FORMULATION AND CHARACTERIZATION OF A FUNCTIONALIZED TOMATO SNACK BAR

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ABSTRACT

FORMULATION AND CHARACTERIZATION OF A FUNCTIONALIZED TOMATO SNACK BAR

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People's current eating habits have led to a rise in diseases. Eating ready-to-eat and snack foods increases the likelihood of developing cardiovascular diseases and obesity. The Mediterranean diet promotes a healthy lifestyle by improving nutrition behaviors. Tomato is one of the indispensable ingredients of the Mediterranean diet. Reformulation of traditional Mediterranean products to increase the adherence of the consumers is getting popular. Microwave-assisted drying systems are also gaining popularity because of their many advantages. In this study, a tomato snack bar enriched with olive powder and pea protein was developed by using microwave-vacuum drying. Formulations also included tomato powder (TP) and low methoxylated pectin (LMP) as a structuring agent.

The moisture content (MC) of the microwave-vacuum-dried samples varied in the range of 13.6%-19.8% and water activity (a_w) values were ~0.6. The LMP and TP concentration affected the color of microwave-vacuum-dried samples. However, the color mainly changed in conventionally dried samples due to browning. In microwave-vacuum-dried samples, lycopene content decreased with increasing LMP, but increased with increasing TP. Textural properties of microwave-vacuum-dried snack bars increased with increasing LMP and TP.

Both texture and FTIR spectroscopy results indicated that there was a network formation due to the contribution of protein and pectin; however, the type of interaction was highly dependent on the drying mechanism. NMR relaxometry data showed that microwave-vacuum-dried samples had a more uniform water distribution. Besides its time and energy efficiency, microwave-vacuum drying improved the color and textural properties of tomato snack bars compared to conventionally dried ones.

Keywords: Microwave Drying, Pectin, Tomato Powder, Snack Bar, Mediterranean Diet

ÖZ

FONKSİYONEL ATIŞTIRMALIK DOMATES BARININ FORMÜLİZASYONU VE KARAKTERİZASYONU

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İnsanların güncel tüketim alışkanlıkları hastalıkların çoğalmasına sebep olmuştur. Hazır ve atıştırmalık gıdaların tüketiminin artması kardiyovasküler hastalıkları ve obeziteyi arttırmıştır. Akdeniz diyeti, beslenme alışkanlıklarını geliştirerek sağlıklı bir yaşam tarzı sunar. Bu diyetin vazgeçilmez bileşenlerinden biri domatestir. Tüketici bağlılığının artması için geleneksel Akdeniz ürünlerinin tekrar formüle edilmesiyle, bu diyet popülerleşmektedir. Bunun yanında, mikrodalga destekli kurutma sistemleri de sağladığı birçok avantaj sayesinde popülerlik kazanmaya devam etmektedir. Bu çalışmada, mikrodalga-vakum kurutma yöntemiyle zeytin tozu ve bezelye proteini ile zenginleştirilmiş bir domatesli atıştırmalık bar geliştirilmiştir. Formülasyonda domates tozu (DT) ve kıvam arttırıcı olarak düşük metoksilli pektin (DMP) kullanılmıştır.

Mikrodalga-vakum yöntemiyle kurutulan numunelerin su miktarları aralığı 13.6-19.8% ve su aktivitesi (a_w) değerleri 0.6'dır. DMP ve DT konsantrasyonları mikrodalga-vakum ile kurutulmuş numunelerin renklerini etkilemiştir. Ancak, geleneksel fırında kurutma yöntemiyle kurutulanların renkleri esmerleşme reaksiyonundan dolayı değişmiştir. Mikrodalga-vakum ile kurutulan numunelerde likopen miktarı DMP arttıkça azalmış, DT arttıkça artmıştır. Artan DMP ve DT

miktarları, mikrodalga-vakum ile kurutulanların dokusal özelliklerini artırmıştır.
Hem doku hem de Fourier dönüşümlü kızılötesi spektroskopi sonuçları göstermiştir ki protein ve pektinin katılımı bir ağ örgüsü oluşturmuştur; öte yandan, bu etkileşim kurutma yöntemine fazlasıyla bağlıdır. Nükleer manyetik rezonans relaksometre sonuçlarına göre mikrodalga-vakum ile kurutulmuş numuneler daha düzenli bir su dağılımına sahiptir. Zaman ve enerji verimliliğinin yanı sıra, mikrodalga-vakum kurutma, atıştırmalık domates barının renk ve doku özelliklerini geleneksel yönteme göre daha fazla geliştirmiştir.

Anahtar Kelimeler: Mikrodalga Kurutma, Pektin, Domates Tozu, Atıştırmalık Bar, Akdeniz Diyeti

Dedicated to my dear family, encouraging professors, and beloved friends

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INTRODUCTION

1.1 Current Eating Habits

Increasing demands for ready-to-eat and snack foods have changed the eating habits of consumers. Consumption of such foods constitutes a risk factor for developing cardiovascular diseases and obesity (Miranda et al., 2019). Many studies are showing how that kind of eating habit causes diseases. Lifestyle can be the most important factor affecting one's health (Mizia et al., 2021). Insufficient lifestyle habits lead to higher overweight and obesity among most people, especially younger populations. Mizia et al. researched the relationship between nutrition behaviors and diseases. In addition to an improperly balanced diet, another major nutrition mistake is the high consumption of processed products and sweetened beverages (2021). Elimination of these bad eating habits can be achieved by having the knowledge of nutrition behaviors in designing a satisfactory lifestyle. There has been a tenfold increase in the number of overweight and obesity among children, and adolescents worldwide (Bentham et al., 2017). Moreover, cardiovascular risk factors and eating patterns of adults were examined in a study (Nicklas et al., 2014). Some health indices were checked such as blood pressure, cholesterol levels, blood glucose, and insulin. These parameters got worse in the case of eating fast food continuously. On the other hand, diet quality has been improved by snacking health-promoting foods. Increasing the intake of fruits, vegetables, proteins, and fibers promotes satiety and reduces the risks of these diseases. Scientific research has proven that nutrition can be the best tool for preventing cardiovascular diseases (Casas et al., 2018). Even heart diseases could be reversed by that. To decrease the risks, designing a balanced and healthy diet with functional foods is gaining interest.

1.2 Mediterranean Diet

The Mediterranean diet is one of the best options for a healthy lifestyle (Casas et al., 2018). The geographical origin of this diet is in Turkey, Greece, Italy, Spain, Lebanon, and Tunisia, and the diet was detected in the late 1950s. The diet comprises fruits and vegetables, olives, vitamins, minerals, omega-3 fatty acids, lycopene, phytosterols, and polyphenols. All these foods and food components are used to prevent many diseases, for instance, hypertension. Moreover, an anti-inflammatory effect could be exerted by the Mediterranean diet. The results have demonstrated that oxidation, blood pressure, fasting glucose, body weight, bad cholesterol (LDL), and inflammation could be lowered by this diet. Bioactive compounds like omega-3 fatty acids, polyphenols, and lycopene present in the diet are directly related to atherosclerosis development with beneficial effects. Another study has reported that daily consumption of these bioactive compounds through taking supplements or by consumption of enriched functional foods has reduced serum triglyceride levels by about 30% (Leslie et al., 2015). Moreover, olive oil in this diet has anti-inflammatory effects with its bioactive compounds. Plant-based components of the Mediterranean diet, such as tomatoes and olives, are good candidates for designing health-promoting snack foods (Ortega, 2006).

