germination (-0.492) with ultrasound and microwave treatments (-0.454) (P≤0.01) by increasing exposure time for ultrasound and microwave treatments (P≤0.05) (-0.344). As the same, the literature

results showed that the fat content of lentil seeds decreased during the germination (El-Adawy et al., 2003; Ghavidel & Prakash, 2007a). The lowest value was 0.15 % for LU5030, which was ultrasound treated germinated red-lentil for 30 min and 50 W/kg and LU1020, which was ultrasound treated germinated red-lentil for 20 min and 10 W/kg (the control value of 1.28 %). Also, there was a decrease in fat content, from 1.28 to 0.20 %, was obtained for LU3030, which was ultrasound treated germinated red-lentil for 30 min and 30 W/kg. Germination, ultrasound and microwave treatments, by increasing exposure time and power of the treatments, decreased the fat content of red-lentil. The major decrement of the fat content was provided by germination from 1.28 to 0.40 %. In this study, it is desired that fat content can be decreased by using these operations/treatments.

Starch content was decreased during germination ($P \leq 0.01$) (-0.608). In addition, literature results showed that germination decreased the starch content of lentil seeds, too (Morad et al., 1980), fat (El-Adawy et al., 2003; Ghavidel & Prakash, 2007a). Also, it decreased due to the treatment of ultrasound and microwave, increasing exposure time and power of the treatments during the germination operation. The initial value of the red-lentil samples was 50.95 %. The lowest value was obtained as 47.93 % for LM51, which was microwave treated during germination at 5 W/kg for 1 min. Also, there was a decrease in the starch content, from 50.95 to 48.07 %, was obtained from LM33, which was microwave treated during germination at 3 W/kg for 3 min. It was found that germination and treatments decrease the starch content of red-lentil samples. Also, the major decrement was obtained by the germination operation from 50.95 to 48.61 %.

3.3.2. The Changes in Color Values of Red-Lentil Samples

The changes in color values during the operations were given in Table 3.4. Also, Pearson test results of red-lentil samples were given in Table A.6. (Appendix).

Table 3.4. Color values of the samples

Sample	CIE L*	CIE a*	CIE b*	CIE YI
LO (control)	44.02^{a} (± 0.37)	11.20^{ab} (± 0.94)	18.42^{a} (± 0.57)	71.47^{a} (± 2.59)
LGO (control)	48.76^{bcdef} (± 0.08)	10.56^{ab} (± 0.97)	19.22^{a} (± 0.81)	67.74^{a} (± 3.17)
LM11	50.49^{def} (± 0.59)	11.86^{ab} (± 1.29)	20.44^{a} (± 1.13)	70.70^{a} (± 3.74)
LM13	49.77^{bcdef} (± 0.36)	12.35^{ab} (± 0.06)	20.79^{a} (± 0.05)	72.88^{a} (± 0.33)
LM15	49.39^{bcdef} (± 1.31)	12.40^{ab} (± 0.47)	20.73^{a} (± 0.47)	73.21^{a} (± 0.42)
LM31	48.43^{bcde} (± 0.76)	11.41^{ab} (± 0.10)	20.33^{a} (± 0.98)	71.69^{a} (± 2.85)
LM33	47.87^{b} (± 0.43)	11.79^{ab} (± 0.41)	19.89^{a} (± 1.36)	71.93^{a} (± 3.89)
LM35	49.40^{bcdef} (± 0.87)	11.81^{ab} (± 0.21)	19.61^{a} (± 0.23)	70.10^{a} (± 1.08)
LM51	49.92^{bcdef} (± 0.95)	11.06^{ab} (± 0.23)	19.75^{a} (± 0.45)	68.63^{a} (± 0.44)
LM53	48.00^{bc} (± 2.08)	11.35^{ab} (± 0.33)	18.80^{a} (± 0.61)	68.88^{a} (± 1.15)
LM55	48.31^{bcd} (± 0.98)	12.71^{b} (± 1.98)	19.82^{a} (± 1.54)	72.82^{a} (± 5.46)
LU1010	50.23^{bcdef} (± 1.42)	10.73^{ab} (± 1.34)	19.67^{a} (± 1.21)	67.64^{a} (± 3.32)
LU1020	50.80^{ef} (± 0.62)	10.17^{ab} (± 0.65)	19.24^{a} (± 0.66)	65.41^{a} (± 1.89)
LU1030	49.59^{bcdef} (± 1.71)	11.37^{ab} (± 1.61)	19.34^{a} (± 2.41)	68.40^{a} (± 5.98)
LU3010	49.77^{bcdef} (± 0.84)	10.71^{ab} (± 0.86)	20.01^{a} (± 0.54)	68.80^{a} (± 3.22)
LU3020	50.84^{f} (± 0.88)	10.28^{ab} (± 0.29)	19.47^{a} (± 0.30)	66.04^{a} (± 0.60)
LU3030	49.56^{bcdef} (± 0.95)	9.97^{a} (± 0.21)	19.15^{a} (± 1.07)	65.94^{a} (± 3.37)
LU5010	49.93^{bcdef} (± 0.32)	10.92^{ab} (± 1.59)	19.80^{a} (± 1.39)	68.43^{a} (± 5.04)
LU5020	50.44^{def} (± 0.42)	11.36^{ab} (± 2.28)	20.65^{a} (± 2.13)	70.43^{a} (± 8.18)
LU5030	50.30^{cdef} (± 1.02)	10.49^{ab} (± 1.77)	19.09^{a} (± 1.35)	65.95^{a} (± 4.64)
n	4	4	4	4
min	44.02	9.97	18.42	65.41
max	50.84	12.71	20.79	73.21
Av.	49.29	11.22	19.71	69.35

n means the number of a run for each data.
± means the standard deviation of "n" number of measurements.
CIE L*: Lightness, CIE a*: Redness, CIE b*: Yellowness, CIE YI: Yellowness Index.
a, b, c etc. show Duncan Test homogeneous groups (P<0.05).

The CIE L* value shows the darkness (0) and lightness (+100). CIE L* value increased with the germination operation (0.738) and the microwave and ultrasound treatments (0.637) (P≤0.01). The increase in exposure power and exposure time of microwave

and ultrasound treatment resulted in an increase in CIE L* value. The highest value of CIE L* (50.84) was obtained for LU3020, which red-lentil was germinated and exposed to the ultrasound (40kHz) operation for 20 min at 30 W/kg. Also, there was an increase in CIE L* value, from 44.02 to 50.80, was obtained for LU1020, which was ultrasound treated germinated red-lentil for 20 min and 10 W/kg. The germination is the major factor for increasing CIE L* value. Because the germination increased the CIE L* value of red-lentil from 44.02 to 48.76. Considering a higher increment in CIE L* value is desired, red-lentil should be germinated and treated with ultrasound at higher power and higher time.

The CIE a* value shows the redness (+) and greenness (-). The CIE a* value did not affect significantly ($P \leq 0.05$) with all operations. Nevertheless, the germination operation and increasing exposure time and power for the ultrasound and microwave operations increased the CIE a* value. However, the ultrasound and microwave treatments decreased the CIE a* value of red-lentil. The highest value obtained was 12.71 for LM55, which was germinated and microwave treated red-lentil for 5 min at 5 W/kg (the initial value of 11.20). Also, there was an increase in CIE a* value, from 11.20 to 12.40 obtained for LM15, which was ultrasound treated germinated red-lentil for 5 min at 1 W/kg. The germination operation and increasing exposure time and power of the ultrasound and microwave treatments increased the redness of red-lentil. The major increment of CIE a* value was provided by the microwave treatment.

The CIE b* value shows the yellowness (+) and blueness (-). The CIE b* value increased with the germination operation, the microwave and ultrasound treatments and by increasing exposure time and power of the treatments during the germination operation. The initial value of the red-lentil sample was 18.42. The highest value was obtained as 20.79 with LM13, which was microwave treated during germination at 1 W/kg for 3 min. Also, there was an increase in CIE b* value, from 18.42 to 20.73 was obtained for LM15, which was microwave treated germinated red-lentil for 5 min. at 1 W/kg. The germination operation and the treatments increase the yellowness of red-lentil.

Yellowness Index (CIE YI) is a measure of the color on the yellow scale that describes the change in color of a sample from clear or white toward yellow (Balcı, 2015). The CIE YI value decreased significantly with the ultrasound and microwave treatments

(P≤0.05) (-0.379). The germination operation and by increasing exposure time and power of the ultrasound and microwave treatments during the germination operation decreased the CIE YI value of red-lentil. The initial value of the red-lentil sample was 71.47. The lowest value was obtained as 65.41 for LU1020, which was ultrasound treated during germination at 10 W/kg for 20 min. Also, there was a decrease in CIE YI value, from 71.47 to 65.94 was obtained for LU3030, which was ultrasound treated germinated red-lentil for 30 min and 30 W/kg. Results show that major decrement provided by the germination operation because the germination operation decreased the CIE YI value of red-lentil from 71.47 to 67.74 only on its own.

3.3.3. The Changes in Ash and Moisture Contents, Hectoliter-Weight, and 1000-Kernels Weight of Red-Lentil Samples

The changes in ash and moisture content, hectoliter-weight, and 1000-kernels weight of red-lentil samples after germination and treatments were presented in Table 3.5. Also, Pearson test results of red-lentil samples were given in Table A.6. (Appendix).

Ash content of the red-lentil samples increased with the ultrasound and microwave treatments, by increasing exposure power and time of the microwave and ultrasound treatments. The highest ash content (6.05 %) was obtained for LM31, which red-lentil was germinated and exposed to the microwave for 1 min at 3 W/kg. Also, there was an increase in the ash content, from 5.35 to 6.01 % was obtained for LM33, which was microwave treated germinated red-lentil for 3 min and 3 W/kg. Germination decreased the ash content of the red-lentil samples from 5.35 to 1.74 %. In addition, some studies show that the germination was increased the ash content of lentil seed (Ghavidel & Prakash, 2007a; Sulieman et al., 2007); however, some investigations showed that the ash content increased during germination (El-Adawy et al., 2003; Morad et al., 1980). ash decreased Considering a higher increment in the ash content is desired, red-lentil should be treated with microwave.

The moisture contents of red-lentil samples were decreased with ultrasound and microwave treatments (P≤0.01) (-0.768), increasing exposure time and power for the ultrasound and microwave treatments. Also, the previous studies showed that the moisture content of the lentil seeds decreased during the germination (El-Adawy et al.,

2003; Ghavidel & Prakash, 2007a; Morad et al., 1980; Sulieman et al., 2007). The lowest value obtained was 8.44 % for LU5010, which was ultrasound treated germinated red-lentil for 10 min and 50 W/kg (the control value of 11.67 %). Also, there was a decrease in moisture content from 11.67 to 8.62 % was obtained for LU3010, which was ultrasound treated germinated red-lentil for 10 min and 30 W/kg. Ultrasound and microwave treatments, increasing exposure time and increasing exposure power of treatments decrease the moisture content of red-lentil. Major decrease in the moisture content was provided by the ultrasound treatments.

The hectoliter-weight of the red-lentil samples decreased during the germination operation (-0.965) and the microwave and ultrasound treatments (-0.537) ($P \leq 0.01$). Also, it decreased by increasing exposure time (-0.359) and power (-0.390) of the ultrasound and microwave treatments during the germination operation ($P \leq 0.05$). The initial value of red-lentil was 81.90 kg/100 L. The lowest value was obtained as 44.02 kg/100 L for LU3010, which was ultrasound treated during germination at 30 W/kg for 10 min. Also, there was a decrease in the hectoliter-weight, from 81.90 to 45.16 kg/100 L, was obtained for LU1020, which was ultrasound treated during germination at 10 W/kg for 20 min.

The 1000-kernels weight decreased significantly ($P \leq 0.01$) with the germination operation (-0.641), the microwave and ultrasound treatments (-0.431), by increasing the exposure time of the treatments during the germination operation (-0.570). The control value of red-lentil sample was 34.44 g. The lowest value was obtained as 29.77 g for LU1020 which was ultrasound treated during germination at 10 W/kg for 20 min. Also, there was a decrease in 1000-kernels weight, from 34.44 to 30.25 g was obtained for LM35, which was microwave treated germinated red-lentil for 5 min and 3 W/kg. Results show that major decrement provided by the germination operation because the germination operation decreased the 1000-kernels weight of red-lentil from 34.44 to 31.58 g only on its own.

Table 3.5. The ash and moisture contents, hectoliter-weight, and 1000-kernels weight of the samples

Sample	AC	MC	HW	TKW
LO (control)	5.35^{cd} (± 0.32)	11.67^{e} (± 0.27)	81.90 (± 0.00)	34.44 (± 0.00)
LGO (control)	1.74^{a} (± 0.11)	14.61^{gh} (± 0.16)	49.54 (± 0.00)	31.58 (± 0.00)
LM11	5.43^{cd} (± 0.14)	13.93^{f} (± 0.57)	47.82 (± 0.00)	30.40 (± 0.00)
LM13	4.67^{b} (± 0.20)	15.36^{ijk} (± 0.11)	49.98 (± 0.00)	32.11 (± 0.00)
LM15	1.91^{a} (± 0.10)	15.16^{hij} (± 0.04)	51.40 (± 0.00)	31.15 (± 0.00)
LM31	6.05^{e} (± 0.24)	16.10^{l} (± 0.18)	52.06 (± 0.00)	33.13 (± 0.00)
LM33	6.01^{e} (± 0.27)	15.92^{kl} (± 0.10)	46.96 (± 0.00)	30.81 (± 0.00)
LM35	5.15^{bcd} (± 0.24)	14.49^{fg} (± 0.03)	49.44 (± 0.00)	30.25 (± 0.00)
LM51	5.01^{bc} (± 0.04)	13.88^{f} (± 0.08)	47.58 (± 0.00)	32.23 (± 0.00)
LM53	4.69^{b} (± 0.01)	15.71^{jkl} (± 0.14)	50.78 (± 0.00)	31.86 (± 0.00)
LM55	5.16^{bcd} (± 0.17)	15.06^{ghi} (± 0.63)	48.04 (± 0.00)	31.32 (± 0.00)
LU1010	5.00^{bc} (± 0.21)	9.54^{d} (± 0.47)	46.52 (± 0.00)	31.75 (± 0.00)
LU1020	4.69^{b} (± 0.13)	9.25^{bcd} (± 0.48)	45.16 (± 0.00)	29.77 (± 0.00)
LU1030	5.21^{cd} (± 0.01)	9.50^{d} (± 0.06)	50.20 (± 0.00)	30.32 (± 0.00)
LU3010	5.14^{bcd} (± 0.33)	8.62^{ab} (± 0.09)	44.02 (± 0.00)	32.02 (± 0.00)
LU3020	5.52^{cd} (± 0.35)	8.69^{abc} (± 0.07)	47.80 (± 0.00)	32.00 (± 0.00)
LU3030	5.47^{cd} (± 0.20)	9.72^{d} (± 0.42)	48.44 (± 0.00)	31.70 (± 0.00)
LU5010	1.90^{a} (± 0.08)	8.44^{a} (± 0.04)	50.44 (± 0.00)	31.66 (± 0.00)
LU5020	5.42^{cd} (± 0.31)	9.22^{bcd} (± 0.23)	48.80 (± 0.00)	30.52 (± 0.00)
LU5030	5.56^{d} (± 0.28)	9.30^{cd} (± 0.03)	49.70 (± 0.00)	30.75 (± 0.00)
n	3	3	1	1
min	1.74	8.44	44.02	29.77
max	6.05	16.10	81.90	34.44
Av.	4.75	12.21	50.33	31.49

n means the number of a run for each data.
± means the standard deviation of "n" number of measurements.
AC: Ash Content (%, d.b.), MC: Moisture Content (%, d.b.),
HW: Hectoliter-Weight (kg/100 L), TKW: 1000-Kernels Weight (g, d.b.).
a, b, c etc. show Duncan Test homogeneous groups ($P<0.05$).

3.3.4. Relationship Between Parameters of Red-Lentil Samples

Pearson test results of red-lentil samples were given in Table A.6. (Appendix).

There is a positive significant correlation between the protein and moisture contents of the samples at level P≤0.01 (0.510). However, a negative significant correlation has been observed between the protein and starch contents of the samples at level P≤0.05 (-0.385). Therefore, the results showed that whenever the protein content of the samples increased; the moisture content increased and the starch content of the samples decreased.