In addition to these plant-based foods, sugar beets, nuts, and legumes such as peas and chickpeas, are considered in this diet (Ortega, 2006). This diet also has many condiments such as garlic, onions, herbs, and spices to increase the nutritional value of foods.

1.2.1 Olives

Olive is another important Mediterranean food product, the demand for it is high, resulting in significant consumption (Uylaşer & Yildiz, 2014). The olive tree is considered one of the oldest cultivated trees in the world, believed to have existed alongside humans for 5000-6000 years. Its developing region is in the Mediterranean Basin (Southern Turkey, Syria, Lebanon, Israel, Egypt, Italy, Portugal, Spain, and Greece). It is found that nearly 97% of the world's olive supply is in Mediterranean countries (Uylaşer & Yildiz, 2014). Olives have been a significant part of the human meal. *Oleaceae* is the family of the olive tree. There are about 30 genera and 600 species in that family. The olive fruit structure is a drupe; it comprises only one seed. The drupe structure consists of endocarp which is surrounding the seed. The color of olive fruit changes with respect to the ripening process. The unripe one is green, but it gets purple and then darker during ripening.

Olives are not only economically beneficial for nations, but they are also highly nutritious (Uylaşer & Yildiz, 2014). The consumption of olive and olive oils can help prevent coronary heart disease and cancers. It is containing a high amount of oil, unsaturated fatty acids, and phenolics. In addition, olive oil contains natural antioxidants which make it resistant to auto-oxidation, and as a result, it is recommended for improving human health. In addition, olives contain various phenolic alcohols that can benefit the human body. The most common ones are hydroxytyrosol, tyrosol, and their glucoside forms. Hydroxytyrosol, known for its significant health advantages, is produced when oleuropein is hydrolyzed (Charoenprasert & Mitchell, 2012).

A common and traditional method for processing olives involves milling the fruit, paste pressing and decantation (Olmo-García et al., 2019). However, this traditional method causes considerable waste generation, such as olive pomace, and liquid effluents (wastewater) during milling. Therefore, it is not practical from both an environmental and economic standpoint. Meanwhile, companies have been searching for new methods to process olives that are cost-effective, feasible from a technical standpoint, and environmentally friendly. In order to reduce waste, new processing methods have been developed. One such method involves using solvent extraction to remove oil from dehydrated pulp. In addition to that, another alternative for that purpose is cold pressing with a screw press, which generates olive oil and pulp pellet. This process would help produce olive flour after grinding the pulp pellet. The powder obtained from this method contains a significant amount of fibers, and bioactive compounds, which can be added to any functional food for enrichment. New approaches to producing olive powder involve utilizing a freeze dryer, and ultrasonic extraction (Cör Andrejč et al., 2022). Additionally, the microencapsulation method can be used in conjunction to create olive flour (Olmo-García et al., 2019).

1.2.2 Tomato

Tomato is one of the world's largest vegetable crops, versatile and popular worldwide (Ali et al., 2021). It is also considered a protective food due to its nutritional characteristics (Waheed et al., 2019). Tomatoes can be grown in regions having a warm climate. The Middle East, Spain, Italy, Pakistan, China, and North America are the countries where tomatoes can be grown widely (Figure 1.1).

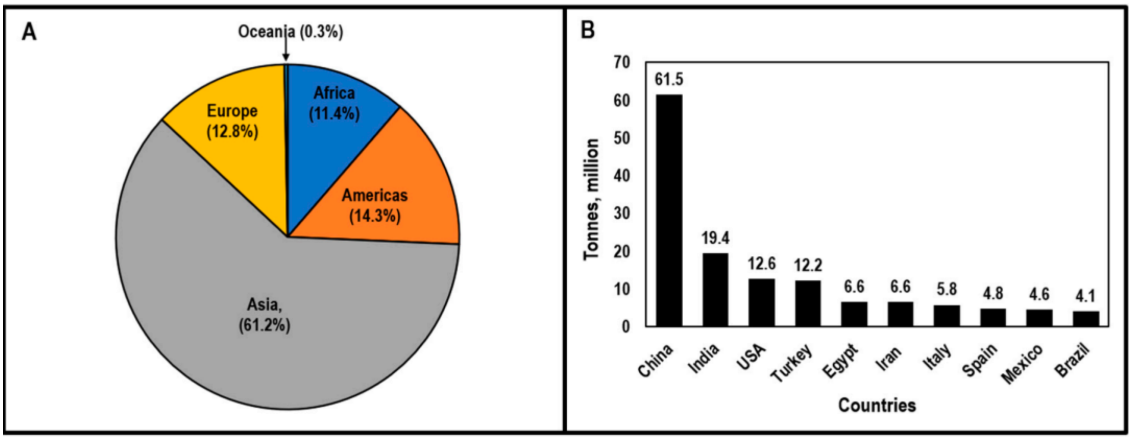

Figure 1.1. Tomato Processing Area and Top Tomato Producers in the World (Acharya et al., 2020).

Most part of the tomato fruit comprises water (about 95% per 100 g fresh weight). Carbohydrates (about 71%), protein (about 16%), and dietary fibers (about 21% per 100 g dry weight) provide functionality to it. Besides vitamins and bioactive compounds, many beneficial minerals exist in tomatoes such as calcium, magnesium, phosphorus, magnesium, and potassium. Moreover, tomatoes comprise many trace elements, such as copper, iron, zinc, and manganese. Sulfur and chlorine in tomatoes play a crucial role in detoxification. pH of tomato is usually about 4-4.5.

Tomato can add value to many foods such as soups, pickles, salads, purees, sauces, and other types. People eating tomatoes daily have lower risks of cancer diseases (Ali et al., 2021). Tomato with its ascorbic acid, fatty acid derivatives, carotenoids, flavonoids, glycosides, and phenolic content is a highly nutritious Mediterranean product. The dietary carotenoid, lycopene, is one of the most important components of tomatoes.

On the other hand, processing tomatoes may cause losing 30% of their full weight (Paulino et al., 2020). Thus, this large amount could be turned into waste, although it comprises many important nutrients. For instance, the peel and seeds of tomatoes, which are usually considered as residue/waste, contain valuable nutritious compounds such as bioactive compounds, dietary fibers, protein, and carotenoids, especially lycopene.

Drying is one of the important food processing techniques used for tomato processing (Kong, Ismail, et al., 2010). Refiner, siever, and decanter are the main stages where the by-products are produced. The drying industry usually uses forced convection ovens for that purpose. It helps increase the shelf life of the tomato product by decreasing the moisture content and water activity level, a_w. There are similar studies reporting the importance of appropriate drying conditions for the preservation of the nutritious compounds in tomatoes and other fruits (Kong, Ismail, et al., 2010; M'hiri et al., 2018). The temperature (50-100 °C) and the drying time (2-6 h) vary with respect to the fruits. As was stated, the water activity of tomato puree decreased to less than 0.6 when the convective drying conditions were established at 55 °C, and 120 min (Paulino et al., 2020). On the other hand, novel drying methods provide better preservation of color and bioactive compounds (i.e. phenolics), and radical scavenging activity in fruits. For example, infrared drying, microwave drying, and microwave-assisted drying techniques led to obtaining better industrial lemon by-product in a study (M'hiri et al., 2018). Moreover, tomatoes synergize with olive oils because adding olive oil to tomato-based foods increases lycopene absorption during cooking (Fielding et al., 2005).

1.2.3 Lycopene

Lycopene, as one of the carotenoids, is a lipophilic compound found mainly in red-colored fruits and vegetables (Leslie et al., 2015). For instance, tomatoes, papaya, and watermelons are foods comprising lycopene in a significant amount. The most abundant carotenoid found in these foods is lycopene (Figure 1.2). Other than that, α-carotene, β-carotene, lutein, and β-cryptoxanthin are present as carotenoids.

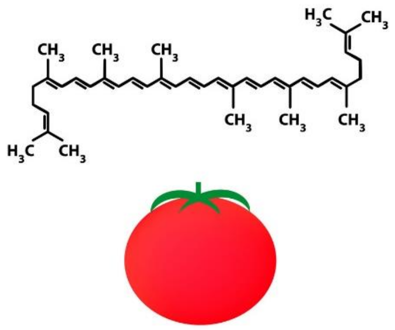

Figure 1.2. Molecular Structure of Lycopene.

Lycopene gives a red color to the foods. It is also an antioxidant and can help reduce many important diseases, such as atherosclerosis, endothelial dysfunction, and oxidation. In addition, it confers cardiovascular benefits and decreases cancer risk. Another research has reported that supplementation of lycopene with tomatoes has significantly decreased bad cholesterol and the risk of heart failure (Cheng et al., 2017).

Lycopene content differs with respect to the plants. Tomato has the highest lycopene (0.72-20 mg/100 g wet basis) among other lycopene-rich fruits (Shi & Le Maguer, 2000). Moreover, most of the lycopene in tomatoes is present in the outer pericarp, the skin of tomatoes. According to the research, five times more lycopene is found in the tomato skin (53.9 mg/ 100 g), compared to the whole tomato pulp (11 mg/100 g). The amount of lycopene increases as the tomato matures.

The processing of tomatoes by heating or drying them into juices or dried products can affect the bioavailability of carotenoids, especially lycopene (Mendelová et al., 2013). Thus, giving heat helps increase the lycopene content with better availability in the human body. Furthermore, there has been huge consumer demand for functional foods with high lycopene content being health-promoting food (Shi & Le Maguer, 2000). Therefore, minimal loss of lycopene with an environmentally friendly purification procedure is highly demanded by many areas, such as the foods, pharmaceutical, and cosmetic industries.

1.3 Pectin

Pectins are acid polysaccharides that are found in many fruits (Witkamp, 2010). Citrus fruits, apples, and quinces comprise a significant amount of pectins. It contributes to the cell structure of all plants by being a high-molecular-weight carbohydrate polymer. The chemical configuration, molecular weight, and source plant types of pectins cause them to express different functionalities. The word 'pectin' originated from the Greek word *pektos*, meaning firm and hard. This shows the ability of pectins to form gels.

Pectins can also be used in many applications, such as food, biomedicine, drugs, and agriculture, by certain modifications (Freitas et al., 2021). In addition to the protection of foodstuff by edible coating, pectins are utilized in bio-based antimicrobial films, cancer treatment, and nanoparticles. A recent study has shown that structurally modified pectins have more expanded functionalities than native pectin (Freitas et al., 2021). Pectin is usually extracted from apples for commercial purposes. There are variable functional groups existing in the pectin structure, which also provide several functional properties. Moreover, pectin is non-toxic, safe, abundant, and low-cost.

The chemistry of pectin indicates that pectin contains a chain of galacturonic acid units, and these units are bonded by α-1,4 glycosidic bonds (Flutto, 2003). The degree of polymerization of pectins can be about 1000 units. Esters existing on the galacturonic acid backbone are the most important component of pectins, compared to other chemicals, for instance, acetyl. Galacturonic acid content is referred to as

%GA, showing the percentage of it in pectins. Food additive pectin is said to be at least 65% GA. When commercial pectin is amidated with ammonia, galacturonamide units are formed in the pectin chain. Degree of esterification (DE) and the degree of amidation (DA) are the terms to define pectins with the percentage of esterified or amidated GA units, respectively. Moreover, the distribution of esters plays a huge role in the local electrostatic charge density of the pectin polymer because the interaction of pectin with the charged molecules such as calcium, other pectins, and proteins is correlated with the degree of esterification (DE). Classification of pectins can be done by low-ester pectin and high-ester pectin. It is the low-ester pectin when the DE value is lower than 50%, whereas high-ester pectin when the DE is higher than 50%. Degree of esterification (DE) is also known as degree of methylation (DM), as the esterification of carbonyl groups is done with methanol. That's why low methoxyl pectin (LMP) is low-ester pectin whereas high methoxyl pectin (HMP) is high-ester pectin (Figure 1.3).

Low methoxyl pectin is present mainly in citrus fruits (Constantin & Istrati, 2018). LMP forms gels in the presence of calcium ions (Ca^{++}) when the temperature cools down. In addition, calcium is sensitive to pH, and its sensitivity decreases when the pH is between 2-4.5. Gelation occurs in this pH range in the presence of LMP and calcium. Therefore, LMP is a good component in tomato products due to the availability of calcium and the convenient pH of tomatoes.

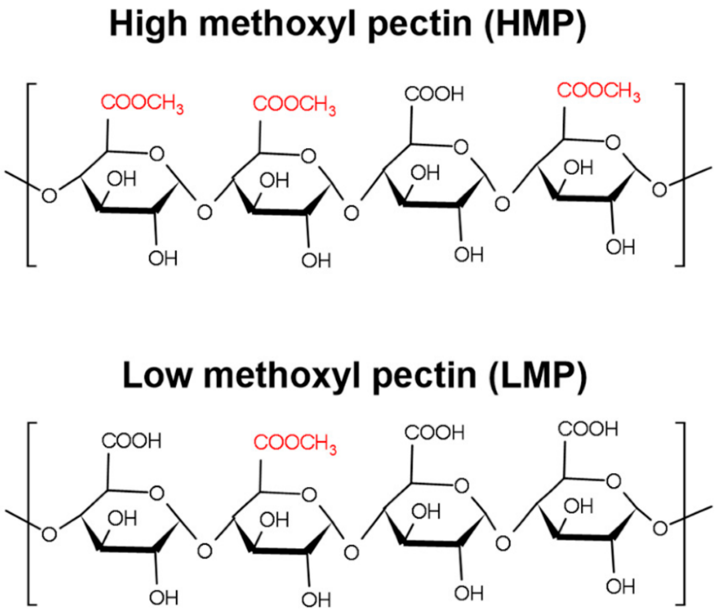

Figure 1.3. Chemical structure of LMP and HMP (Steigerwald et al., 2022).