While there is a negative significant correlation between fat content and CIE L* value of the samples at level P≤0.01 (-0.646). However, positive significant correlations have been observed between the fat content and hectoliter-weight of the samples at level P≤0.01 (0.539) and between the fat content and 1000-kernels weight (0.399) and moisture content (0.316) of the samples at level P≤0.05. As the fat content of the samples increased; CIE L* value decreased, but the moisture content, hectoliter-weight and 1000-kernels weight of the samples increased.

There are positive correlations between the starch content and hectoliter-weight of the samples at level P≤0.01 (0.585) and 1000-kernels weight at level P≤0.05 (0.384). However, it has been observed that there is a negative correlation between the starch content and CIE L* value of the samples at level P≤0.01 (-0.491). As the starch content of the samples decreases, an increment observed in term of CIE L* value. However, the starch content decreases, decrements observed in terms of hectoliter-weight and 1000-kernels weight.

Additionally, there is a positive significant correlation between CIE L* value and CIE b* value of red-lentil samples at level P≤0.05 (0.378). Negative significant correlations have been observed between CIE L* value and hectoliter-weight (-0.760) and 1000-kernels weight (-0.590) of the samples at level P≤0.01 and the moisture content at level P≤0.05 (-0.347). It has been observed that the CIE L* value increases as CIE b* value increases and the hectoliter-weight, 1000-kernels weight and moisture content of the samples decreases.

There are positive significant correlations between CIE a* value and the moisture content (0.493), CIE b* (0.745) and CIE YI (0.932) values of the samples at level P≤0.01. As CIE a* value of the samples increases, increments in terms of the moisture content, CIE b* and CIE YI values have been observed.

Besides, it has been observed that there is a positive significant correlation between CIE b* and CIE YI values of the samples at level P≤0.01 (0.788). Therefore, CIE YI* value increases as CIE b* value of the samples increases.

As the moisture content of the samples increases, an increment has been observed in CIE YI value. Therefore, there is a positive significant correlation between the moisture content and CIE YI value of the samples at level P≤0.01 (0.487).

Likewise, a positive significant correlation at level P≤0.01 (0.662) has been observed between the hectoliter-weight and 1000-kernels weight of the samples. As hectoliter-weight of the samples increases, 1000-kernels weight increases, too.

3.3.5. Red-Lentil Yield

Whole processes were initiated with 110 g of red-lentil. Therefore, it was investigated that how many grams of dried red-lentil were produced from 110 g of treated and germinated red-lentil. The yield during germination process was given in Table 3.6.

According to Table 3.6, the highest red-lentil yield was obtained for LM31; however, the lowest red-lentil yield was obtained from LU5030 sample.

Table 3.6. Red-Lentil yield data.

Sample	Red-Lentil (g)	Cleaned (3.0 mm) (g)	Germinated (g)	Dried (g)
LO	110	107.15	NO	NO
LGO	110	106.06	189	108.49
LM11	110	106.15	196	105.63
LM13	110	106.87	193	108.49
LM15	110	107.02	189	108.68
LM31	110	107.03	187	109.46
LM33	110	106.87	190	108.32
LM35	110	106.62	200	107.95
LM51	110	107.58	198	108.88
LM53	110	106.09	187	107.80
LM55	110	106.90	190	108.12
LU1010	110	106.12	210	100.00
LU1020	110	107.01	214	100.30
LU1030	110	106.68	212	100.80
LU3010	110	106.94	213	101.00
LU3020	110	106.95	215	101.00
LU3030	110	105.86	207	100.00
LU5010	110	106.45	214	100.00
LU5020	110	105.90	211	101.00
LU5030	110	104.14	204	98.00

The mesh size for the cleaning is according to Turkish Standards (TS 143:2008).

3.3.6. Sensory Analysis

Results are given in Table 3.7. as the average of points which are given according to the quality criterions by the panelists.

Red-Lentil-1 sample was LO, which was ungerminated and untreated red-lentil (control).

Red-Lentil-2 sample was LM13, which was microwave treated red-lentil during the germination operation in every 6 hours for 3 min and 1 W/kg.

Red-Lentil-3 sample was LU1020, which was ultrasound treated red-lentil during the germination operation in every 6 hours for 20 min and 10 W/kg at 40 kHz.

Table 3.7. The average of sensory analysis results of red-lentil soup samples.

Quality Criterions	Sample Codes – Score Out of 5		
	Red-Lentil-1	Red-Lentil-2	Red-Lentil-3
Flavor	2.73^{a} (± 1.03)	2.73^{a} (± 0.88)	2.87^{a} (± 1.25)
Odor	3.60^{b} (± 0.51)	2.60^{a} (± 0.91)	2.60^{a} (± 1.06)
Texture	3.13^{a} (± 0.83)	2.60^{a} (± 0.91)	3.27^{a} (± 0.88)
Appearance	3.40^{c} (± 0.74)	1.73^{a} (± 0.46)	2.60^{b} (± 0.74)
Overall Effect	3.13^{a} (± 1.03)	2.60^{a} (± 1.18)	3.27^{a} (± 1.03)
Average	3.20 (± 0.29)	2.45 (± 0.36)	2.92 (± 0.30)

± means the standard deviation measurements.
a, b, c etc. show Duncan Test homogeneous groups ($P<0.05$).

As the flavor, the best red-lentil soup was LU1020, sample which was dominated according to the others.

According to odor, LO red-lentil soup was chosen the best by panelists.

The texture of the soup samples as compared, LU1020 red-lentil soup was better than the other red-lentil soup samples.

In terms of appearance, LO red-lentil soup sample was scored better than the other samples.

According to the answer to overall effect asked the panelists, LU1020 red-lentil soup sample was better than the others.

Finally, according to all criteria, LO red-lentil soup was the highest score. Likewise, LU1020 was not bad according to the panelists. A score of LO and LU1020 soup samples are close to each other.

CHAPTER 4.

CONCLUSIONS

The present study was aimed to fill the gap in the literature about the production of bulgur from germinated wheat, the effect of microwave and ultrasound treatments during germination of wheat and red-lentil. Also, it was aimed to meet the consumer demands by improving the color of wheat, bulgur, and red-lentil.

This study reveals that;

- In terms of protein content;
    - Microwave treatment during germination of wheat increased the protein content of wheat.
    - Considering a higher increment in the protein content, bulgur should be produced from germinated and treated wheat with ultrasound at higher power. Also, the protein content of bulgur samples increased with increase in exposure power ($P \leq 0.05$)
    - Germination and germination with high power ultrasound increased the protein content of red-lentil.
- In terms of fat content;
    - The fat content of wheat samples decreased by germination and with increasing exposure time and power of treatments.
    - Ultrasound, microwave treatments and increasing exposure time decrease the fat content of bulgur.
    - Germination, ultrasound and microwave treatments, by increasing exposure time and power of the treatments, decreased the fat content of

- red-lentil. The major decrement of the fat content was provided by the germination operation.

- In terms of starch content;
  - It was founded that germination decreases the starch content of wheat, bulgur and lentil samples.
  - Increasing exposure time of the ultrasound and microwave treatments decreases the starch content of wheat and bulgur samples.
  - Also, ultrasound and microwave applications decrease the starch content.

- In terms of color values,
  - The germination is the major factor for increasing CIE L* value of wheat and bulgur.
  - The germination operation and the treatments increase the yellowness of wheat.
  - The CIE b* value of bulgur decreased during microwave and ultrasound treatments.
  - Considering a higher increment in CIE L* value is desired, red-lentil should be germinated and treated with ultrasound at higher power and higher time.

REFERENCES

Abdel-Rahman, A.-H. Y. (1984). Improvement of nutritive value in corn for human nutrition. *Food Chemistry*. **13**, 17-23.

Adolph, W. H., Shammas, E. I., Halaby, S. H. (1955). The nutritive value of legume proteins and legume-wheat mixed proteins in near east diets. *Journal of Food Science*. **20**, 31-34.

Adom, K. K., Sorrells, M. E., Liu, R. H. (2003). Phytochemical profiles and antioxidant activity of wheat varieties. *Journal of agricultural and food chemistry*. **51**, 7825-7834.

Ahmed, A., Javed, I., Akram, M., Akhtar, S. (2003). Germination scenario of barley genotypes to chloride and sulphate salinities of sodium. *International Journal of Agriculture and Biology*. **5**, 258-261.

Aladjadjiyan, A. (2002). Increasing carrot seeds (Daucus carota L.), cv. Nantes, viability through ultrasound treatment. *Bulgarian Journal of Agricultural Science (Bulgaria)*.

Aladjadjiyan, A. (2003). The effect of pre-sowing treatment by physical methods on seed germination in some ornamental tree species. *Rastenievdni Nauki (Bulgaria)*.

Aladjadjiyan, A. (2010). Effect of microwave irradiation on seeds of lentils (lens culinaris, med.). *Romanian Journal of Biophysics*. **20**, 213-221.

Aladjadjiyan, A. (2011). Ultrasonic stimulation of the development of lentils and wheat seedlings. *Romanian Journal of Biophysics*. **21**, 179-188.

Alajaji, S. A., El-Adawy, T. A. (2006). Nutritional composition of chickpea (Cicer arietinum L.) as affected by microwave cooking and other traditional cooking methods. *Journal of Food Composition and Analysis*. **19**, 806-812.

Amarowicz, R., Estrella, I., Hernández, T., Dueñas, M., Troszyńska, A., Kosińska, A., Pegg, R. B. (2009). Antioxidant activity of a red lentil extract and its fractions. *International journal of molecular sciences*. **10**, 5513-5527.

Amarowicz, R., Estrella, I., Hernández, T., Robredo, S., Troszyńska, A., Kosińska, A., Pegg, R. B. (2010). Free radical-scavenging capacity, antioxidant activity, and phenolic composition of green lentil (Lens culinaris). *Food Chemistry*. **121**, 705-711.

Amarowicz, R., Pegg, R. B. (2008). Legumes as a source of natural antioxidants. *European Journal of Lipid Science and Technology*. **110**, 865-878.

Andlauer, W., Furst, P. (1998). Antioxidative power of phytochemicals with special reference to cereals. *Cereal foods world (USA)*.

Antoine, C., Peyron, S., Mabille, F., Lapierre, C., Bouchet, B., Abecassis, J., Rouau, X. (2003). Individual contribution of grain outer layers and their cell wall structure to the mechanical properties of wheat bran. *Journal of agricultural and food chemistry*. **51**, 2026-2033.

AOAC. Association of Official Analytical Chemists. 1990. Official methods of analysis of the Association of Official Analytical Chemists. Arlington, VA, USA.

Augustin, J., Cole, C., Fellman, J., Matthews, R., Tassinari, P., Woo, H. (1983). Nutrient content of sprouted wheat and selected legumes. *Cereal foods world (USA)*.

Augustin, J., Klein, B. (1989). Nutrient composition of raw, cooked, canned, and sprouted legumes.

Balcı, F. (2015). Research on color changes during bulgur production and the development of new systems to obtain yellow bulgur. Doctorate, Gaziantep University Institute of Science and Technology, 138, Gaziantep/Turkey.

Bamdad, F., Dokhani, S., Keramat, J. (2009). Functional Assessment and Subunit Constitution of Lentil (Lens culinaris) Proteins during Germination. *International Journal of Agriculture and Biology*. **11**, 690-694.

Banik, S., Bandyopadhyay, S., Ganguly, S. (2003). Bioeffects of microwave: A brief review. *Bioresour Technol*. **87**, 155-159.

Bartolomé, B., Estrella, I., Hernandez, T. (1997). Changes in phenolic compounds in lentils (Lens culinaris) during germination and fermentation. *Zeitschrift für Lebensmitteluntersuchung und-Forschung A*. **205**, 290-294.

Bau, H., Villaume, C., Mejean, L. (2000). Effects of soybean (Glycine max) germination on biologically active components, nutritional values of seeds, and biological characteristics in rats. *Food/Nahrung*, 2-6.

Bau, H., Villaume, C., Nicolas, J. P., Méjean, L. (1999). Effect of germination on chemical composition, biochemical constituents and antinutritional factors of soya bean (Glycine max) seeds. *Journal of the Science of Food and Agriculture*, 1-9.

Baublis, A. J., Lu, C., Clydesdale, F. M., Decker, E. A. (2000). Potential of wheat-based breakfast cereals as a source of dietary antioxidants. *Journal of the American College of Nutrition*. **19**, 308S-311S.

Bayram, M. (2000). Bulgur around the world. *Cereal Foods World*. **45**, 80-82.

Bayram, M. (2003). Production of bulgur-like foods from soybean and rye. Ph. D., Gaziantep University Institute of Science and Technology, Gaziantep, Turkey.

Bayram, M. (2005). Modelling of cooking of wheat to produce bulgur. *Journal of Food Engineering*. **71**, 179-186.

Bayram, M. (2006). Determination of the cooking degree for bulgur production using amylose/iodine, centre cutting and light scattering methods. *Food Control*. **17**, 331-335.

Bayram, M. (2007). Application of bulgur technology to food aid programs. *Cereal Foods World*. **52**.

Bayram, M., Kaya, A., Öner, M. (2003). Color-sorting systems for bulgur production. *Cereal Foods World*. **48**, 168-172.

Bayram, M., Kaya, A., Öner, M. D. (2004a). Changes in properties of soaking water during production of soy-bulgur. *Journal of Food Engineering*. **61**, 221-230.

Bayram, M., Kaya, A., Öner, M. D. (2004b). Water absorption, leaching and color changes during the soaking for production of soy-bulgur. *Journal of Food Process Engineering*. **27**, 119-141.

Bayram, M., Öner, M. (1996). Bulgur üretiminin bugünkü durumu ve sorunları. II. Un-Bulgur-Bisküvi Sempozyumu (Symposium book), Karaman-Turkey, 165-177.

Bayram, M., Öner, M. (2002). The new old wheat: convenience and nutrition driving demand for bulgur. *World Grain (November)*, 51-53.

Bayram, M., Öner, M., Eren, S. (1996). State of the art and problems encountered in bulgur production. *Food Technology-Turkey*. **1**, 39-45.

Bayram, M., Öner, M. D. (2005). Stone, disc and hammer milling of bulgur. *Journal of Cereal Science*. **41**, 291-296.

Bayram, M., Öner, M. D. (2007). Bulgur milling using roller, double disc and vertical disc mills. *Journal of Food Engineering*. **79**, 181-187.

Bayram, M., Öner, M. D., Eren, S. (2004c). Effect of cooking time and temperature on the dimensions and crease of the wheat kernel during bulgur production. *Journal of Food Engineering*. **64**, 43-51.

Bayram, M., Öner, M. D., Kaya, A. (2004d). Influence of soaking on the dimensions and colour of soybean for bulgur production. *Journal of Food Engineering*. **61**, 331-339.

Beal, A. D., Mottram, D. S. (1993). An evaluation of the aroma characteristics of malted barley by free-choice profiling. *Journal of the Science of Food and Agriculture*. **61**, 17-22.

Bhatty, R. (1988). Composition and quality of lentil (Lens culinaris Medik): a review. *Canadian Institute of Food Science and Technology Journal*. **21**, 144-160.

Bilgiçli, N. (2009). Effects of cooking and drying processes on physical, chemical and sensory properties of legume based bulgur. *Journal of Food Processing and Preservation*. **33**, 590-604.

Bingham, S. A., Day, N. E., Luben, R., Ferrari, P., Slimani, N., Norat, T., Clavel-Chapelon, F., Kesse, E., Nieters, A. and Boeing, H. (2003). Dietary fibre in food and protection against colorectal cancer in the European Prospective Investigation into Cancer and Nutrition (EPIC): an observational study. *The Lancet*. **361**, 1496-1501.

Bryant JA. (1985). Seed physiology. London: Edward Arnold.

Buffler CR. (1993). Microwave cooking and processing. New York: Van Nostrand Reinhold.

Butz, P., Tauscher, B. (2002). Emerging technologies: chemical aspects. *Food Research International*. **35**, 279-284.

Callaway, J. (2004). Hempseed as a nutritional resource: an overview. *Euphytica*. **140**, 65-72.

Campana, L., Sempe, M., Filgueira, R. (1986). Effect of microwave energy on drying wheat. *Cereal chemistry (USA)*.

Campana, L., Sempe, M., Filgueira, R. (1993). Physical, chemical, and baking properties of wheat dried with microwave energy. *Cereal Chemistry*.

Carbonell, M. V., Martinez, E., Amaya, J. M. (2000). Stimulation of germination in rice (Oryza sativa L.) by a static magnetic field. *Electromagnetic Biology and Medicine*. **19**, 121-128.

Certel, M. (1990). Makarnalık (Tr. Durum) ve ekmeklik (Tr. aestivum) buğdaylardan farklı ısıl işlem uygulamalarıyla üretilen bulgur ve ürünlerinin fiziksel, kimyasal ve duyusal kalite özellikleri. Ph. D., Atatürk University Instute of Science and Technology, Erzurum, Turkey.

Chandrasekaran, S., Ramanathan, S., Basak, T. (2013). Microwave food processing: A review. *Food Research International*. **52**, 243-261.

Chang, K., Harrold, R. (1988). Changes in selected biochemical components, in vitro protein digestibility and amino acids in two bean cultivars during germination. *Journal of Food Science*. **53**, 783-787.

Chavan, J., Kadam, S., Beuchat, L. R. (1989). Nutritional improvement of cereals by sprouting. *Critical Reviews in Food Science & Nutrition*. **28**, 401-437.

Chemat, F., Hoarau, N. (2004). Hazard analysis and critical control point (HACCP) for an ultrasound food processing operation. *Ultrasonics Sonochemistry*. **11**, 257-260.

Chemat, F., Zill e, H., Khan, M. K. (2011). Applications of ultrasound in food technology: Processing, preservation and extraction. *Ultrasonics Sonochemistry*. **18**, 813-835.

Datta, A. (1990). Heat and mass transfer in the microwave processing of food. *Chemical Engineering Progress*. **86**, 47-53.

Datta AK. (2001). Handbook of microwave technology for food application. New York: CRC Press.

Decareau R. (1985). Microwaves in the food processing industry. Orlando: Academic Press.

Deshpande, U. S., Deshpande, S. S. (1991). *Foods of plant origin*. Springer US, 137-300.

Dhaliwal, Y., Aggarwal, R. (1999). Composition of fat in soybeans as affected by duration of germination and drying temperature. *Journal of Food Science and Technology*. **36**, 266-267.

Doty, N. C., Baker, C. W. (1976). Microwave conditioning of hard red spring wheat. I. Effects of wide power range on flour and bread quality. *Cereal Chemistry*. **54**, 717-727.

Dreher ML, Cho SS. (2001). Handbook of Dietary Fiber. New York: CRC Press.

El-Adawy, T., Rahma, E., El-Bedawey, A., El-Beltagy, A. (2003). Nutritional potential and functional properties of germinated mung bean, pea and lentil seeds. *Plant Foods for Human Nutrition*. **58**, 1-13.

Finney P, Friedman M. (1978). Nutritional Improvement of Food and Feed Proteins. Chicago, Illinois: Springer Science & Business Media.

Finney P, Nozzolillo C, Lea PJ, Loewus FA. (1983). Mobilization of Reserves in Germination. 17: New York: Plenum Press.

Florez, M., Carbonell, M. V., Martínez, E. (2007). Exposure of maize seeds to stationary magnetic fields: Effects on germination and early growth. *Environmental and Experimental Botany*. **59**, 68-75.

Frias, J., Diaz-Pollan, C., Hedley, C. L., Vidal-Valverde, C. (1995). Evolution of trypsin inhibitor activity during germination of lentils. *Journal of agricultural and food chemistry*. **43**, 2231-2234.

Frias, J., Fernandez-Orozco, R., Zielinski, H., Piskula, M., Kozlowska, H., Vidal-Valverde, C. (2002). Effect of germination on the content of vitamins C and E of lentils. *Polish Journal of Food and Nutrition Sciences*. **11**, 76-78.

Gallego-Juárez, J. A., Fuente, E. R. (2004). Effect of power ultrasound on mass transfer in food processing. The 18th International Congress on Acoustics, International Congress on Acoustics, 1853-1854, Kyoto International Conference Hall, Kyoto, Japan.

Ghanem, K. Z., Hussein, L. (1999). Calcium bioavailability of selected Egyptian foods with emphasis on the impact of fermentation and germination. *International Journal of Food Sciences and Nutrition*. **50**, 351-356.

Ghavidel, R. A., Prakash, J. (2007a). The impact of germination and dehulling on nutrients, antinutrients, in vitro iron and calcium bioavailability and in vitro starch and protein digestibility of some legume seeds. *LWT - Food Science and Technology*. **40**, 1292-1299.

Ghavidel, R. A., Prakash, J. (2007b). The impact of germination and dehulling on nutrients, antinutrients, in vitro iron and calcium bioavailability and in vitro starch and protein digestibility of some legume seeds. *LWT-Food Science and Technology*. **40**, 1292-1299.

Ghorpade, V., Kadam, S. (1989). Germination. *W CRC Handbook of World Food Legumes: Nutritional Chemistry, Processing Technology, and Utilization*. **3**, 165-176.

Górecki RJ, Fordoński G, Halmajan H, Horbowicz M, Jones RG, Lahuta LB, Hedley CL. (2000). Carbohydrates in Grain Legume Seeds: Improving Nutritional Quality and Agronomic Characteristics. King's Lynn, Norfolk: CABI Publishing.

Goupy, P., Hugues, M., Boivin, P., Amiot, M. J. (1999). Antioxidant composition and activity of barley (Hordeum vulgare) and malt extracts and of isolated phenolic compounds. *Journal of the Science of Food and Agriculture*. **79**, 1625-1634.

Goussous, S., Samarah, N., Alqudah, A., Othman, M. (2010). Enhancing seed germination of four crop species using an ultrasonic technique. *Experimental agriculture*. **46**, 231-242.

Han, I. H., Baik, B.-K. (2006). Oligosaccharide content and composition of legumes and their reduction by soaking, cooking, ultrasound, and high hydrostatic pressure. *Cereal Chemistry*. **83**, 428-433.

Harmuth-Hoene, A.-E. (1988). Der einfluß der keimung auf die proteinqualität von weizen und mungbohnen - stickstoffbilanzversuche an wachsenden ratten. *Zeitschrift für Ernährungswissenschaft*. **27**, 40-47.

Harmuth-Hoene, A.-E., Bognar, A. E., Kornemann, U., Diehl, J. F. (1987). Der einfluß der keimung auf den nährwert von weizen, mungbohnen und kichererbsen. *Zeitschrift für Lebensmittel-Untersuchung und Forschung*. **185**, 386-393.

Hatcher, D., Kruger, J. (1997). Simple phenolic acids in flours prepared from Canadian wheat: Relationship to ash content, color, and polyphenol oxidase activity 1. *Cereal Chemistry*. **74**, 337-343.

Hayta, M., Alpaslan, M., Çakmaklı, U. (2003). Physicochemical and Sensory Properties of Soymilk-incorporated Bulgur. *Journal of Food Science*. **68**, 2800-2803.

Hebling, S., da Silva, W. (1995). Effects of low intensity ultrasound on the germination of corn seeds (Zea mays L.) under different water availabilities. *Scientia Agricola*. **52**, 514-520.

Heinonen, M., Ollilainen, V., Linkola, E., Varo, P., Koivistoinen, P. (1989). Carotenoids and retinoids in Finnish foods: Cereal and bakery products. *Cereal Chem*. **66**, 270-273.

Hidalgo, A., Brandolini, A., Pompei, C., Piscozzi, R. (2006). Carotenoids and tocols of einkorn wheat (< i> Triticum monococcum</i> ssp.< i> monococcum</i> L.). *Journal of Cereal Science*. **44**, 182-193.

Honke, J., Kozłowska, H., Vidal-Valverde, C., Frias, J., Górecki, R. (1998). Changes in quantities of inositol phosphates during maturation and germination of legume seeds. *Zeitschrift für Lebensmitteluntersuchung und-Forschung A*. **206**, 279-283.

Hsu, D., Leung, H., Morad, M., Finney, P., Leung, C. (1982). Effect of germination on electrophoretic, functional, and bread-baking properties of yellow pea, lentil, and faba bean protein isolates. *Cereal Chemistry*.

Hung, P. V., Maeda, T., Yamamoto, S., Morita, N. (2012). Effects of germination on nutritional composition of waxy wheat. *J Sci Food Agric*. **92**, 667-672.

Ibrahim, S., Habiba, R., Shatta, A., Embaby, H. (2002). Effect of soaking, germination, cooking and fermentation on antinutritional factors in cowpeas. *Food/Nahrung*. **46**, 92-95.

Ijarotimi, O. (2012). Influence of germination and fermentation on chemical composition, protein quality and physical properties of wheat flour (Triticumaestivum). *J. Cereals Oil seeds*. **3**, 35-47.

Iqbal, A., Khalil, I. A., Ateeq, N., Khan, M. S. (2006). Nutritional quality of important food legumes. *Food Chemistry*. **97**, 331-335.

ISO, B. (1998). 10520: 1998. *Native starch. Determination of starch content. Ewers polarimetric method, ISBN: 0*. **580**, 0.

Jacobs, D., Meyer, K. A., Kushi, L. H., Folsom, A. R. (1998). Whole-grain intake may reduce the risk of ischemic heart disease death in postmenopausal women: the Iowa Women's Health Study. *The American journal of clinical nutrition*. **68**, 248-257.

Jacobs Jr, D. R., Slavin, J., Marquart, L. (1995). Whole grain intake and cancer: A review of the literature. *Nutrition and cancer*. **24**, 221-229.

Jahn-Deesbach, W., Schipper, A. (1991). Proteinqualität von keimgetreide. *Getreide Mehl und Brot*. **1**, 45.

Jenkins, D., Wolever, T., Jenkins, A. L., Giordano, C., Giudici, S., Thompson, L. U., Kalmusky, J., Josse, R. G. and Wong, G. S. (1986). Low glycemic response to traditionally processed wheat and rye products: bulgur and pumpernickel bread. *The American journal of clinical nutrition*. **43**, 516-520.

Joshi, M., Adhikari, B., Panozzo, J., Aldred, P. (2010). Water uptake and its impact on the texture of lentils (< i> Lens culinaris</i>). *Journal of Food Engineering*. **100**, 61-69.

Jyothi, E., Reddy, P. (1981). The effect of germination and cooking on the in vitro digestibility of starch in some legumes. *Nutrition Reports International (USA)*.

Kadakal, Ç., Ekinci, R., Yapar, A. (2007). The effect of cooking and drying on the water-soluble vitamins content of bulgur. *Food Science and Technology International*. **13**, 349-354.

Kadlec, P., Dostálová, J., Jana, B., Michaela, S. (2008). Degradation of α-galactosides during the germination of grain legume seeds. *Czech J. Food Sci.* **26**, 99-108.

Karadavut, U., Genç, A. (2010). Relationships between Chemical Composition and Seed Yield of some Lentil (*Lens culinaris*) Cultivars. *International Journal of Agriculture and Biology*. **12**, 625-628.

Karadavut, U., Palta, Ç. (2010). Chemical performance of multi-environment trials in lens (Lens culinaris M.). *Journal of the Science of Food and Agriculture*. **90**, 117-120.

Kasum, C. M., Jacobs, D. R., Nicodemus, K., Folsom, A. R. (2002). Dietary risk factors for upper aerodigestive tract cancers. *International Journal of cancer*. **99**, 267-272.

Kaushik, G., Satya, S., Naik, S. (2010). Effect of domestic processing techniques on the nutritional quality of the soybean. *Mediterranean Journal of Nutrition and Metabolism*. **3**, 39-46.

Kavas, A., El, S. N. (1992). Changes in nutritive value of lentils and mung beans during germination. *Chemie, Mikrobiologie, Technologie der Lebensmittel*. **14**, 3-9.

Khatoon, N., Prakash, J. (2004). Nutritional quality of microwave-cooked and pressure-cooked legumes. *International Journal of Food Sciences and Nutrition*. **55**, 441-448.

King, R. D., Puwastien, P. (1987). Effects of germination on the proximate composition and nutritional quality of winged bean (Psophocarpus tetragonolobus) seeds. *Journal of Food Science*. **52**, 106-108.

Kobus, Z. (2008). Dry matter extraction from valerian roots (Valeriana officinalis L.) with the help of pulsed acoustic field. *International Agrophysics*. **22**, 133.

Koca, A., Anıl, M. (1996). The effects of different wheat kinds and cooking methods on bulgur quality. *GIDA*. **21**, 369-374.

Köksel, H., Edney, M., Özkaya, B. (1999). Barley bulgur: effect of processing and cooking on chemical composition. *Journal of Cereal Science*. **29**, 185-190.

Kraujutiene, I., Steponavičius, D., Matusevičius, P., Steponavičienė, A. (2010). Comparative evaluation of qualitative values in germinated and ungerminated wheat grain grown in different technologies. *Annals. Food Science and Technology*. **11**, 6.

Kuo, Y.-H., Rozan, P., Lambein, F., Frias, J., Vidal-Valverde, C. (2004). Effects of different germination conditions on the contents of free protein and non-protein amino acids of commercial legumes. *Food Chemistry*. **86**, 537-545.

Kylen, A. M., McCready, R. M. (1975). Nutrients in seeds and sprouts of alfalfa, lentils, mung beans and soybeans. *Journal of Food Science*. **40**, 1008-1009.

Lin, P. Y., Lai, H. M. (2006). Bioactive compounds in legumes and their germinated products. *J Agric Food Chem*. **54**, 3807-3814.

Lintschinger, J., Fuchs, N., Moser, H., Jäger, R., Hlebeina, T., Markolin, G., Gössler, W. (1997). Uptake of various trace elements during germination of wheat, buckwheat and quinoa. *Plant Foods for Human Nutrition*. **50**, 223-237.

Liu, Y., Yoshikoshi, A., Wang, B., Sakanishi, A. (2003). Influence of ultrasonic stimulation on the growth and proliferation of Oryza sativa Nipponbare callus cells. *Colloids and Surfaces B: Biointerfaces*. **27**, 287-293.

Liyana-Pathirana, C. M., Shahidi, F. (2007). The antioxidant potential of milling fractions from breadwheat and durum. *Journal of Cereal Science*. **45**, 238-247.

López-Amorós, M., Hernandez, T., Estrella, I. (2006). Effect of germination on legume phenolic compounds and their antioxidant activity. *Journal of Food Composition and Analysis*. **19**, 277-283.

Lorenz, K., D'Appolonia, B. (1980). Cereal sprouts: composition, nutritive value, food applications. *Critical Reviews in Food Science & Nutrition*. **13**, 353-385.

Lorenz, K., Valvano, R. (1981). Functional characteristics of sprout-damaged soft white wheat flours. *Journal of Food Science*. **46**, 1018-1020.

Maillard, M.-N., Berset, C. (1995). Evolution of antioxidant activity during kilning: role of insoluble bound phenolic acids of barley and malt. *Journal of agricultural and food chemistry*. **43**, 1789-1793.

Malleshi, N., Klopfenstein, C. (1996). Proximate composition, amino acid and vitamin contents of malted chickpea, mungbean and their seed coats. *Journal of Food Science and Technology*. **33**, 479-482.

Marconi, E., Carcea, M. (2001). Pasta from nontraditional raw materials. *Cereal Foods World*. **46**, 522-530.

Markov, G., Krastev, G., Gogadzhev, A. (1987). Influence of ultrasound on the productivity of pepper and cucumbers. *Rastenievudni nauki*. **24**.

Mason, T., Paniwnyk, L., Lorimer, J. (1996). The uses of ultrasound in food technology. *Ultrasonics Sonochemistry*. **3**, S253-S260.

Mbithi-Mwikya, S., Van Camp, J., Yiru, Y., Huyghebaert, A. (2000). Nutrient and antinutrient changes in finger millet (Eleusine coracan) during sprouting. *LWT-Food Science and Technology*. **33**, 9-14.

Mbithi, S., Van Camp, J., Rodriguez, R., Huyghebaert, A. (2001). Effects of sprouting on nutrient and antinutrient composition of kidney beans (Phaseolus vulgaris var. Rose coco). *European Food Research and Technology*. **212**, 188-191.

Megat Rusydi, M. R., Noraliza, C. W., Azrina, A., Zulkhairi, A. (2011). Nutritional changes in germinated legumes and rice varieties. *International Food Research Journal*. **18**, 705-713.