1.4 Snacks

Because of changes in consumer lifestyles, there has been considerable interest in the production of fast foods and snacks (Constantin & Istrati, 2018). Easily prepared foods have gained a tendency among consumers. Snacks are considered good alternatives for quick meals, especially when they have significant nutritional value. There are various snack types in the food industry to fulfill customer needs (Saldivar, 2015). Potato chips, extruded snacks, ready-to-eat popcorn, nuts, and granola products could be common examples of that. However, the risks of obesity and chronic health issues can increase by eating unhealthy snacks and skipping breakfast (Mostafavi et al., 2021). On the other hand, there has been a huge increase in the number of health-conscious customers. Thus, more plant-based, vegan-type health-promoting alternatives of snacks with high nutritional value have been demanded nowadays.

The definition of health-promoting natural food products is made with different versions. For example, functional foods, farmafoods, nutraceutical foods, and vitafoods are such names used for this purpose. Some components of natural foods can be added or altered to make the food functional. Functional foods supply not only essential nutrients such as vitamins and minerals but also enriched components providing health benefits. Moreover, there are five main roles of functional foods in the body. These are disease prevention, reducing the duration of convalescence, defending the body, control of body functions, and reducing the effects of aging.

1.4.1 Snack Bars

Currently, snack bar has gained attention since consumers prefer ready-to-eat nutritious foods (Constantin & Istrati, 2018). It is known to be convenient for handling and storage. They are usually made of fruits, nuts, and cereals. Many important healthy nutrients, such as dietary fibers and bioactive compounds, can be delivered by snack bars. Classification of functional snack bars can be done into three categories: *organic snack bars, wellness snacks, and energy and nutrition bars*. Consumption of snack bars is done with different purposes: as a meal part (breakfast, lunch, or between meals), as a dessert after meals, or as a replacement for a meal (either breakfast or lunch). There are several factors that influence the consumption of snack bars. These include satisfying the craving for something sweet, saving time, using them as an energy source, for weight loss, and taking advantage of their protein, fiber, and vitamin contents, among others. It is possible to see new fruit-, vegetable-, cereal-based, and high-protein snack bars on the shelves of grocery stores every week. These bars usually contain high amounts of sugar and starch, which provide taste and texture (Bhattacharya, 2023). However, a health-promoting snack bar that is low in sugar and starch, but rich in fiber and protein is preferable. The demand for snack bars with high-protein content has grown considerably in recent years, especially among people who are dieting and doing sports activities

(Constantin & Istrati, 2018). Because of its high protein content (10-30% w/w) and other nutritious ingredients, it has been a better alternative to conventional snacks. Wheat, soy, milk protein, and cereal-added snack bars are easily found in the market. Moreover, different snack bar types have been developed due to the tendency to eat more health-promoting foods rather than eating sweet products such as fruit-based, wheat/soy-based, cereal-based, fruit and vegetable-based, and high-protein snack bar. The usage of natural sweeteners (honey, fig or date) is preferable from the point of health. Furthermore, health-promoting snack bars provide not only macronutrients (proteins, carbohydrates, and fats) but also micronutrients (vitamins, minerals, etc.).

1.4.2 Snack Bar Production

As it is seen in the Figure 1.4, conventional snack bar production often includes molding and baking steps (Ramírez-Jiménez et al., 2018). As Constantin & Istrati suggests the conventional production of snack bars mainly starts by mixing the dry and wet ingredients, blending, molding, baking, cooling, and packing (2018). The conventional oven is usually used for the baking process at high temperatures (120-160 °C). The duration of baking differs with respect to the snack bar type and its ingredients, either dry or wet-based ingredients (15 min-3 hours). Moreover, filling/coating can be an additional step in some types. During production, high temperatures (above 60°C) for long times result in the degradation of some functional constituents, such as the phenolics that show antioxidant activity (Choulitoudi et al., 2021). Processes with faster heating times are usually preferred for such functional products.

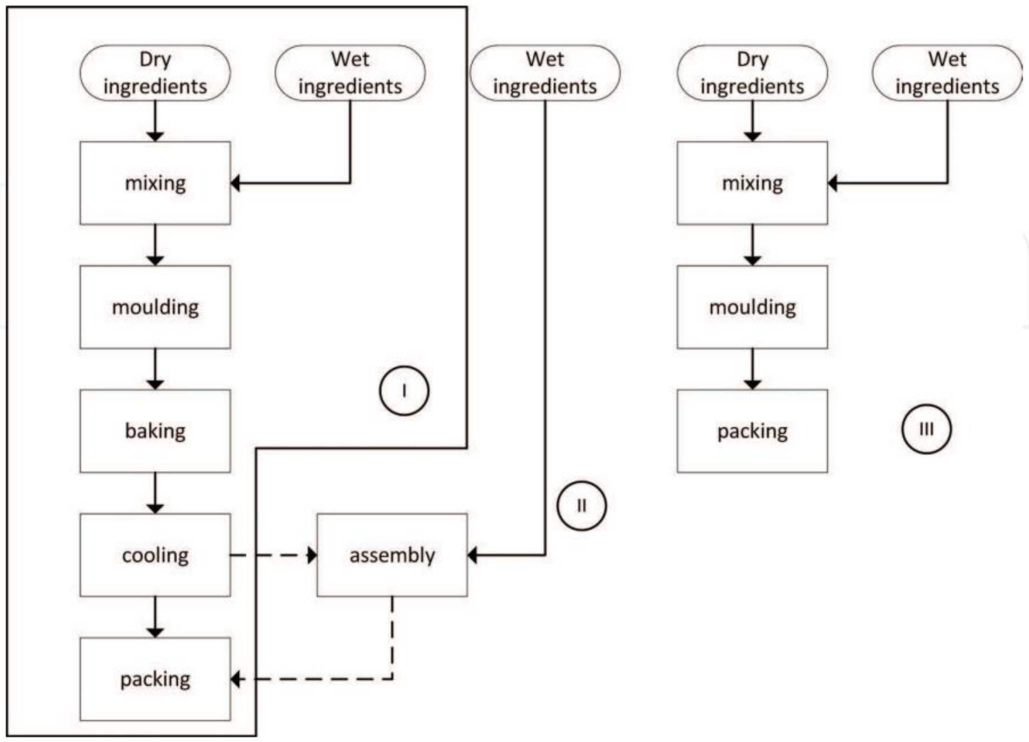

Figure 1.4. Flow chart of baked (1), baked with filling (2), and cold formed snack bars (3) (Constantin & Istrati, 2018).

The energy and time invested in producing snacks are crucial for economic reasons (Szydłowska et al., 2022). Additionally, the quality of the food is directly linked to the baking process's temperature and time. Lower quality of food is obtained as the temperature and time of processing increase. There is another study emphasizing that the development of health-promoting snack bars with high protein, fiber, vitamin content, and antioxidant activity can be produced with the use of minimally processed organic ingredients (Szydłowska et al., 2020).