Mehta, P., Bedi, B. (1993). In vitro protein and starch digestibility in selected germinated legume flours. *Indian J Nutr Diet*. **30**, 149-153.

Meyer, K. A., Kushi, L. H., Jacobs, D. R., Slavin, J., Sellers, T. A., Folsom, A. R. (2000). Carbohydrates, dietary fiber, and incident type 2 diabetes in older women. *The American journal of clinical nutrition*. **71**, 921-930.

Mikola, M., Brinck, O., Jones, B. L. (2001). Characterization of oat endoproteinases that hydrolyze oat avenins. *Cereal Chemistry*. **78**, 55-58.

Miller, H. E., Rigelhof, F., Marquart, L., Prakash, A., Kanter, M. (2000). Antioxidant content of whole grain breakfast cereals, fruits and vegetables. *Journal of the American College of Nutrition*. **19**, 312S-319S.

Miyoshi, K., Mii, M. (1988). Ultrasonic treatment for enhancing seed germination of terrestrial orchid, Calanthe discolor, in asymbiotic culture. *Scientia horticulturae*. **35**, 127-130.

Morad, M. M., Leung, H. K., Hsu, D. L., Finney, P. L. (1980). Effect of germination on physicochemical and bread-baking properties of yellow pea, lentil, and faba bean flours and starches. *Cereal Chemistry*. **57**, 390-396.

Morad, M. M., Rubenthaler, G. L. (1983). Germination of soft white wheat and its effect on flour fractions, breadbaking, and crumb firmness. *Cereal Chemistry*. **60**, 413-417.

Morris, J., Marr, J. W., Clayton, D. (1977). Diet and heart: A postscript. *BMJ*. **2**, 1307-1314.

Naing, K. M. M. K. M., Pe, H. (1995). Amylase activity of some roots and sprouted cereals and beans. *Food and Nutrition Bulletin*. **16**.

Nandi, N., Banerjee, S. (1950). Effect of germination on the vitamin C content of pulses grown in Bengal. *Indian Pharm.* **5**, 202.

Nicodemus, K. K., Jacobs Jr, D. R., Folsom, A. R. (2001). Whole and refined grain intake and risk of incident postmenopausal breast cancer (United States). *Cancer Causes & Control*. **12**, 917-925.

Nnanna, I. A., Phillips, R. D. (1989). Amino acid composition protein quality and water-soluble vitamin content of germinated cowpeas (Vigna unguiculata). *Plant Foods for Human Nutrition*. **39**, 187-200.

Nnanna, I. A., Phillips, R. D., McWatters, K. H., Hung, Y. (1990). Effect of germination on the physical, chemical, and sensory characteristics of cowpea products: flour, paste, and akara. *Journal of agricultural and food chemistry*. **38**, 812-816.

Nouri, N. (1988). Bulgur-ein beitrag zur vollwert-und vegetarischen ernaehrung. *Getreide Mehl und Brot*.

Ohtsubo, K. i., Suzuki, K., Yasui, Y., Kasumi, T. (2005). Bio-functional components in the processed pre-germinated brown rice by a twin-screw extruder. *Journal of Food Composition and Analysis*. **18**, 303-316.

Okazaki, K., Ishihara, S. (1980). Studies on the effects of drying on the quality of high-moisture wheat [Triticum aestivum, grain]. *Research Bulletin of the Hokkaido National Agricultural Experiment Station*.

Oomah, B. D., Caspar, F., Malcolmson, L. J., Bellido, A.-S. (2011). Phenolics and antioxidant activity of lentil and pea hulls. *Food Research International*. **44**, 436-441.

Oprica, L. (2008). Effect of microwave on the dynamics of some oxidoreductase enzymes in Brassica napus germination seeds. *Analele Stiintifice ale Universitatii" Alexandru Ioan Cuza" din Iasi Sec. II a. Genetica si Biologie Moleculara*. **9**.

Ozboy, O., Koksel, H. (1998). The effects of bulgur production on various chemical properties of wheats. *Glda*. **23**, 449-457.

Özkaya, B., Özkaya, H., Köksel, H. (1996). Riboflavin-, thiamin-und mineralstoffgehalte in bulgur aus verschiedenen durumweizensorten. *Getreide, Mehl und Brot*. **50**, 347-349.

Panfili, G., Fratianni, A., Irano, M. (2003). Normal phase high-performance liquid chromatography method for the determination of tocopherols and tocotrienols in cereals. *Journal of agricultural and food chemistry*. **51**, 3940-3944.

Panfili, G., Fratianni, A., Irano, M. (2004). Improved normal-phase high-performance liquid chromatography procedure for the determination of carotenoids in cereals. *Journal of agricultural and food chemistry*. **52**, 6373-6377.

Parker, M. L., Ng, A., Waldron, K. W. (2005). The phenolic acid and polysaccharide composition of cell walls of bran layers of mature wheat (Triticum aestivum L. cv. Avalon) grains. *Journal of the Science of Food and Agriculture*. **85**, 2539-2547.

Pawar, V., Sawate, A., Ingle, U. (1986). Changes in phytate phosphorus and minerals during germination and cooking of moth bean (Phaseolus aconitifolius Jacq) seeds. *Journal of Food Science and Technology*. **23**, 36-39.

Pence, J., Robertson, J., Ferrel, R. (1964). Effects of processing on B-vitamin+ mineral contents of bulgur. *Food Technology*. **18**, 765-&.

Piyasena, P., Mohareb, E., McKellar, R. (2003). Inactivation of microbes using ultrasound: a review. *International Journal of Food Microbiology*. **87**, 207-216.

Povey MJ, Mason TJ. (1998). Ultrasound in food processing. London: Springer Science & Business Media.

Price, T. (1988). Seed sprout production for human consumption-A review. *Canadian Institute of Food Science and Technology Journal*. **21**, 57-65.

Prodanov, M., Sierra, I., Vidal-Valverde, C. (1997). Effect of germination on the thiamine, riboflavin and niacin contents in legumes. *Zeitschrift für Lebensmitteluntersuchung und-Forschung A*. **205**, 48-52.

Ragha, L., Mishra, S., Ramachandran, V., Bhatia, M. S. (2011). Effects of low-power microwave fields on seed germination and growth rate. *Journal of Electromagnetic Analysis and Applications*. **3**, 165.

Rajkó, R., Szabó, G., Vidal-Valverde, C., Kovács, E. (1997). Designed experiments for reducing antinutritive agents in soybean by microwave energy. *Journal of agricultural and food chemistry*. **45**, 3565-3569.

Randhir, R., Lin, Y.-T., Shetty, K. (2004). Stimulan of phenolics, antioxidant and antimicrobial activities in dark germinated mung bean sprouts in response to peptide and phytochemical elicitortios. *Process Biochemistry*. **39**, 637-646.

Ranum, P. (1996). Bulgur: an ancient food feeds hungry children. *Cereal Foods World*.

Rao, B. S., Prabhavathi, T. (1982). Tannin content of foods commonly consumed in India and its influence on ionisable iron. *Journal of the Science of Food and Agriculture*. **33**, 89-96.

Reddy, B., Kushalappa, M., Raghavan, G., Stevenson, M. (1995). Eradication of seedborne Diaporthe phaseolorum in soybean by microwave treatment. 66th Annual meeting of the Canadian Phytopathological Society, June, 25-28.

Reddy, M. B., Raghavan, G., Kushalappa, A., Paulitz, T. (1998). Effect of microwave treatment on quality of wheat seeds infected with Fusarium graminearum. *Journal of agricultural engineering research*. **71**, 113-117.

Ribeiro, R., Melo, I. (1990). Composition and nutritive value of chickpea. *Options Méditerranéennes-Série Séminaires*. **9**, 107-111.

Riera, E., Golas, Y., Blanco, A., Gallego, J., Blasco, M., Mulet, A. (2004). Mass transfer enhancement in supercritical fluids extraction by means of power ultrasound. *Ultrasonics Sonochemistry*. **11**, 241-244.

Rimm, E. B., Ascherio, A., Giovannucci, E., Spiegelman, D., Stampfer, M. J., Willett, W. C. (1996). Vegetable, fruit, and cereal fiber intake and risk of coronary heart disease among men. *Jama*. **275**, 447-451.

Rimsten, L., Haraldsson, A. K., Andersson, R., Alminger, M., Sandberg, A. S., Åman, P. (2002). Effects of malting on β-glucanase and phytase activity in barley grain. *Journal of the Science of Food and Agriculture*. **82**, 904-912.

Ryan, E., Galvin, K., O'Connor, T., Maguire, A., O'Brien, N. (2007). Phytosterol, squalene, tocopherol content and fatty acid profile of selected seeds, grains, and legumes. *Plant Foods for Human Nutrition*. **62**, 85-91.

Sabry, Z., Tannous, R. (1961). Effect of parboiling on thiamine, riboflavin, and niacin contents of wheat. *Cereal Chemistry*. **38**, 536-&.

Sadowska, J., Fornal, J., Vidal-Valverde, C., Frias, J. (1999). Natural fermentation of lentils: Functional properties and potential in breadmaking of fermented lentil flour. *Food/Nahrung*. **43**, 396-401.

Sangronis, E., Machado, C. (2007). Influence of germination on the nutritional quality of< i> Phaseolus vulgaris</i> and< i> Cajanus cajan</i>. *LWT-Food Science and Technology*. **40**, 116-120.

Sattar, A., Durrani, S., Mahmood, F., Ahmad, A., Khan, I. (1989). Effect of soaking and germination temperatures on selected nutrients and antinutrients of mungbean. *Food Chemistry*. **34**, 111-120.

Savage, G. P. (1991). Lentils: 0 forgotten crop.

Savelkoul, F., Van der Poel, A., Tamminga, S. (1992). The presence and inactivation of trypsin inhibitors, tannins, lectins and amylase inhibitors in legume seeds during germination. A review. *Plant Foods for Human Nutrition*. **42**, 71-85.

Schiffmann, R. (1986). Food product development for microwave processing. *Food technology (USA)*.

Seibold RL. (1990). Cereal grass: Nature's greatest health gift. Wisconsin: Keats Publishing.

Sheshetawy, H. E. E., Faid, S. M. (2010). Influence of partial replacement of beef meat by germinated lentil on quality characteristics of dry fermented sausage. *World Journal of Dairy and Food Sciences*. **5**, 197-206.

Shimomura, S. (1990). The effects of ultrasonic irradiation on sprouting radish seed. Ultrasonics Symposium, 1990. Proceedings., IEEE 1990, IEEE, 1665-1667.

Shimomura, S. (1998). The effects of ultrasonic irradiation on germination. Ultrasonics Symposium, 1998. Proceedings., 1998 IEEE, IEEE, 1439-1442.

Sierra, I., Vidal-Valverde, C. (1999). Kinetics of free and glycosylated B6 vitamers, thiamin and riboflavin during germination of pea seeds. *Journal of the Science of Food and Agriculture*. **79**, 307-310.

Singh, B., Dodda, L. (1979). Studies on the preparation and nutrient composition of bulgur from triticale. *Journal of Food Science*. **44**, 449-452.

Smigel, K. (1992). Fewer colon polyps found in men with high-fiber, low-fat diets. *Journal of the National Cancer Institute*. **84**, 80-81.

Sosulski, F., Krygier, K., Hogge, L. (1982). Free, esterified, and insoluble-bound phenolic acids. 3. Composition of phenolic acids in cereal and potato flours. *Journal of agricultural and food chemistry*. **30**, 337-340.

Šramková, Z., Gregová, E., Šturdík, E. (2009). Chemical composition and nutritional quality of wheat grain. *Acta Chimica Slovaca*. **2**, 115-138.

Stevenson, L., Phillips, F., O'Sullivan, K., Walton, J. (2012). Wheat bran: its composition and benefits to health, a European perspective. *Int J Food Sci Nutr*. **63**, 1001-1013.

Suberbie, F., Mendizabal, D., Mendizabal, C. (1981). Germination of soybeans and its modifying effects on the quality of full-fat soy flour. *Journal of the American Oil Chemists' Society*. **58**, 192-194.

Sulieman, M. A., ElTyeb, M. M., Abbass, M. A., Ibrahim, E. E. A., Babiker, E. E., ElTinay, A. H. (2007). Changes in chemical composition, phytate, phytase activity and minerals extractability of sprouted lentil cultivars. *Journal of Biological Sciences*. **7**, 776-780.

Swaminathan, M. (1974). Pulses-essentials of food and nutrition. *Madras: Ganesh and Co*, 355-356.

Tharanathan, R., Mahadevamma, S. (2003). Grain legumes - a boon to human nutrition. *Trends in Food Science & Technology*. **14**, 507-518.

Thompson, L. U. (1994). Antioxidants and hormone-mediated health benefits of whole grains. *Critical Reviews in Food Science & Nutrition*. **34**, 473-497.

Tkachuk, R. (1979). Free amino acids in germinated wheat. *Journal of the Science of Food and Agriculture*. **30**, 53-58.

Troszyńska, A., Estrella, I., Lamparski, G., Hernández, T., Amarowicz, R., Pegg, R. B. (2011). Relationship between the sensory quality of lentil (< i> Lens culinaris</i>) sprouts and their phenolic constituents. *Food Research International*. **44**, 3195-3201.

Trugo, L., Donangelo, C., Trugo, N., Bach Knudsen, K. E. (2000). Effect of heat treatment on nutritional quality of germinated legume seeds. *Journal of agricultural and food chemistry*. **48**, 2082-2086.

Ungureanu, E., Maniu, C. L., Cretescu, I. (2009). Consideration on the peroxidase activity during Hippophae rhamnoides seeds germination exposed to radiofrequency electromagnetic field influence. *Analele Stiintifice ale Universitatii" Alexandru Ioan Cuza" din Iasi Sec. II a. Genetica si Biologie Moleculara*. **10**.

Uppal, V., Bains, K. (2012). Effect of germination periods and hydrothermal treatments on in vitro protein and starch digestibility of germinated legumes. *Journal of Food Science and Technology*. **49**, 184-191.

Urbano, G., Aranda, P., Vılchez, A., Aranda, C., Cabrera, L., Porres, J. M., López-Jurado, M. a. (2005a). Effects of germination on the composition and nutritive value of proteins in Pisum sativum, L. *Food Chemistry*. **93**, 671-679.

Urbano, G., Lopez-Jurado, M., Hernandez, J., Fernandez, M., Moreu, M.-C., Frias, J., Diaz-Pollan, C., Prodanov, M. and Vidal-Valverde, C. (1995). Nutritional assessment of raw, heated, and germinated lentils. *Journal of agricultural and food chemistry*. **43**, 1871-1877.

Urbano, G., López-Jurado, M., ławomir Frejnagel, S., Gómez-Villalva, E., Porres, J. M., Frías, J., Vidal-Valverde, C., Aranda, P. (2005b). Nutritional assessment of raw and germinated pea (Pisum sativum L.) protein and carbohydrate by in vitro and in vivo techniques. *Nutrition*. **21**, 230-239.

Uwaegbute, A., Iroegbu, C., Eke, O. (2000). Chemical and sensory evaluation of germinated cowpeas (Vigna unguiculata) and their products. *Food Chemistry*. **68**, 141-146.

Valamoti, S. M. (2002). Food remains from Bronze Age-Archondiko and Mesimeriani Toumba in northern Greece? *Vegetation History and Archaeobotany*. **11**, 17-22.

Vaughan JG, Judd PA. (2006). The Oxford book of health foods. OUP Oxford.

Vidal-Valverde, C., Frias, J. (1992). Changes in carbohydrates during germination of lentils. *Zeitschrift für Lebensmittel-Untersuchung und Forschung*. **194**, 461-464.

Vidal-Valverde, C., Frias, J., Estrella, I., Gorospe, M. J., Ruiz, R., Bacon, J. (1994). Effect of processing on some antinutritional factors of lentils. *Journal of agricultural and food chemistry*. **42**, 2291-2295.

Vidal-Valverde, C., Frias, J., Sierra, I., Blazquez, I., Lambein, F., Kuo, Y.-H. (2002). New functional legume foods by germination: effect on the nutritive value of beans, lentils and peas. *European Food Research and Technology*. **215**, 472-477.

Vijayaraghavan, K. (1981). Pulses: Nutritional considerations. Grain legumes: agronomy and crop improvement, processing and storage, marketing, and nutrition, proceedings of the workshop, New Delhi, January 1981/ed. and comp. AS Aiyar, KR Iyer, Bombay, India: Protein Foods and Nutriton Development Association of India, 1981.

Walde, S., Balaswamy, K., Velu, V., Rao, D. (2002). Microwave drying and grinding characteristics of wheat (Triticum aestivum). *Journal of Food Engineering*. **55**, 271-276.

Wambura, P., Yang, W., Wang, Y. (2008). Power ultrasound enhanced one-step soaking and gelatinization for rough rice parboiling. *International Journal of Food Engineering*. **4**.

Wanasundara, P., Shahidi, F., Brosnan, M. (1999). Changes in flax (Linum usitatissmum) seed nitrogenous compounds during germination. *Food Chemistry*. **65**, 289-295.

WCRF/AICR. World Cancer Research Fund/American Institute for Cancer Research. 2007. Physical activity, and the prevention of cancer: A global perspective. London and Washington, DC.

Williams P, Singh U, Summerfield R. (1988). World crops: Cool season food legumes. Dordrecht, The Netherlands: Springer Netherlands.

Yaldagard, M., Mortazavi, S. A., Tabatabaie, F. (2008a). Application of ultrasonic waves as a priming technique for accelerating and enhancing the germination

of barley seed: Optimization of method by the Taguchi approach. *Journal of the Institute of Brewing*. **114**, 14-21.

Yaldagard, M., Mortazavi, S. A., Tabatabaie, F. (2008b). Effect of ultrasonic power on the activity of barley's alpha-amylase from post-sowing treate of seeds. *World Applied Sciences Journal*. **3**, 91-95.

Yaldagard, M., Mortazavi, S. A., Tabatabaie, F. (2008c). Influence of ultrasonic stimulation on the germination of barley seed and its alpha-amylase activity. *African Journal of Biotechnology*. **7**.

Yang, T. B., B. Ooraikul, F (2001). Studies on germination conditions and antioxidant contents of wheat grain. *International Journal of Food Sciences and Nutrition*. **52**, 319-330.

Yıldırım, A., Bayram, M., Öner, M. D. (2008). Ternary milling of bulgur with four rollers. *Journal of Food Engineering*. **84**, 394-399.

Yıldırım, A., Öner, M. D., Bayram, M. (2011). Fitting Fick's model to analyze water diffusion into chickpeas during soaking with ultrasound treatment. *Journal of Food Engineering*. **104**, 134-142.

Yıldırım, A., Öner, M. D., Bayram, M. (2013). Effect of soaking and ultrasound treatments on texture of chickpea. *Journal of Food Science and Technology*. **50**, 455-465.

Yoshida, H., Takagi, S., Hirakawa, Y. (2000). Molecular species of triacylglycerols in the seed coats of soybeans (glycine max L.) following microwave treatment. *Food Chemistry*. **70**, 63-69.

Zandomeneghi, M., Festa, C., Carbonaro, L., Galleschi, L., Lenzi, A., Calucci, L. (2000). Front-surface absorbance spectra of wheat flour: determination of carotenoids. *Journal of agricultural and food chemistry*. **48**, 2216-2221.

Zia-Ul-Haq, M., Ahmad, S., Shad, M. A., Iqbal, S., Qayum, M., Ahmad, A., Luthria, D., Amarowicz, R. (2011). Compositional studies of lentil (Lens culinaris Medik.) cultivars commonly grown in Pakistan. *Pak. J. Bot*. **43**, 1563-1567.

Zieliński, H., Frias, J., Piskuła, M. K., Kozłowska, H., Vidal-Valverde, C. (2006). The effect of germination process on the superoxide dismutase-like activity and thiamine, riboflavin and mineral contents of rapeseeds. *Food Chemistry*. **99**, 516-520.

APPENDIX

A1. Whole Data Obtained for Wheat

Table A.1. Whole data obtained for wheat

Sample	Protein Content (%, d.b.) (n=3)	Fat Content (%, d.b.) (n=3)	Starch Content (%, d.b.) (n=3)	CIE L* (n=4)	CIE a* (n=4)	CIE b* (n=4)	CIE YI (n=4)	Hectoliter-Weight (kg/100 L) (n=1)	1000-Kernels Weight (g, d.b.) (n=1)	Ash Content (%, d.b.) (n=3)	Moisture Content (%, d.b.) (n=3)	Water Absorption Capacity (%, d.b.) (n=3)
WO	9.93	1.89	70.73	50.92	9.37	25.85	76.85	85.14	43.56	1.52	8.36	31.78
WO	9.89	1.90	70.03	51.08	9.64	25.38	76.28	85.14	43.56	1.39	7.70	32.02
WGO	9.74	1.36	61.81	54.20	8.42	28.20	76.63	68.22	42.06	1.23	16.13	32.51
WGO	9.47	1.37	62.14	55.03	8.30	29.06	77.21	68.22	42.06	1.25	15.82	32.34
WM11	10.54	1.22	61.99	55.18	8.68	28.85	77.24	70.92	41.00	1.26	12.65	32.01
WM11	10.78	1.34	65.16	54.97	8.71	28.91	77.58	70.92	41.00	1.36	11.62	29.02
WM13	9.91	1.22	63.00	55.68	8.38	29.24	77.08	76.94	42.08	1.30	12.20	29.85
WM13	9.86	1.30	61.57	54.37	8.89	29.30	78.97	76.94	42.08	1.29	11.48	32.51
WM15	10.60	1.72	66.74	54.68	8.88	29.65	79.26	69.30	40.55	1.31	15.33	25.35
WM15	10.31	1.73	71.48	54.21	8.64	28.82	77.95	69.30	40.55	1.23	15.40	27.31
WM31	10.30	1.27	67.19	54.40	8.72	29.09	78.37	73.98	42.87	1.05	12.37	25.64
WM31	9.97	1.31	62.84	53.76	9.00	29.36	79.76	73.98	42.87	1.07	12.47	28.17
WM33	10.50	1.29	63.08	52.73	9.04	29.02	80.14	69.64	40.62	1.19	11.38	31.48
WM33	9.97	1.20	66.09	53.28	8.82	28.45	78.39	69.64	40.62	1.23	11.17	28.58
WM35	9.81	1.23	62.38	54.98	8.67	30.02	79.30	68.02	44.58	1.28	11.91	26.29

WM35	10.01	1.26	62.95	52.72	8.98	28.14	78.63	68.02	44.58	1.35	11.04	27.42
WM51	10.76	1.40	63.86	53.94	9.01	29.22	78.89	71.16	41.09	1.23	12.70	32.89
WM51	10.80	1.43	65.70	54.04	9.19	29.70	80.31	71.16	41.09	1.31	12.37	32.35
WM53	10.41	1.25	64.27	54.56	8.78	29.94	79.61	69.82	43.54	1.35	12.46	32.21
WM53	9.52	1.37	70.16	54.22	8.60	28.79	77.85	69.82	43.54	1.38	12.98	30.88
WM55	9.11	1.50	68.53	53.71	8.77	28.77	78.52	69.58	42.68	1.33	12.83	29.68
WM55	8.59	1.50	65.01	53.16	9.11	29.22	80.19	69.58	42.68	1.33	13.00	30.81
WU1010	9.58	1.42	64.05	54.51	9.26	30.02	80.53	69.90	39.50	1.38	9.02	33.16
WU1010	9.13	1.51	68.59	53.97	9.03	28.95	78.97	69.90	39.50	1.29	9.95	31.80
WU1020	9.59	2.02	62.38	54.12	9.05	30.39	81.15	75.24	39.72	1.38	7.85	32.95
WU1020	9.86	1.97	67.47	53.40	9.39	30.40	82.27	75.24	39.72	1.39	7.55	30.86
WU1030	9.36	1.52	61.74	54.62	8.86	29.52	79.08	70.80	39.24	1.29	10.84	28.38
WU1030	9.54	1.52	64.60	54.85	8.62	29.56	78.63	70.80	39.24	1.24	10.78	31.11
WU3010	8.50	1.23	65.18	54.44	8.81	28.53	77.54	74.10	41.52	1.27	11.34	32.41
WU3010	9.34	1.14	69.02	55.63	8.73	29.62	77.91	74.10	41.52	1.18	11.39	29.52
WU3020	9.14	1.49	61.89	56.55	8.45	27.19	73.10	76.06	42.74	1.30	10.94	27.65
WU3020	9.46	1.48	62.01	55.44	8.66	27.60	74.97	76.06	42.74	1.40	10.57	30.26
WU3030	9.42	1.35	64.83	55.50	9.11	29.60	78.79	74.50	42.19	1.43	6.46	29.05
WU3030	9.15	1.38	66.10	56.11	9.03	30.43	79.47	74.50	42.19	1.30	6.61	28.54
WU5010	9.85	1.84	64.21	54.87	8.98	29.53	79.02	71.82	41.08	1.34	10.09	27.62
WU5010	9.71	1.98	70.47	56.01	8.78	30.08	78.65	71.82	41.08	1.38	9.98	29.92
WU5020	9.22	1.42	61.77	54.74	8.74	27.67	75.80	74.66	42.89	1.41	7.17	28.46
WU5020	9.63	1.35	67.87	56.43	8.76	28.90	76.43	74.66	42.89	1.46	7.24	27.85
WU5030	9.87	1.20	68.15	54.19	8.98	29.21	79.10	73.98	40.15	1.45	8.85	32.92
WU5030	10.73	1.17	66.44	55.08	8.82	29.68	78.90	73.98	40.15	1.31	8.89	32.47

d.b. means the dry basis

n means the number of a run for each data

A2. Whole Data Obtained for Bulgur

Table A.2. Whole data obtained for bulgur

Sample	Protein Content (%, d.b.) (n=3)	Fat Content (%, d.b.) (n=3)	Starch Content (%, d.b.) (n=3)	CIE L* (n=4)	CIE a* (n=4)	CIE b* (n=4)	CIE YI (n=4)	Hectoliter-Weight (kg/100 L) (n=1)	1000-Kernels Weight (g, d.b.) (n=1)	Ash Content (%, d.b.) (n=3)	Moisture Content (%, d.b.) (n=3)	Water Absorption Capacity (%, d.b.) (n=3)
BO	9.74	0.70	67.38	56.60	8.16	29.75	76.90	62.68	5.64	0.94	14.70	118.42
BO	10.54	0.76	67.33	56.55	8.22	30.25	77.81	62.68	5.64	0.98	13.99	126.10
BGO	10.13	0.82	60.03	56.70	7.66	29.33	75.47	62.98	6.58	1.09	15.10	115.34
BGO	9.65	0.75	62.13	57.87	7.44	29.94	75.08	62.98	6.58	1.09	15.09	119.83
BM11	10.69	1.21	64.84	57.97	7.44	29.49	74.46	63.94	5.37	1.22	15.53	120.05
BM11	9.83	1.22	62.71	57.30	7.51	29.40	74.92	63.94	5.37	1.24	15.27	112.59
BM13	10.19	0.73	61.71	58.54	7.37	30.08	74.87	56.98	4.87	1.08	14.49	114.58
BM13	10.16	0.68	62.34	57.92	7.64	30.38	76.14	56.98	4.87	1.10	14.20	107.38
BM15	10.49	0.93	69.12	57.50	7.78	29.58	75.41	60.42	5.34	1.12	14.86	123.27
BM15	10.39	0.86	68.07	58.16	7.55	30.00	75.26	60.42	5.34	1.18	14.86	115.01
BM31	10.17	1.28	65.01	58.85	7.41	29.78	74.20	55.64	7.13	1.07	14.18	113.61
BM31	9.90	1.16	64.07	59.06	7.13	29.90	73.87	55.64	7.13	1.18	13.77	112.47
BM33	9.55	0.77	62.81	57.34	7.64	29.85	75.78	63.36	6.19	1.05	13.75	112.01
BM33	10.45	0.79	66.31	57.40	7.47	29.62	75.12	63.36	6.19	0.95	13.85	113.97
BM35	10.01	0.79	59.31	58.03	7.46	29.25	74.05	65.24	4.65	1.03	14.35	114.70
BM35	10.23	0.73	62.31	58.17	7.33	29.03	73.41	65.24	4.65	1.02	14.50	107.44
BM51	10.63	0.87	62.73	57.94	7.49	29.74	74.94	55.62	5.40	1.08	15.55	119.54
BM51	10.57	0.81	66.57	58.11	7.60	30.08	75.47	55.62	5.40	1.01	15.83	128.60
BM53	10.39	0.92	64.51	58.24	7.63	30.22	75.64	58.82	5.61	0.98	14.94	114.50

BM53	9.69	0.95	68.69	58.16	7.57	29.63	74.72	58.82	5.61	1.02	14.99	105.62
BM55	10.18	0.86	63.51	58.55	7.55	29.77	74.61	63.08	5.58	0.92	15.64	116.07
BM55	10.58	0.84	68.80	58.29	7.44	29.52	74.25	63.08	5.58	1.00	15.61	127.88
BU1010	10.05	0.64	68.63	59.77	7.08	28.58	71.21	58.68	4.52	1.02	13.64	111.40
BU1010	10.28	0.60	64.20	60.44	6.95	29.67	72.26	58.68	4.52	1.09	13.52	122.47
BU1020	10.35	0.59	62.30	60.47	7.01	29.54	72.11	62.12	3.53	1.05	11.99	120.81
BU1020	10.28	0.62	65.47	60.33	7.13	29.92	72.97	62.12	3.53	1.07	11.81	128.58
BU1030	10.50	0.56	65.26	60.79	6.86	29.14	71.10	56.60	3.35	1.02	10.29	120.29
BU1030	9.97	0.58	61.51	60.00	7.01	29.26	72.04	56.60	3.35	1.00	10.70	109.47
BU3010	10.10	0.73	64.74	59.11	7.16	30.09	74.20	59.36	4.67	1.00	12.60	124.60
BU3010	10.43	0.66	69.30	58.83	7.14	28.90	72.48	59.36	4.67	0.97	12.57	126.87
BU3020	10.35	0.86	60.75	59.01	7.15	29.22	72.89	65.50	5.44	1.04	12.26	116.49
BU3020	10.50	0.84	61.45	58.53	7.23	29.07	73.10	65.50	5.44	1.07	12.10	113.59
BU3030	9.98	0.51	65.70	61.23	6.89	30.24	72.52	60.86	4.86	0.99	10.69	120.84
BU3030	9.96	0.54	63.59	60.10	7.06	28.83	71.36	60.86	4.86	1.03	10.78	110.03
BU5010	10.64	1.07	64.81	58.60	7.31	28.53	72.34	59.00	6.03	0.95	17.64	104.11
BU5010	11.66	1.01	69.85	59.24	7.31	28.66	72.02	59.00	6.03	0.93	17.76	114.46
BU5020	10.55	0.56	64.07	59.60	6.99	29.71	72.97	61.00	4.56	1.23	10.75	113.02
BU5020	10.23	0.57	65.05	58.66	7.42	29.07	73.03	61.00	4.56	1.13	10.70	114.15
BU5030	10.39	0.87	68.42	57.26	7.19	27.82	72.00	59.84	4.62	1.01	14.43	117.48
BU5030	10.25	0.85	65.33	57.67	7.27	28.89	73.54	59.84	4.62	0.94	13.50	125.56

d.b. means the dry basis
n means the number of a run for each data

A3. Whole Data Obtained for Red-Lentil

Table A.3. Whole data obtained for red-lentil

Sample	Protein Content (%, d.b.) (n=3)	Fat Content (%, d.b.) (n=3)	Starch Content (%, d.b.) (n=3)	CIE L* (n=4)	CIE a* (n=4)	CIE b* (n=4)	CIE YI (n=4)	Hectoliter-Weight (kg/100 L) (n=1)	1000-Kernels Weight (g, d.b.) (n=1)	Ash Content (%, d.b.) (n=3)	Moisture Content (%, d.b.) (n=3)
LO	18.34	1.24	51.44	44.28	11.86	18.83	73.30	81.90	34.44	5.58	11.86
LO	18.76	1.31	50.45	43.76	10.53	18.02	69.64	81.90	34.44	5.13	11.48
LGO	20.23	0.40	49.43	48.70	9.87	18.65	65.50	49.54	31.58	1.67	14.72
LGO	19.66	0.40	47.80	48.81	11.25	19.80	69.99	49.54	31.58	1.82	14.50
LM11	19.82	0.36	48.40	50.07	10.95	19.64	68.06	47.82	30.40	5.53	14.33
LM11	19.98	0.40	48.04	50.91	12.77	21.24	73.35	47.82	30.40	5.33	13.52
LM13	20.62	0.26	48.75	50.02	12.39	20.76	72.65	49.98	32.11	4.53	15.44
LM13	19.21	0.28	47.73	49.51	12.31	20.83	73.11	49.98	32.11	4.82	15.28
LM15	20.15	0.38	49.80	48.47	12.07	20.40	72.91	51.40	31.15	1.98	15.14
LM15	19.99	0.38	48.00	50.32	12.73	21.06	73.51	51.40	31.15	1.84	15.19
LM31	20.40	0.52	49.03	47.89	11.48	21.03	73.71	52.06	33.13	6.22	16.22
LM31	19.92	0.57	48.37	48.97	11.34	19.64	69.68	52.06	33.13	5.88	15.97
LM33	20.08	1.21	47.88	48.18	11.50	18.93	69.19	46.96	30.81	6.20	15.99
LM33	19.56	1.20	48.26	47.57	12.08	20.85	74.68	46.96	30.81	5.82	15.85
LM35	19.63	0.51	47.83	50.01	11.96	19.45	69.33	49.44	30.25	4.98	14.51
LM35	19.72	0.53	48.73	48.79	11.66	19.77	70.86	49.44	30.25	5.31	14.47
LM51	20.59	0.33	48.12	50.59	11.23	20.07	68.95	47.58	32.23	5.04	13.82
LM51	19.29	0.34	47.75	49.25	10.90	19.43	68.32	47.58	32.23	4.98	13.93
LM53	19.66	1.21	49.25	49.47	11.12	19.24	68.07	50.78	31.86	4.68	15.62