1.4.3 Quality Parameters of Snack Bars

According to Szydłowska et al., the textural quality of a snack bar is preferable when it's soft, smooth, easy to bite, and chew since a wide group of people can eat that (2020). That's why the water activity of snack bars needs to have some limits to avoid hard texture. Moreover, it cannot be too high for microbiological reasons. Microbiological growth can be observed above 0.7 water activity levels. Meanwhile, commercial protein-added tomato snack bars have a water activity (a_w) level of 0.6-0.65, which a_w was also selected in this thesis research. According to a research, ready-to-eat foods like snacks are predisposed to microbes such as bacteria, fungi, and parasites during their shelf life (Ihuoma et al., 2022). Microbial foodborne illness may be observed in the case of contaminated snack consumption. The research revealed that *Staphylococcus, Lactobacillus, and Bacillus spp*. were the most common microbes found in cereal-based (maize) nut-added snack bars. On the other hand, another study has pointed out that *Salmonella spp, Listeria monocytogenes, and Escherichia coli* could be the pathogenic microorganisms observed in snack bars (Johannessen et al., 2004).

Moreover, acidity (pH) level also affects the microbial contamination of snack bars (Johannessen et al., 2004). The lower the pH, the higher the acidity (pH< 4.5). Most of the microorganisms cannot grow in acidic pH. Besides, in prevention of microbial contamination, and elimination or minimization of the growth, vacuum packaging or modified atmosphere packaging can be used (Szydłowska et al., 2020).

1.5 Microwave Processing

There are novel processing techniques used in many areas of manufacturing (Baghel, 2023). Baghel has noted that various industries utilize electromagnetic waves, including radio waves, infrared rays, ultraviolet rays, X-rays, and gamma rays. (2023). Likewise, microwaves, one of these rays, are utilized for various applications. Its wavelength is between 1 mm to 1 m. Electromagnetic waves have different wavelengths and frequencies, and they are as fast as the speed of light. Microwave has a frequency range between 0.3 and 300 GHz (Figure 1.5). Generally, microwave ovens applications and industrial purposes have frequencies of 915 MHz, 2.45 GHz, and 5.8 GHz (Graf et al., 2020). Both the electric and magnetic fields are concentrated in the direction of propagation together. Therefore, it's a direct heating process. When a dielectric material is exposed to an electric field, it causes the ions or the materials to be temporarily polarized dipolar molecules since internal friction and vibrations of other molecules are achieved due to the electric field, thereby inducing heat. Thus, electromagnetic energy is converted to thermal energy.

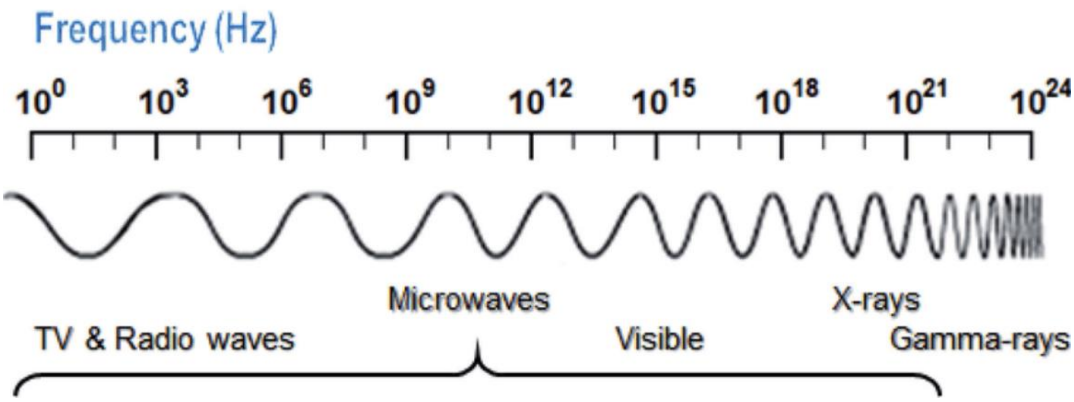

Figure 1.5. Electromagnetic wave spectrum (Ari Adi et al., 2019).

The working procedure of microwaves is by heating or cooking sample (i.e., food) through electromagnetic radiation in the microwave frequency range. Microwave radiation excites polar molecules, for example, it causes the water molecules to vibrate, and it forces the water from the interior to the surface of the materials. Thus, thermal energy can be transferred to the water molecules. Drying takes place in three phases, firstly, conversion of electromagnetic energy into heat, then rapid evaporation of water through diffusion, and finally reducing the rates of drying after the moisture vaporization is completed.

Microwave processing is considered one of the latest and fastest heating technologies. It has many advantages compared to the conventional processes. Moreover, microwave provides a certain economic advantage due to its shorter processing time and lower energy cost. Owing to the hybrid and selective heating of microwave processing, more uniform and homogenous heating is achieved. The microwave is used not only in the food industry but also in various parts of the manufacturing and processing industry. Since microwave application provides some important advantages, such as rapid processing, penetration radiation, controllable electric field distribution, selective heat, and lower environmental impact, the use of material processing and industrial applications has been increasingly common. The techniques applied in microwave processing are drying, curing, firing, vulcanization, and food processing (Guo et al., 2017).

Microwave-assisted extraction techniques have also been quite common in chemical products for material processing; for example, biofuels, cellulose, resins, and pharmaceuticals (Pérez-Serradilla & Luque de Castro, 2011). Furthermore, microwave applications can be observed in the drying of powder, foam, wood, and fabric industry (Rattanadecho, 2015).

There are various factors affecting microwave processing technology (Hu et al., 2021). These factors are divided into two: microwave factors and material factors. Microwave power, duration of operation, radio frequency, and power density are the microwave factors, whereas dielectric properties, penetration depth, moisture, and geometry of the sample are considered material factors.

The food industry has taken an interest in microwave processing due to the drawbacks of conventional methods, such as loss of nutrient, and changes in color, texture, and flavor (Hu et al., 2021). For example, surface hardening due to conventional methods can be avoided by microwaves. The microwave applications of food processing are drying, cooking, baking, thawing and tempering, pasteurization and sterilization, and blanching.

1.5.1 Microwave-Assisted Processes

Microwave-assisted heating systems have gained significant interest due to their several advantages (Yılmaz et al., 2018). There are various processing techniques applied with the assistance of microwaves to avoid deterioration and nutrient loss (González-Cavieres et al., 2021). Furthermore, it helps to decrease processing time and energy consumption. Microwave-vacuum dryers, microwave with infrared assistance, and microwave with heat impingement are such examples for that.

In microwave heating, water molecules in foods collide as they try to align themselves with the oscillating electric field. Thus, heat is generated by these molecular collisions of water molecules (Kutlu Kantar et al., 2021; Pu & Sun, 2017). This heat generation enhances moisture loss and creates a pressure gradient within the sample. The high pressure inside the material causes the water molecules to flow from the interior to the surface and increases the drying rate (Zhang et al., 2006). Therefore, microwave-assisted drying systems are highly efficient in terms of time and energy. Increasing temperatures of food samples upon microwave application could be detrimental to some heat-sensitive functional components.

1.5.2 Microwave-Vacuum Dryers

This microwave vacuum drying technology that prevents high temperatures is the involvement of a vacuum during microwave processing (González-Cavieres et al., 2021). As water evaporates at a lower temperature under vacuum than atmospheric conditions, vacuum drying can better for preserving heat-sensitive components (Pu & Sun, 2017).