LM53	19.84	1.22	48.66	46.53	11.59	18.37	69.69	50.78	31.86	4.70	15.81
LM55	19.81	0.24	49.78	47.61	11.31	18.73	68.96	48.04	31.32	5.28	14.62
LM55	18.78	0.23	49.50	49.00	14.12	20.91	76.68	48.04	31.32	5.04	15.51
LU1010	19.16	0.24	48.57	49.23	9.78	18.82	65.29	46.52	31.75	5.15	9.21
LU1010	18.94	0.24	49.60	51.23	11.68	20.53	69.99	46.52	31.75	4.86	9.87
LU1020	20.30	0.15	48.67	50.36	9.71	18.77	64.07	45.16	29.77	4.78	8.91
LU1020	19.16	0.14	48.34	51.24	10.63	19.70	66.74	45.16	29.77	4.59	9.58
LU1030	17.96	0.29	49.16	48.39	10.23	17.64	64.17	50.20	30.32	5.20	9.54
LU1030	18.92	0.29	47.95	50.80	12.51	21.05	72.63	50.20	30.32	5.22	9.46
LU3010	19.10	0.28	49.34	50.37	10.10	19.63	66.52	44.02	32.02	4.91	8.69
LU3010	17.91	0.29	49.42	49.18	11.32	20.40	71.08	44.02	32.02	5.37	8.56
LU3020	19.33	0.21	48.08	50.21	10.49	19.26	66.47	47.80	32.00	5.27	8.63
LU3020	18.70	0.21	48.19	51.46	10.08	19.68	65.62	47.80	32.00	5.76	8.74
LU3030	19.52	0.20	47.91	48.88	10.12	19.90	68.33	48.44	31.70	5.33	10.02
LU3030	19.72	0.20	48.25	50.23	9.82	18.39	63.56	48.44	31.70	5.61	9.42
LU5010	19.44	1.11	49.11	50.16	12.04	20.78	72.00	50.44	31.66	1.84	8.47
LU5010	20.14	1.01	48.58	49.71	9.79	18.82	64.87	50.44	31.66	1.96	8.42
LU5020	19.16	0.25	49.39	50.14	12.97	22.16	76.22	48.80	30.52	5.20	9.38
LU5020	17.84	0.24	49.58	50.73	9.75	19.15	64.65	48.80	30.52	5.64	9.06
LU5030	19.01	0.15	49.69	51.03	11.75	20.05	69.23	49.70	30.75	5.37	9.28
LU5030	19.81	0.15	48.53	49.58	9.24	18.14	62.68	49.70	30.75	5.76	9.32

d.b. means the dry basis
n means the number of a run for each data

A4. Pearson Correlation Coefficients for Wheat

Table A.4. Pearson correlation coefficients for wheat

Parameters	Germ.	Treat.	Power	Time	PC	FC	SC	CIE L*	CIE a*	CIE b*	CIE YI	HW	TKW	AC	MC
Germ.															
Treat.	0.474**														
Power	0.421**	0.421**													
Time	0.421**	0.421**	0.375*												
PC	-0.046	-0.345*	-0.025	-0.110											
FC	-0.421**	0.024	-0.265	-0.152	-0.067										
SC	-0.395*	-0.035	0.095	-0.053	0.026	0.336*									
CIE L*	0.656**	0.563**	0.283	0.233	-0.147	-0.287	-0.252								
CIE a*	-0.530**	0.028	-0.037	-0.088	-0.073	0.434**	0.308	-0.628**							
CIE b*	0.727**	0.446**	0.289	0.376*	0.095	-0.124	0.142	0.484**	-0.107						
CIE YI	0.248	0.136	0.117	0.246	0.192	0.141	0.066	-0.237	0.484**	0.722**					
HW	-0.736**	-0.022	-0.237	-0.285	-0.086	-0.325*	0.228	-0.251	0.427**	-0.540**	-0.319*				
TKW	-0.299	-0.445**	0.171	-0.077	-0.123	-0.202	-0.034	-0.124	-0.105	-0.447**	-0.413**	0.206			
AC	-0.350*	0.185	0.073	0.119	-0.167	0.382*	0.218	-0.074	0.330*	-0.228	-0.110	0.356*	0.096		
MC	0.275	-0.563**	-0.149	-0.127	0.229	-0.226	-0.134	-0.008	-0.551**	0.046	-0.076	-0.570**	0.068	-0.556**	
WAC	-0.182	-0.101	-0.143	-0.362*	-0.005	0.003	-0.046	-0.268	0.231	-0.031	0.170	0.151	-0.292	0.221	-0.080

**: Correlation is significant at the 0.01 level (2-tailed).

*: Correlation is significant at the 0.05 level (2-tailed).

Germ.: Germination, Treat.: Treatment, Power: Exposure Power, Time: Exposure Time

PC: Protein Content (%, d.b.), FC: Fat Content (%, d.b.), SC: Starch Content (%, d.b.), CIE L*: Lightness, CIE a*: Redness, CIE b*: Yellowness, CIE YI: Yellowness Index, HW: Hectoliter-Weight (kg/100L), TKW: 1000-Kernels Weight (g, d.b.), AC: Ash Content (%, d.b.), MC: Moisture Content (%, d.b.), WAC: Water Absorption Capacity (%, d.b.).

A5. Pearson Correlation Coefficients for Bulgur

Table A.5. Pearson correlation coefficients for bulgur

Parameters	Germ.	Treat.	Power	Time	PC	FC	SC	CIE L*	CIE a*	CIE b*	CIE YI	HW	TKW	AC	MC
Germ.															
Treat.	0.474**														
Power	0.421**	0.421**													
Time	0.421**	0.421**	0.375*												
PC	0.079	0.282	0.321*	-0.001											
FC	0.086	-0.319*	0.175	-0.263	0.162										
SC	-0.217	0.095	0.192	-0.020	0.347*	0.083									
CIE L*	0.398*	0.728**	0.095	0.303	0.089	-0.448**	-0.041								
CIE a*	-0.628**	-0.819**	-0.220	-0.354*	-0.076	0.325*	0.144	-0.848**							
CIE b*	-0.211	-0.488**	-0.277	-0.189	-0.254	-0.044	-0.161	-0.048	0.349*						
CIE YI	-0.496**	-0.861**	-0.263	-0.353*	-0.204	0.300	-0.028	-0.774**	0.897**	0.659**					
HW	-0.163	-0.177	-0.180	0.084	-0.114	-0.032	-0.249	-0.285	0.197	-0.119	0.137				
TKW	-0.113	-0.597**	0.066	-0.475**	-0.050	0.668**	0.041	-0.536**	0.493**	0.192	0.513**	0.048			
AC	0.247	-0.104	-0.256	-0.101	-0.135	0.219	-0.256	-0.010	-0.077	0.214	0.094	0.033	0.050		
MC	-0.065	-0.511**	0.124	-0.344*	0.278*	0.673**	0.209	-0.587**	0.555**	-0.012	0.448**	-0.015	0.593**	-0.123	
WAC	-0.197	-0.007	-0.120	-0.111	0.236	-0.175	0.309	0.035	0.033	0.225	0.113	0.024	-0.201	-0.122	-0.090

**: Correlation is significant at the 0.01 level (2-tailed).
*: Correlation is significant at the 0.05 level (2-tailed).
Germ.: Germination, Treat.: Treatment, Power: Exposure Power, Time: Exposure Time
PC: Protein Content (%, d.b.), FC: Fat Content (%, d.b.), SC: Starch Content (%, d.b.), CIE L*: Lightness, CIE a*: Redness, CIE b*: Yellowness, CIE YI: Yellowness Index, HW: Hectoliter-Weight (kg/100L), TKW: 1000-Kernels Weight (g, d.b.), AC: Ash Content (%, d.b.), MC: Moisture Content (%, d.b.).

A6. Pearson Correlation Coefficients for Red-Lentil

Table A.6. Pearson correlation coefficients for red-lentil

Parameters	Germ.	Treat.	Power	Time	PC	FC	SC	CIE L*	CIE a*	CIE b*	CIE YI	HW	TKW	AC
Germ.														
Treat.	0.474**													
Power	0.421**	0.421**												
Time	0.421**	0.421**	0.375*											
PC	0.301	-0.290	0.030	-0.001										
FC	-0.492**	-0.454**	0.014	-0.344*	0.081									
SC	-0.608**	-0.175	-0.095	-0.224	-0.385*	0.240								
CIE L*	0.738**	0.637**	0.256	0.292	0.081	-0.646**	-0.491**							
CIE a*	0.007	-0.305	0.020	0.163	0.052	0.129	0.043	-0.036						
CIE b*	0.289	0.059	0.063	0.064	0.098	-0.192	-0.162	0.378*	0.745**					
CIE YI	-0.136	-0.379*	-0.058	-0.007	0.047	0.221	0.133	-0.213	0.932**	0.788**				
HW	-0.965**	-0.537**	-0.390*	-0.359*	-0.213	0.539**	0.585**	-0.760**	0.058	-0.262	0.190			
TKW	-0.641**	-0.431**	-0.157	-0.570**	-0.067	0.399*	0.384*	-0.590**	-0.036	-0.134	0.152	0.662**		
AC	-0.108	0.211	0.225	0.189	-0.281	-0.096	-0.006	-0.071	-0.058	-0.086	-0.046	0.023	0.045	
MC	0.042	-0.768**	-0.084	-0.017	0.510**	0.316*	-0.144	-0.347*	0.493**	0.176	0.487**	0.067	0.138	-0.058

**: Correlation is significant at the 0.01 level (2-tailed).

*: Correlation is significant at the 0.05 level (2-tailed).

Germ.: Germination, Treat.: Treatment, Power: Exposure Power, Time: Exposure Time

PC: Protein Content (%, d.b.), FC: Fat Content (%, d.b.), SC: Starch Content (%, d.b.), CIE L*: Lightness, CIE a*: Redness, CIE b*: Yellowness, CIE YI: Yellowness Index, HW: Hectoliter-Weight (kg/100L), TKW: 1000-Kernels Weight (g, d.b.), AC: Ash Content (%, d.b.), MC: Moisture Content (%, d.b.).

A7. ANOVA Results for All Parameters of Wheat

Table A.7. ANOVA results for all parameters of wheat

Source	Dependent Variable	Type III SS	df	Mean Square	F	Sig.
Corrected Model	Protein Content	10.872[a]	19	0.572	5.978	0.000
	Fat Content	2.291[b]	19	0.121	52.378	0.000
	Starch Content	211.261[c]	19	11.119	1.683	0.128
	CIE L*	47.827[d]	19	2.517	5.665	0.000
	CIE a*	2.473[e]	19	0.130	4.496	0.001
	CIE b*	39.303[f]	19	2.069	6.581	0.000
	CIE YI	98.966[g]	19	5.209	7.449	0.000
	Hectoliter-Weight	602.956[h]	19	31.735	.	.
	1000-Kernels Weight	82.914[h]	19	4.364	.	.
	Ash Content	0.297[i]	19	0.016	5.323	0.000
	Moisture Content	238.247[j]	19	12.539	112.106	0.000
	Water Absorption Capacity	156.889[k]	19	8.257	4.444	0.001
Intercept	Protein Content	2777.087	1	2777.087	29014.123	0.000
	Fat Content	65.732	1	65.732	28548.087	0.000
	Starch Content	125401.093	1	125401.093	18976.459	0.000
	CIE L*	84100.805	1	84100.805	189262.770	0.000
	CIE a*	2304.913	1	2304.913	79603.289	0.000
	CIE b*	23496.809	1	23496.809	74757.987	0.000
	CIE YI	176105.819	1	176105.819	251831.573	0.000
	Hectoliter-Weight	159070.153	1	159070.153	.	.
	1000-Kernels Weight	50869.473	1	50869.473	.	.
	Ash Content	50.926	1	50.926	17351.109	0.000
	Moisture Content	3367.226	1	3367.226	30104.167	0.000
	Water Absorption Capacity	26869.273	1	26869.273	14459.742	0.000
Germination	Protein Content	0.093	1	0.093	0.972	0.336
	Fat Content	0.281	1	0.281	121.998	0.000

	Starch Content	70.644	1	70.644	10.690	0.004
	CIE L*	13.068	1	13.068	29.409	0.000
	CIE a*	1.311	1	1.311	45.278	0.000
	CIE b*	9.090	1	9.090	28.922	0.000
	CIE YI	0.126	1	0.126	0.180	0.676
	Hectoliter-Weight	286.286	1	286.286	.	.
	1000-Kernels Weight	2.250	1	2.250	.	.
	Ash Content	0.046	1	0.046	15.750	0.001
	Moisture Content	63.123	1	63.123	564.342	0.000
	Water Absorption Capacity	0.276	1	0.276	0.148	0.704
Treatment	Protein Content	3.162	1	3.162	33.040	0.000
	Fat Content	0.167	1	0.167	72.415	0.000
	Starch Content	0.632	1	0.632	0.096	0.760
	CIE L*	6.996	1	6.996	15.744	0.001
	CIE a*	0.039	1	0.039	1.359	0.258
	CIE b*	0.159	1	0.159	0.505	0.486
	CIE YI	1.660	1	1.660	2.374	0.139
	Hectoliter-Weight	52.321	1	52.321	.	.
	1000-Kernels Weight	11.067	1	11.067	.	.
	Ash Content	0.051	1	0.051	17.249	0.000
	Moisture Content	99.467	1	99.467	889.273	0.000
	Water Absorption Capacity	4.326	1	4.326	2.328	0.143
Exposure Power	Protein Content	0.551	2	0.276	2.878	0.080
	Fat Content	0.348	2	0.174	75.488	0.000
	Starch Content	23.969	2	11.984	1.814	0.189
	CIE L*	0.041	2	0.020	0.046	0.955
	CIE a*	0.011	2	0.006	0.194	0.825
	CIE b*	1.801	2	0.901	2.865	0.081
	CIE YI	6.374	2	3.187	4.558	0.023
	Hectoliter-Weight	4.716	2	2.358	.	.
	1000-Kernels Weight	27.921	2	13.960	.	.
	Ash Content	0.063	2	0.032	10.768	0.001
	Moisture Content	2.429	2	1.214	10.858	0.001
	Water Absorption Capacity	25.496	2	12.748	6.860	0.005
Exposure Time	Protein Content	0.354	2	0.177	1.848	0.183

	Fat Content	0.004	2	0.002	0.913	0.417
	Starch Content	16.161	2	8.080	1.223	0.316
	CIE L*	0.184	2	0.092	0.207	0.815
	CIE a*	0.078	2	0.039	1.347	0.283
	CIE b*	1.614	2	0.807	2.568	0.102
	CIE YI	6.554	2	3.277	4.686	0.021
	Hectoliter-Weight	44.901	2	22.451	.	.
	1000-Kernels Weight	3.421	2	1.711	.	.
	Ash Content	0.042	2	0.021	7.133	0.005
	Moisture Content	7.337	2	3.669	32.799	0.000
	Water Absorption Capacity	12.036	2	6.018	3.239	0.060
Germination * Treatment	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.
	1000-Kernels Weight	0.000	0	.	.	.
	Ash Content	0.000	0	.	.	.
	Moisture Content	0.000	0	.	.	.
	Water Absorption Capacity	0.000	0	.	.	.
Germination * Power Exposure	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.
	1000-Kernels Weight	0.000	0	.	.	.
	Ash Content	0.000	0	.	.	.
	Moisture Content	0.000	0	.	.	.
	Water Absorption Capacity	0.000	0	.	.	.