As shown in the Figure 1.6, there is an example of a microwave-vacuum drying system with its representation. This microwave-vacuum dryer system consists of vacuum pump, control box, microwave vacuum chamber, motor drive, microwave applicator set, chiller, and refrigeration system (Baldovino et al., 2015). Vacuum pump leads to decrease the pressure inside the microwave vacuum chamber. Control box is used to monitor the temperature, pH, humidity, and other processing parameters. Motor drive and microwave applicator set generate microwave radiation in the microwave frequency range. Chiller and refrigeration system function to cool down the vacuum chamber, and the pump.

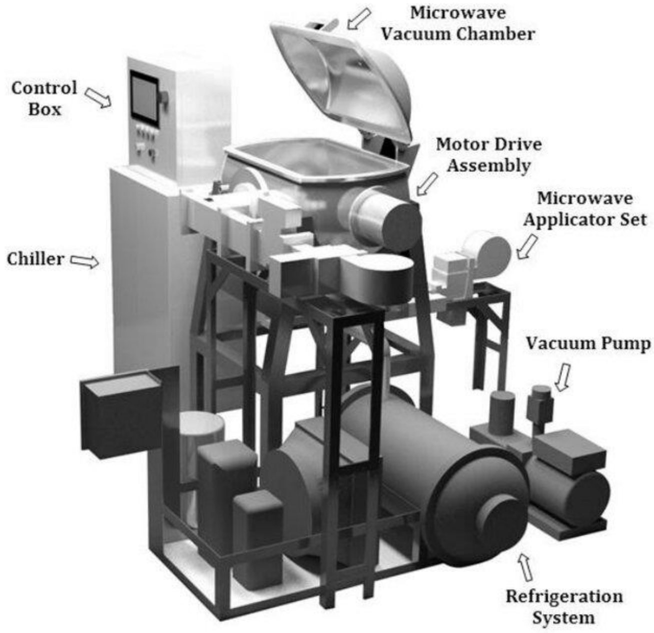

Figure 1.6. Comprehensive overview of the microwave-vacuum dryer (Baldovino et al., 2015).

There are many studies about microwave-vacuum-drying of fruits and vegetables, such as apple, carrot, banana, tomato slices, and berries (Drouzaf & Schuberp, 1996; Han et al., 2010; Monteiro et al., 2015; Nahimana & Zhang, 2011; Sunjka et al., 2004). These studies reported that the microwave-vacuum-dried products had a more porous structure, were softer, and had better rehydration properties than the conventionally dried ones. Additionally, high-quality products in terms of appearance, color, taste, aroma, and texture were obtained by using microwave-vacuum drying (Borquez et al., 2014).

Although microwave-vacuum drying has been used for several fruits and vegetables in several studies, there is no study on the production of a functional tomato snack bar by using this method. In this study, a tomato snack bar containing several functional ingredients, such as olive powder and pea protein isolate, was prepared by using microwave-vacuum drying.

The efficiency of the process and the product quality were compared with conventional oven drying using physical, chemical, and textural analyses of the tomato snack bars. FTIR spectroscopy and Time domain (TD) NMR relaxometry experiments were also performed for detailed analysis at the molecular level.

1.6 Aim of the Study

The snack bar market and the Mediterranean diet have an increasing demand among consumers, but there is no tomato snack bar enriched with pea protein, olive powders, salt, and spices. Manufacturers have always been searching for a more cost-effective way to produce snack bars since extended processing times and increased energy consumption can lead to higher costs. The drying process of food at high temperatures and for long periods in a conventional oven can affect the nutritive compounds in the food. Therefore, it has become important to preserve the nutritional value of food. This study aims to create a healthy and nutritious tomato snack bar using microwave-vacuum drying.

The scope of the thesis research is mainly two parts: formulation and characterization of the snack bar. To make the tomato snack bar, the ingredients of pea protein, olive powder, salt, and spices (red pepper, mint, thyme) were mixed with varying concentrations of LMP (0, 1, 2, 3%) and TP (0, 8, 12, 16%). These ingredients add functionality to the samples. Characterization of the tomato snack bar was later performed by investigating its textural, physical, and chemical properties by changing formulations and drying methods. It is also aimed to compare the efficiency of microwave-vacuum drying with that of a conventional oven, as well as the resulting product quality.

CHAPTER 2

MATERIAL AND METHOD

2.1 Materials

Fresh tomatoes were obtained from The Kraft Heinz Food (Balıkesir, Turkey). Fresh tomatoes were cleaned, and a hot break procedure (85℃ for 3 min) was applied to inactivate the enzymes. Tomato pomace and juice were obtained separately by sieving. Pea protein isolate (PPI) was obtained from Vegrano (Başakşehir, Istanbul). Olive powder was prepared by means of a freeze-drying process after the homogenization of green olives (Sinem Argün, 2022). Salt, mint, thyme, and red pepper powder were bought from a local market. Low methoxylated pectin (LMP, 27%) was obtained from Cargill (Balıkesir, Turkey). Acetone, hexane, ethanol, potassium nitrate, sodium bromide, sodium chloride, sodium hydroxide, magnesium chloride, and potassium acetate were purchased from Merck (Darmstadt, Germany); ammonium sulfate, potassium sulfate, potassium chloride, and potassium carbonate were purchased from IsoLab (Istanbul, Turkey).

2.2 Preparation of the Tomato Snack Bar

Ingredients of tomato snack bar and their amounts are given in Table 2.1. Tomato powder (TP) was prepared by drying the tomato skins and seeds at 55℃ for 48 h (with a MC below 8%) and then grinding the dried material using a household grinder. The LMP, PPI and salt were mixed with tomato juice in a beaker using a high-speed mixer (Ultraturrax T25, IKA WERKE, Staufen, Germany) at 14,000 rpm for 2 min. Then, the other ingredients were added into the beaker and mixed manually until the mixture became homogeneous. The mixture was molded in barshaped geometry and allowed for setting overnight at 4℃ (Figure 2.2). Following this, a microwave-vacuum oven (2 kW, 2450 MHz, Plazmatek, Isparta, Turkey) was used to dry the bars. IMPI test showed that the power of the maximum power of microwave was 1200 W. Vacuum was performed at 150 Torr (0.02 MPa). Water activity (a_w), which was determined as 0.6 with preliminary experiments, and was chosen as the main criterion in snack bar preparation (Figure 2.1).

Figure 2.1. Microwave-vacuum dryer

Table 2.1 Composition of the tomato snack bar.

Ingredients	Amounts (g)
Tomato juice	100
PPI	10
Salt	2
Olive powder	2
Mint	1
Thyme	1
Red pepper powder	1
LMP	1/2/3
TP	8/12/16

Figure 2.2. Photo of the molded tomato snack bars before drying

In preliminary experiments, the power of the microwave was changed from 25% to 100% (the set values) with different durations to obtain the a_w of samples close to 0.6. Above this value, microbial growth was observed; however, at this value, at least the growth of pathogenic microorganisms was suppressed. Below this value, the samples became too hard, which created textural problems. Therefore, a_w of samples was decided to be kept at this value based on the preliminary experiments. The time values for 25%, 50%, 75%, and 100% microwave powers were found to be 28 min, 14 min, 7 min, and 5 min, respectively. For microwave-vacuum application, 100% microwave power for 5 min processing conditions were chosen due to time and energy efficiency.