Germination * Time Exposure	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.
	1000-Kernels Weight	0.000	0	.	.	.
	Ash Content	0.000	0	.	.	.
	Moisture Content	0.000	0	.	.	.
	Water Absorption Capacity	0.000	0	.	.	.
Treatment * Power Exposure	Protein Content	1.441	2	0.720	7.526	0.004
	Fat Content	0.047	2	0.024	10.211	0.001
	Starch Content	1.317	2	0.658	0.100	0.906
	CIE L*	10.627	2	5.314	11.958	0.000
	CIE a*	0.334	2	0.167	5.760	0.011
	CIE b*	1.351	2	0.676	2.150	0.143
	CIE YI	29.790	2	14.895	21.300	0.000
	Hectoliter-Weight	37.352	2	18.676	.	.
	1000-Kernels Weight	2.110	2	1.055	.	.
	Ash Content	0.010	2	0.005	1.723	0.204
	Moisture Content	6.065	2	3.033	27.113	0.000
	Water Absorption Capacity	23.831	2	11.915	6.412	0.007
Treatment * Time Exposure	Protein Content	1.870	2	0.935	9.766	0.001
	Fat Content	0.364	2	0.182	79.111	0.000
	Starch Content	21.755	2	10.878	1.646	0.218
	CIE L*	0.624	2	0.312	0.702	0.507
	CIE a*	0.003	2	0.001	0.050	0.951
	CIE b*	1.566	2	0.783	2.491	0.108
	CIE YI	4.128	2	2.064	2.952	0.075
	Hectoliter-Weight	29.251	2	14.625	.	.
	1000-Kernels Weight	4.861	2	2.431	.	.
	Ash Content	0.009	2	0.004	1.451	0.258
	Moisture Content	8.987	2	4.494	40.175	0.000

	Water Absorption Capacity	22.219	2	11.110	5.979	0.009
Power Exposure * Time Exposure	Protein Content	0.994	4	0.248	2.596	0.067
	Fat Content	0.467	4	0.117	50.736	0.000
	Starch Content	15.864	4	3.966	0.600	0.667
	CIE L*	2.138	4	0.534	1.203	0.340
	CIE a*	0.246	4	0.062	2.125	0.115
	CIE b*	5.284	4	1.321	4.203	0.012
	CIE YI	18.108	4	4.527	6.474	0.002
	Hectoliter-Weight	63.638	4	15.909	.	.
	1000-Kernels Weight	15.289	4	3.822	.	.
	Ash Content	0.066	4	0.017	5.627	0.003
	Moisture Content	36.916	4	9.229	82.511	0.000
	Water Absorption Capacity	31.326	4	7.831	4.214	0.012
Germination * Treatment * Power Exposure	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.
	1000-Kernels Weight	0.000	0	.	.	.
	Ash Content	0.000	0	.	.	.
	Moisture Content	0.000	0	.	.	.
	Water Absorption Capacity	0.000	0	.	.	.
Germination * Treatment * Time Exposure	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.
	1000-Kernels Weight	0.000	0	.	.	.
	Ash Content	0.000	0	.	.	.

	Moisture Content	0.000	0	.	.	.
	Water Absorption Capacity	0.000	0	.	.	.
Germination * Power Exposure * Time Exposure	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.
	1000-Kernels Weight	0.000	0	.	.	.
	Ash Content	0.000	0	.	.	.
	Moisture Content	0.000	0	.	.	.
	Water Absorption Capacity	0.000	0	.	.	.
Treatment * Power Exposure * Time Exposure	Protein Content	2.401	4	0.600	6.271	0.002
	Fat Content	0.471	4	0.118	51.174	0.000
	Starch Content	57.780	4	14.445	2.186	0.108
	CIE L*	2.779	4	0.695	1.564	0.223
	CIE a*	0.432	4	0.108	3.727	0.020
	CIE b*	2.829	4	0.707	2.250	0.100
	CIE YI	20.264	4	5.066	7.244	0.001
	Hectoliter-Weight	13.699	4	3.425	.	.
	1000-Kernels Weight	10.350	4	2.588	.	.
	Ash Content	0.004	4	0.001	0.368	0.829
	Moisture Content	9.204	4	2.301	20.573	0.000
	Water Absorption Capacity	19.393	4	4.848	2.609	0.066
Germination * Treatment * Power Exposure * Time Exposure	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.
	1000-Kernels Weight	0.000	0	.	.	.

		Ash Content	0.000	0	.	.	.
		Moisture Content	0.000	0	.	.	.
		Water Absorption Capacity	0.000	0	.	.	.
	Error	Protein Content	1.914	20	0.096		
		Fat Content	0.046	20	0.002		
		Starch Content	132.165	20	6.608		
		CIE L*	8.887	20	0.444		
		CIE a*	0.579	20	0.029		
		CIE b*	6.286	20	0.314		
		CIE YI	13.986	20	0.699		
		Hectoliter-Weight	0.000	20	0.000		
		1000-Kernels Weight	.000	20	0.000		
		Ash Content	0.059	20	0.003		
		Moisture Content	2.237	20	0.112		
		Water Absorption Capacity	37.164	20	1.858		
	Total	Protein Content	3851.643	40			
		Fat Content	86.583	40			
		Starch Content	171100.369	40			
		CIE L*	118461.580	40			
		CIE a*	3147.645	40			
		CIE b*	33677.470	40			
		CIE YI	245868.740	40			
		Hectoliter-Weight	211950.585	40			
		1000-Kernels Weight	69581.814	40			
		Ash Content	69.104	40			
		Moisture Content	5056.095	40			
		Water Absorption Capacity	36556.763	40			
	Corrected Total	Protein Content	12.787	39			
		Fat Content	2.337	39			
		Starch Content	343.426	39			
		CIE L*	56.714	39			
		CIE a*	3.052	39			
		CIE b*	45.589	39			
		CIE YI	112.952	39			
		Hectoliter-Weight	602.956	39			

1000-Kernels Weight	82.914	39
Ash Content	0.356	39
Moisture Content	240.484	39
Water Absorption Capacity	194.054	39

a. R Squared = 0.850 (Adjusted R Squared = 0.708)
b. R Squared = 0.980 (Adjusted R Squared = 0.962)
c. R Squared = 0.615 (Adjusted R Squared = 0.250)
d. R Squared = 0.843 (Adjusted R Squared = 0.694)
e. R Squared = 0.810 (Adjusted R Squared = 0.630)
f. R Squared = 0.862 (Adjusted R Squared = 0.731)
g. R Squared = 0.876 (Adjusted R Squared = 0.759)
h. R Squared = 1.000 (Adjusted R Squared = 1.000)
i. R Squared = 0.835 (Adjusted R Squared = 0.678)
j. R Squared = 0.991 (Adjusted R Squared = 0.982)
k. R Squared = 0.808 (Adjusted R Squared = 0.627)

A8. ANOVA Results for All Parameters of Bulgur

Table A.8. ANOVA results for all parameters of bulgur

Source	Dependent Variable	Type III SS	df	Mean Square	F	Sig.
Corrected Model	Protein Content	2.886[a]	19	0.152	1.256	0.308
	Fat Content	1.450[b]	19	0.076	58.139	0.000
	Starch Content	198.995[c]	19	10.473	2.114	0.052
	CIE L*	49.432[d]	19	2.602	14.974	0.000
	CIE a*	3.315[e]	19	0.174	11.337	0.000
	CIE b*	8.221[f]	19	0.433	2.195	0.044
	CIE YI	94.282[g]	19	4.962	13.605	0.000
	Hectoliter-Weight	346.114[h]	19	18.217	.	.
	1000-Kernels Weight	32.356[h]	19	1.703	.	.
	Ash Content	0.230[i]	19	0.012	7.400	0.000
	Moisture Content	134.795[j]	19	7.094	137.118	0.000
	Water Absorption Capacity	992.913[k]	19	52.259	1.717	0.119
Intercept	Protein Content	3024.913	1	3024.913	25005.999	0.000
	Fat Content	18.105	1	18.105	13794.242	0.000
	Starch Content	121920.054	1	121920.054	24609.607	0.000
	CIE L*	98011.440	1	98011.440	564086.500	0.000
	CIE a*	1620.023	1	1620.023	105281.755	0.000
	CIE b*	25264.721	1	25264.721	128190.379	0.000
	CIE YI	160150.868	1	160150.868	439082.271	0.000
	Hectoliter-Weight	107456.872	1	107456.872	.	.
	1000-Kernels Weight	817.938	1	817.938	.	.
	Ash Content	31.086	1	31.086	18984.044	0.000
	Moisture Content	5622.666	1	5622.666	108671.551	0.000
	Water Absorption Capacity	399685.702	1	399685.702	13134.383	0.000
Germination	Protein Content	0.063	1	0.063	0.517	0.481
	Fat Content	0.003	1	0.003	2.305	0.145

	Starch Content	39.376	1	39.376	7.948	0.011
	CIE L*	0.504	1	0.504	2.901	0.104
	CIE a*	0.410	1	0.410	26.619	0.000
	CIE b*	0.133	1	0.133	0.676	0.421
	CIE YI	4.326	1	4.326	11.862	0.003
	Hectoliter-Weight	0.090	1	0.090	.	.
	1000-Kernels Weight	0.884	1	0.884	.	.
	Ash Content	0.017	1	0.017	10.321	0.004
	Moisture Content	0.563	1	0.563	10.872	0.004
	Water Absorption Capacity	21.856	1	21.856	0.718	0.407
Treatment	Protein Content	0.156	1	0.156	1.290	0.270
	Fat Content	0.389	1	0.389	296.034	0.000
	Starch Content	1.365	1	1.365	.276	0.605
	CIE L*	16.147	1	16.147	92.931	0.000
	CIE a*	1.303	1	1.303	84.705	0.000
	CIE b*	2.879	1	2.879	14.606	0.001
	CIE YI	51.313	1	51.313	140.685	0.000
	Hectoliter-Weight	0.002	1	0.002	.	.
	1000-Kernels Weight	8.142	1	8.142	.	.
	Ash Content	0.014	1	0.014	8.551	0.008
	Moisture Content	41.045	1	41.045	793.301	0.000
	Water Absorption Capacity	33.892	1	33.892	1.114	0.304
Exposure Power	Protein Content	0.725	2	0.363	2.998	0.073
	Fat Content	0.038	2	0.019	14.662	0.000
	Starch Content	30.753	2	15.377	3.104	0.067
	CIE L*	3.324	2	1.662	9.564	0.001
	CIE a*	0.140	2	0.070	4.541	0.024
	CIE b*	0.492	2	0.246	1.249	0.308
	CIE YI	0.397	2	0.198	0.544	0.589
	Hectoliter-Weight	31.839	2	15.920	.	.
	1000-Kernels Weight	6.673	2	3.336	.	.
	Ash Content	0.046	2	0.023	13.946	0.000
	Moisture Content	21.565	2	10.782	208.396	0.000
	Water Absorption Capacity	16.731	2	8.366	0.275	0.762
Exposure Time	Protein Content	0.257	2	0.128	1.062	0.365

	Fat Content	0.309	2	0.155	117.901	0.000
	Starch Content	21.277	2	10.638	2.147	0.143
	CIE L*	0.103	2	0.052	0.298	0.746
	CIE a*	0.035	2	0.018	1.153	0.336
	CIE b*	1.089	2	0.544	2.762	0.087
	CIE YI	4.233	2	2.116	5.802	0.010
	Hectoliter-Weight	48.329	2	24.164	.	.
	1000-Kernels Weight	3.783	2	1.891	.	.
	Ash Content	0.014	2	0.007	4.327	0.027
	Moisture Content	22.667	2	11.334	219.051	0.000
	Water Absorption Capacity	67.224	2	33.612	1.105	0.351
Germination * Treatment	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.
	1000-Kernels Weight	0.000	0	.	.	.
	Ash Content	0.000	0	.	.	.
	Moisture Content	0.000	0	.	.	.
	Water Absorption Capacity	0.000	0	.	.	.
Germination * Power Exposure	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.
	1000-Kernels Weight	0.000	0	.	.	.
	Ash Content	0.000	0	.	.	.
	Moisture Content	0.000	0	.	.	.
	Water Absorption Capacity	0.000	0	.	.	.

Germination * Time Exposure	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter Weight	0.000	0	.	.	.
	1000-Kernels-Weight	0.000	0	.	.	.
	Ash Content	0.000	0	.	.	.
	Moisture Content	0.000	0	.	.	.
	Water Absorption Capacity	0.000	0	.	.	.
Treatment * Power Exposure	Protein Content	0.173	2	0.086	0.714	0.502
	Fat Content	0.125	2	0.063	47.805	0.000
	Starch Content	2.137	2	1.068	0.216	0.808
	CIE L*	6.689	2	3.345	19.250	0.000
	CIE a*	0.117	2	0.058	3.796	0.040
	CIE b*	1.168	2	0.584	2.963	0.075
	CIE YI	3.797	2	1.899	5.205	0.015
	Hectoliter-Weight	7.697	2	3.848	.	.
	1000-Kernels Weight	1.317	2	0.659	.	.
	Ash Content	0.032	2	0.016	9.681	0.001
	Moisture Content	3.788	2	1.894	36.602	0.000
	Water Absorption Capacity	167.388	2	83.694	2.750	0.088
Treatment * Time Exposure	Protein Content	0.337	2	0.168	1.392	0.272
	Fat Content	0.048	2	0.024	18.193	0.000
	Starch Content	23.475	2	11.737	2.369	0.119
	CIE L*	0.221	2	0.111	0.637	0.539
	CIE a*	0.061	2	0.031	1.996	0.162
	CIE b*	0.043	2	0.022	0.110	0.896
	CIE YI	0.144	2	0.072	0.197	0.823
	Hectoliter Weight	74.581	2	37.291	.	.
	1000-Kernels-Weight	0.042	2	0.021	.	.
	Ash Content	0.065	2	0.033	19.951	0.000
	Moisture Content	13.886	2	6.943	134.191	0.000

	Water Absorption Capacity	90.909	2	45.454	1.494	0.249
Power Exposure * Time Exposure	Protein Content	0.807	4	0.202	1.667	0.197
	Fat Content	0.108	4	0.027	20.485	0.000
	Starch Content	23.977	4	5.994	1.210	0.338
	CIE L*	5.008	4	1.252	7.205	0.001
	CIE a*	0.063	4	0.016	1.018	0.422
	CIE b*	1.036	4	0.259	1.314	0.299
	CIE YI	1.612	4	0.403	1.105	0.382
	Hectoliter-Weight	110.519	4	27.630	.	.
	1000-Kernels Weight	1.755	4	0.439	.	.
	Ash Content	0.034	4	0.008	5.142	0.005
	Moisture Content	15.106	4	3.777	72.992	0.000
	Water Absorption Capacity	222.323	4	55.581	1.826	0.163
Germination * Treatment * Power Exposure	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.
	1000-Kernels Weight	0.000	0	.	.	.
	Ash Content	0.000	0	.	.	.
	Moisture Content	0.000	0	.	.	.
	Water Absorption Capacity	0.000	0	.	.	.
Germination * Treatment * Time Exposure	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.
	1000-Kernels Weight	0.000	0	.	.	.
	Ash Content	0.000	0	.	.	.