A conventional air oven (Alveo, Konya, Tukey) was used at 120°C for 75 min for the control samples (1% LMP, 8% TP). The duration of drying in a conventional oven was determined in the preliminary experiments to bring the a_w of samples again close to 0.6.

2.3 Analysis of Tomato Snack Bars

2.3.1 Color Measurements

For color determination, CIE$L^*a^*b^*$ values were measured using a portable spectrocolorimeter (Serlab SL400, İstanbul, Turkey). Results were obtained from three different points of one sample, and the average values were reported.

2.3.2 Moisture Content and Water Activity

The moisture content (MC) of samples was determined gravimetrically by drying the samples at 105°C.
The a_w was determined by using Aqua Lab 4TE Dew Point & Water Activity Meter (Decagon Devices Inc., Pullman, Wash., U.S.A.) at 25°C.

2.3.3 Sorption Isotherm of the Snack Bars

The sorption isotherm of tomato snack bars was determined by using the static method described elsewhere(Erbaş et al., 2016). One type of snack bar formulation (2% LMP, 12% TP) was used for the analysis. The sorption isotherm was obtained by plotting the MC versus a_w. Experimental data fitted well with the Guggenheim-Anderson-de Boer (GAB) model. The GAB equation is expressed as;

$$\text{MC}=\frac{M_0CKa_w}{(1-Ka_w)\times(1-Ka_w+CKa_w)},$$

where M_0 is the monolayer MC, and C and K are the free sorption constants (Sahin & Sumnu, 2006). The obtained GAB equation was;

$$\frac{a_w}{MC}=-0.08\,a_w^2+0.0792\,a_w+0.093\ (R^2 = 0.992)$$

2.3.4 Lycopene Content

Lycopene extraction was performed by conventional solvent extraction (Sharma & Le Maguer, 1996). For this purpose, 1 g of snack bar was mixed with 25 ml of hexane: acetone: ethanol (2:1:1) mixture. This mixture was mixed by using a digital orbital shaker (Daihan Scientific, Wonju, Korea) at 200 rpm for 1 min, and then kept in a dark place for 1 hour. Then, 10 ml of distilled water was added, and the mixture was kept in the dark for an additional 10 min for the phase separation to take place. The upper hexane phase was diluted properly and transferred to a quartz cuvette (10 mm path length), and the absorbance value was determined with a spectrophotometer (Optizen POP UV-Visible, Mecasys, Daejeon, Korea) at 503 nm wavelength. Hexane was used as the blank. The amount of lycopene was calculated by using the following equation (Abdullahi et al., 2020)

Lycopene (mg/kg fresh wt.) = $A_{503} \times 172^1$ / W,

where W is the weight of the sample (g) and A is the absorbance at 503 nm.

2.3.5 Texture Analysis

Texture Profile Analysis (TPA) was performed with a texture analyzer instrument (CT3 Brookfield, Middleboro, USA) with at least two replicates. Snack bars were compressed with a 12.7 mm diameter cylindrical probe. The samples were deformed at a deformation rate of 25% with a trigger load of 0.1 N. Cross head moved at a speed of 0.5 mm/s. Measurements were done at room temperature. Hardness (N), gumminess (N), chewiness (g.cm), and cohesiveness data were obtained from the TPA diagram.

2.3.6 Structural Analysis by Fourier Transform Infrared Spectroscopy

The powder forms of individual ingredients and tomato snack bars were examined using an IR Affinity-1 Spectrometer equipped with Attenuated Total Reflectance (ATR) attachment (Shimadzu Corporation, Kyoto, Japan). The samples were scanned in the region of 4000-500 cm^{-1} at a resolution of 16 cm^{-1} for 32 scans (Zechmeister et al., 1943).

2.3.7 Determination of water distribution by using NMR relaxometry

Samples were placed into a 20.34 MHz ^{1}HNMR system (Spin Track SB4, Mary El, Russia) to measure T_1 and T_2 relaxation times. For T_1 and T_2 measurements, the Saturation Recovery and Carr-Purcell-Meiboom-Gill sequences were used, respectively. T_1 measurements were done with 600 ms time of observation, 2.5 ms initial step, 16 number of points, 500 ms repetition delay, and 8 number of scans. T_2 measurements were done with a relaxation period (T_R) of 500 ms, 0.5 ms echo time, 1800 echoes, and 128 scans. Discrete component analysis of decaying T_2 curves was performed by using XPFit software (Softonics Inc., Israel).

2.3.8 Statistical analysis

ANOVA was performed using MINITAB 19 (Minitab Inc. State College, PA, USA). The pairwise comparisons were made by using Tukey's test at a significance level of 0.05. Correlations were performed using the Pearson correlation test.

CHAPTER 3

RESULTS AND DISCUSSION

3.1 Formulation and visual appearance of the tomato snack bars

The main ingredient of the snack bar was tomato juice. The pea protein isolate (PPI), TP, and LMP had functions in texturizing the bar. PPI is mainly composed of globular proteins, such as legumin and vicilin (Shand et al., 2007). These globular proteins underwent heat-induced gelation during the drying of the snack bar and formed a network structure. The pH of the snack bar (~pH 4.3) and the presence of salt ions also favored the aggregation of proteins, which enhanced the formation of network. Another techno-functional property of PPI was to provide juiciness to the sample by increasing the water holding capacity (Shanthakumar et al., 2022). Apart from its texture-giving properties; PPI increased the protein content of the snack bars with a balanced amino acid profile (Moreno et al., 2020).

Photos of microwave- vacuum-dried tomato snack bars without LMP are shown in Figure 3.1 before and after drying. These pictures showed that the amount of TP had an important effect on the structure. The samples in Figure 2.1 were the same as the sample in Figure 3.1 at 16% TP before drying. The decreasing concentration of TP resulted in a deformation of the shape, which was mainly because of the decreased dry material content.