	Moisture Content	0.000	0	.	.	.
	Water Absorption Capacity	0.000	0	.	.	.
Germination * Power Exposure * Time Exposure	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.
	1000-Kernels Weight	0.000	0	.	.	.
	Ash Content	0.000	0	.	.	.
	Moisture Content	0.000	0	.	.	.
	Water Absorption Capacity	0.000	0	.	.	.
Treatment * Power Exposure * Time Exposure	Protein Content	0.090	4	0.022	0.185	0.943
	Fat Content	0.421	4	0.105	80.116	0.000
	Starch Content	55.289	4	13.822	2.790	0.054
	CIE L*	5.449	4	1.362	7.840	0.001
	CIE a*	0.058	4	0.014	0.935	0.464
	CIE b*	0.913	4	0.228	1.159	0.358
	CIE YI	2.817	4	0.704	1.931	0.145
	Hectoliter-Weight	50.676	4	12.669	.	.
	1000-Kernels Weight	6.057	4	1.514	.	.
	Ash Content	0.007	4	0.002	1.004	0.429
	Moisture Content	12.571	4	3.143	60.739	0.000
	Water Absorption Capacity	330.086	4	82.522	2.712	0.059
Germination * Treatment * Power Exposure * Time Exposure	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.
	1000-Kernels Weight	0.000	0	.	.	.

	Ash Content	0.000	0	.	.	.
	Moisture Content	0.000	0	.	.	.
	Water Absorption Capacity	0.000	0	.	.	.
Error	Protein Content	2.419	20	0.121		
	Fat Content	0.026	20	0.001		
	Starch Content	99.083	20	4.954		
	CIE L*	3.475	20	0.174		
	CIE a*	0.308	20	0.015		
	CIE b*	3.942	20	0.197		
	CIE YI	7.295	20	0.365		
	Hectoliter-Weight	0.000	20	0.000		
	1000-Kernels Weight	0.000	20	0.000		
	Ash Content	0.033	20	0.002		
	Moisture Content	1.035	20	0.052		
	Water Absorption Capacity	608.610	20	30.430		
Total	Protein Content	4220.731	40			
	Fat Content	27.220	40			
	Starch Content	168093.831	40			
	CIE L*	137281.246	40			
	CIE a*	2174.088	40			
	CIE b*	34806.235	40			
	CIE YI	218626.839	40			
	Hectoliter-Weight	147172.650	40			
	1000-Kernels Weight	1112.708	40			
	Ash Content	44.132	40			
	Moisture Content	7774.973	40			
	Water Absorption Capacity	547571.479	40			
Corrected Total	Protein Content	5.306	39			
	Fat Content	1.476	39			
	Starch Content	298.078	39			
	CIE L*	52.907	39			
	CIE a*	3.622	39			
	CIE b*	12.163	39			
	CIE YI	101.576	39			
	Hectoliter-Weight	346.114	39			

1000-Kernels Weight	32.356	39
Ash Content	0.263	39
Moisture Content	135.830	39
Water Absorption Capacity	1601.523	39

a. R Squared = 0.544 (Adjusted R Squared = 0.111)
b. R Squared = 0.982 (Adjusted R Squared = 0.965)
c. R Squared = 0.668 (Adjusted R Squared = 0.352)
d. R Squared = 0.934 (Adjusted R Squared = 0.872)
e. R Squared = 0.915 (Adjusted R Squared = 0.834)
f. R Squared = 0.676 (Adjusted R Squared = 0.368)
g. R Squared = 0.928 (Adjusted R Squared = 0.860)
h. R Squared = 1.000 (Adjusted R Squared = 1.000)
i. R Squared = 0.875 (Adjusted R Squared = 0.757)
j. R Squared = 0.992 (Adjusted R Squared = 0.985)
k. R Squared = 0.620 (Adjusted R Squared = 0.259)

A9. ANOVA Results for All Parameters of Red-Lentil

Table A.9. ANOVA results for all parameters of red-lentil.

Source	Dependent Variable	Type III SS	df	Mean Square	F	Sig.
Corrected Model	Protein Content	12.586[a]	19	0.662	2.066	0.058
	Fat Content	5.502[b]	19	0.290	565.035	0.000
	Starch Content	19.348[c]	19	1.018	2.823	0.013
	CIE L*	88.455[d]	19	4.656	4.887	0.000
	CIE a*	22.402[e]	19	1.179	0.958	0.536
	CIE b*	16.024[f]	19	0.843	0.653	0.821
	CIE YI	235.050[g]	19	12.371	0.906	0.583
	Hectoliter-Weight	2253.617[h]	19	118.611	.	.
	1000-Kernels Weight	44.598[h]	19	2.347	.	.
	Ash Content	64.749[i]	19	3.408	75.311	0.000
	Moisture Content	342.474[j]	19	18.025	226.202	0.000
Intercept	Protein Content	10821.675	1	10821.675	33744.445	0.000
	Fat Content	9.884	1	9.884	19286.222	0.000
	Starch Content	69585.482	1	69585.482	192877.784	0.000
	CIE L*	68091.991	1	68091.991	71477.149	0.000
	CIE a*	3619.130	1	3619.130	2940.476	0.000
	CIE b*	11003.613	1	11003.613	8524.118	0.000
	CIE YI	139869.869	1	139869.869	10244.685	0.000
	Hectoliter-Weight	86224.105	1	86224.105	.	.
	1000-Kernels Weight	29400.384	1	29400.384	.	.
	Ash Content	638.501	1	638.501	14110.526	0.000
	Moisture Content	4331.428	1	4331.428	54356.884	0.000
Germination	Protein Content	1.946	1	1.946	6.068	0.023
	Fat Content	0.766	1	0.766	1493.902	0.000
	Starch Content	5.429	1	5.429	15.048	0.001
	CIE L*	22.420	1	22.420	23.535	0.000

	CIE a*	0.403	1	0.403	0.328	0.573
	CIE b*	0.640	1	0.640	0.496	0.489
	CIE YI	13.876	1	13.876	1.016	0.325
	Hectoliter-Weight	1047.170	1	1047.170	.	.
	1000-Kernels Weight	8.180	1	8.180	.	.
	Ash Content	13.032	1	13.032	288.002	0.000
	Moisture Content	8.644	1	8.644	108.472	0.000
Treatment	Protein Content	4.644	1	4.644	14.481	0.001
	Fat Content	0.568	1	0.568	1107.339	0.000
	Starch Content	0.558	1	0.558	1.545	0.228
	CIE L*	10.857	1	10.857	11.397	0.003
	CIE a*	12.840	1	12.840	10.432	0.004
	CIE b*	1.554	1	1.554	1.204	0.286
	CIE YI	126.900	1	126.900	9.295	0.006
	Hectoliter-Weight	18.720	1	18.720	.	.
	1000-Kernels Weight	0.853	1	0.853	.	.
	Ash Content	0.003	1	0.003	0.071	0.793
	Moisture Content	316.010	1	316.010	3965.739	0.000
Exposure Power	Protein Content	0.032	2	0.016	0.049	0.952
	Fat Content	0.447	2	0.223	435.713	0.000
	Starch Content	1.986	2	0.993	2.752	0.088
	CIE L*	3.540	2	1.770	1.858	0.182
	CIE a*	1.457	2	0.729	0.592	0.563
	CIE b*	0.960	2	0.480	0.372	0.694
	CIE YI	2.642	2	1.321	0.097	0.908
	Hectoliter-Weight	7.505	2	3.752	.	.
	1000-Kernels Weight	3.331	2	1.665	.	.
	Ash Content	8.115	2	4.057	89.666	0.000
	Moisture Content	0.617	2	0.308	3.870	0.038
Exposure Time	Protein Content	0.125	2	0.062	0.195	0.825
	Fat Content	0.404	2	0.202	394.379	0.000
	Starch Content	0.238	2	0.119	0.330	0.723
	CIE L*	0.826	2	0.413	0.433	0.654
	CIE a*	0.752	2	0.376	0.306	0.740
	CIE b*	0.859	2	0.430	0.333	0.721

	CIE YI	0.121	2	0.060	0.004	0.996
	Hectoliter-Weight	15.342	2	7.671	.	.
	1000-Kernels Weight	5.773	2	2.887	.	.
	Ash Content	1.387	2	0.694	15.327	0.000
	Moisture Content	2.394	2	1.197	15.024	0.000
Germination * Treatment	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.
	1000-Kernels Weight	0.000	0	.	.	.
	Ash Content	0.000	0	.	.	.
	Moisture Content	0.000	0	.	.	.
Germination * Power Exposure	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.
	1000-Kernels Weight	0.000	0	.	.	.
	Ash Content	0.000	0	.	.	.
	Moisture Content	0.000	0	.	.	.
Germination * Time Exposure	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.

	1000-Kernels Weight	0.000	0	.	.	.
	Ash Content	0.000	0	.	.	.
	Moisture Content	0.000	0	.	.	.
Treatment * Power Exposure	Protein Content	0.382	2	0.191	0.596	0.561
	Fat Content	0.338	2	0.169	329.436	0.000
	Starch Content	0.023	2	0.011	0.032	0.969
	CIE L*	2.691	2	1.346	1.413	0.267
	CIE a*	0.757	2	0.378	0.307	0.739
	CIE b*	3.978	2	1.989	1.541	0.239
	CIE YI	17.532	2	8.766	0.642	0.537
	Hectoliter-Weight	23.705	2	11.852	.	.
	1000-Kernels Weight	3.082	2	1.541	.	.
	Ash Content	4.460	2	2.230	49.284	0.000
	Moisture Content	1.830	2	0.915	11.481	0.000
Treatment * Time Exposure	Protein Content	0.200	2	0.100	0.312	0.736
	Fat Content	1.005	2	0.503	980.883	0.000
	Starch Content	2.083	2	1.042	2.887	0.079
	CIE L*	5.177	2	2.588	2.717	0.090
	CIE a*	1.617	2	0.808	0.657	0.529
	CIE b*	1.019	2	0.509	0.395	0.679
	CIE YI	15.717	2	7.859	0.576	0.571
	Hectoliter-Weight	7.214	2	3.607	.	.
	1000-Kernels Weight	1.251	2	0.626	.	.
	Ash Content	12.016	2	6.008	132.778	0.000
	Moisture Content	2.335	2	1.168	14.653	0.000
Power Exposure * Time Exposure	Protein Content	1.892	4	0.473	1.475	0.247
	Fat Content	.638	4	0.160	311.241	0.000
	Starch Content	4.452	4	1.113	3.085	0.039
	CIE L*	2.499	4	0.625	0.656	0.630
	CIE a*	1.068	4	0.267	0.217	0.926
	CIE b*	0.677	4	0.169	0.131	0.969
	CIE YI	19.844	4	4.961	0.363	0.832
	Hectoliter-Weight	23.223	4	5.806	.	.
	1000-Kernels Weight	1.842	4	0.461	.	.
	Ash Content	13.148	4	3.287	72.642	0.000

	Moisture Content	2.445	4	0.611	7.671	0.001
Germination * Treatment * Power Exposure	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.
	1000-Kernels Weight	0.000	0	.	.	.
	Ash Content	0.000	0	.	.	.
	Moisture Content	0.000	0	.	.	.
Germination * Treatment * Time Exposure	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.
	1000-Kernels Weight	0.000	0	.	.	.
	Ash Content	0.000	0	.	.	.
	Moisture Content	0.000	0	.	.	.
Germination * Power Exposure * Time Exposure	Protein Content	0.000	0	.	.	.
	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.
	1000-Kernels Weight	0.000	0	.	.	.
	Ash Content	0.000	0	.	.	.
	Moisture Content	0.000	0	.	.	.
	Protein Content	3.176	4	0.794	2.476	0.077

	Fat Content	0.767	4	0.192	373.908	0.000
	Starch Content	0.170	4	0.043	0.118	0.975
	CIE L*	2.978	4	0.745	0.782	0.550
	CIE a*	2.968	4	0.742	0.603	0.665
Treatment * Power Exposure * Time	CIE b*	2.832	4	0.708	0.548	0.702
Exposure	CIE YI	38.138	4	9.535	0.698	0.602
	Hectoliter-Weight	57.926	4	14.482	.	.
	1000-Kernels Weight	9.997	4	2.499	.	.
	Ash Content	6.139	4	1.535	33.915	0.000
	Moisture Content	4.343	4	1.086	13.626	0.000
Germination * Treatment * Power	Protein Content	0.000	0	.	.	.
Exposure * Time Exposure	Fat Content	0.000	0	.	.	.
	Starch Content	0.000	0	.	.	.
	CIE L*	0.000	0	.	.	.
	CIE a*	0.000	0	.	.	.
	CIE b*	0.000	0	.	.	.
	CIE YI	0.000	0	.	.	.
	Hectoliter-Weight	0.000	0	.	.	.
	1000-Kernels Weight	0.000	0	.	.	.
	Ash Content	6.414	20	0.321	.	.
	Moisture Content	0.010	20	0.001	.	.
Error	Protein Content	7.215	20	0.361		
	Fat Content	19.053	20	0.953		
	Starch Content	24.616	20	1.231		
	CIE L*	25.818	20	1.291		
	CIE a*	273.058	20	13.653		
	CIE b*	0.000	20	0.000		
	CIE YI	0.000	20	0.000		
	Hectoliter-Weight	0.905	20	0.045		
	1000-Kernels Weight	1.594	20	0.080		
	Ash Content	6.414	20	0.321		
	Moisture Content	0.010	20	0.001		
Total	Protein Content	15157.324	40			
	Fat Content	14.700	40			
	Starch Content	95221.710	40			

	CIE L*	97291.615	40
	CIE a*	5087.717	40
	CIE b*	15585.936	40
	CIE YI	192921.072	40
	Hectoliter-Weight	103573.946	40
	1000-Kernels Weight	39705.623	40
	Ash Content	969.865	40
	Moisture Content	6305.966	40
Corrected Total	Protein Content	19.000	39
	Fat Content	5.512	39
	Starch Content	26.563	39
	CIE L*	107.508	39
	CIE a*	47.018	39
	CIE b*	41.841	39
	CIE YI	508.109	39
	Hectoliter-Weight	2253.617	39
	1000-Kernels Weight	44.598	39
	Ash Content	65.654	39
	Moisture Content	344.068	39

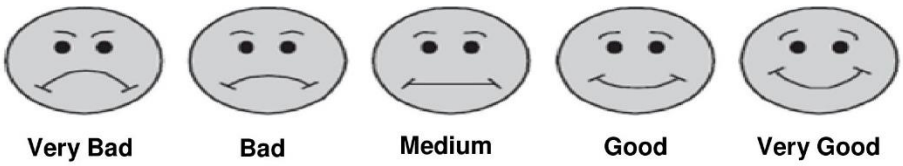
a. R Squared = 0.662 (Adjusted R Squared = 0.342)
b. R Squared = 0.998 (Adjusted R Squared = 0.996)
c. R Squared = 0.728 (Adjusted R Squared = 0.470)
d. R Squared = 0.823 (Adjusted R Squared = 0.654)
e. R Squared = 0.476 (Adjusted R Squared = 0.021)
f. R Squared = 0.383 (Adjusted R Squared = 0.203)
g. R Squared = 0.463 (Adjusted R Squared = 0.048)
h. R Squared = 1.000 (Adjusted R Squared = 1.000)
i. R Squared = 0.986 (Adjusted R Squared = 0.973)
j. R Squared = 0.995 (Adjusted R Squared = 0.991)

A10. Form of Sensory Analysis

SCORING TEST					
PANELIST NAME-SURNAME:				**DATE:**	
PRODUCT:				**TIME:**	
STATEMENT: In terms of the quality criteria given below, give scores out of 5 to the Sample 1, 2 and 3.					
QUALITY CRITERIA	**SAMPLE CODES**				
	SAMPLE 1		**SAMPLE 2**		**SAMPLE 3**
TASTE					
SMELL					
TEXTURE					
APPEARANCE					
POINTS VALUES	1 = VERY BAD	2 = BAD	3 = MEDIUM	4 = GOOD	5 = VERY GOOD

OVERALL EFFECT:

- FOR SAMPLE 1;



- FOR SAMPLE 2;

- FOR SAMPLE 3;

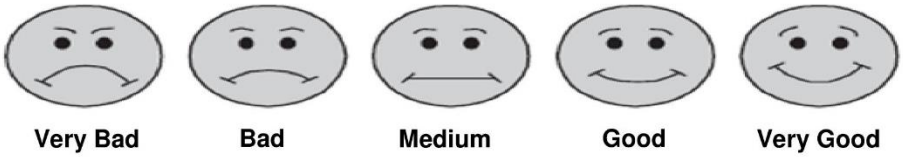


Figure A.1. Form of sensory analysis