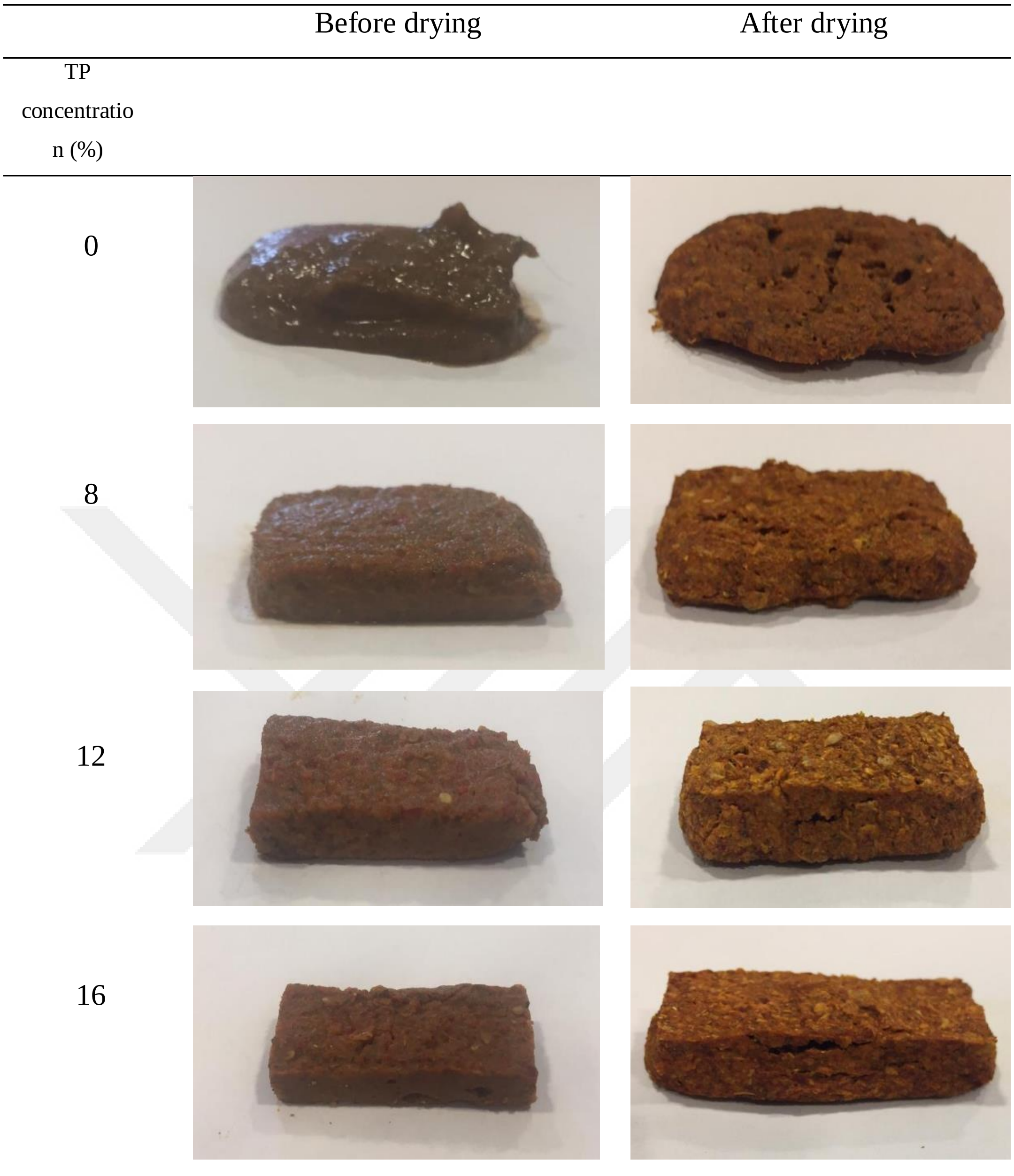

Figure 3.1. Photos of the tomato snack bars without LMP at different TP concentrations before and after microwave-vacuum drying

The color values of the dried samples are desired to be close to tomato red so that consumers can accept the product easily. Additionally, the browning of samples is undesirable due to the production of off-color and off-flavors. In Table 2, color measurement results of dried tomato snack bars are given. The a^* values represent the redness of samples, and the presence of TP increased this value for the microwave-vacuum-dried samples, whereas the presence and different concentrations of LMP did not affect this value. The a^* value mainly changed due to the increasing concentrations of lycopene, which was abundantly present in TP (Kong et al., 2010). On the other hand, the lightness (L^*) values of the conventionally dried sample (26.5±0.2) were much lower than the microwave-vacuum-dried one (40.7±2.0), which contained 1% LMP and 8% TP. This was explained by the Maillard reaction that took place between pectin and protein present in the formulation at high temperatures of conventional drying (Acquistucci, 2000). The browning of the surface of samples is common in conventional heating due to the Maillard reaction, as a result of high temperature accompanied by dehydration. However, in microwave heating, the cool ambient temperature inside the oven limited the Maillard browning reactions (Michalak et al., 2020). The reduced pressure in the microwave-vacuum oven lowers the temperature and can further slowdown the Maillard reaction. Consequently, in tomato snack bar production, color preservation was found to be higher in microwave-vacuum drying compared to the conventional drying.

Table 3.1 Effect of LMP and TP concentration on color values of dried tomato snack bars

LMP (%)	TP (%)	L^*	a^*	b^*
0	0	38.5±2.6^{abc}	13.7±0.8^{d}	23.4±1.9^{f}
0	8	42.3±3.4^{a}	20.2±2.2^{ab}	31.3±2.8^{abc}
0	12	42.5±1.9^{a}	20.7±1.2^{ab}	32.8±2.1^{ab}
0	16	42.5±3.6^{a}	21.7±2.9^{a}	32.9±2.2^{a}
1	0	33.8±5.3^{c}	14.4±0.8^{cd}	20.5±2.9^{g}
1	8	40.7±2.0^{abA}	19.0±1.8^{abA}	28.3±1.5^{cdA}
1	12	37.8±0.9^{abc}	21.3±2.5^{a}	28.2±1.8^{cde}
1	16	42.7±2.3^{a}	22.2±1.2^{a}	33.1±1.3^{a}
2	0	35.5±1.0^{bc}	17.8±1.5^{bc}	23.4±0.9^{f}
2	8	38.9±1.7^{abc}	21.6±1.6^{ab}	29.2±1.4^{abcd}
2	12	39.9±0.9^{ab}	21.0±1.7^{ab}	28.8±2.7^{cde}
2	16	37.4±1.8^{abc}	20.2±2.3^{ab}	28.4±2.0^{de}
3	0	37.3±2.2^{abc}	18.4±2.2^{ab}	25.5±2.5^{ef}
3	8	39.0±3.2^{ab}	20.6±2.9^{ab}	29.9±3.6^{bcd}
3	12	39.0±3.9^{ab}	22.1±1.3^{a}	29.4±3.2^{abcd}
3	16	40.7±1.2^{ab}	19.6±1.9^{ab}	29.3±0.8^{cd}
1†	8	26.5±0.15^{B}	13.1±0.8^{A}	15.3±0.5^{B}

†Represents the conventionally dried sample. Different small letters indicate significant differences ($p<0.05$) within the microwave-vacuum-dried samples, whereas different capital letters indicate significant differences ($p<0.05$) between conventionally dried and microwave-vacuum-dried samples at the same LMP and TP concentration. Errors are represented as standard deviations.

3.2 Moisture content and water activity

MC of samples ranged from 13.6% to 19.8%, and the average a_w of samples was found to be around 0.6 (Table 3). Almost all samples containing LMP above 2% had an a_w value less than or equal to 0.6. This could be related to the efficient water-holding capacity of pectin molecules (Stephen & Cummings, 1979). On the other hand, samples without LMP and with 1% LMP had a_w values close to or higher than 0.6. This finding showed that LMP held the free water efficiently, and therefore increasing concentrations of LMP decreased the a_w.

Table 3.2 MC and a_w of tomato snack bars

LMP (%)	TP (%)	MC (%)	a_w
0	0	18.0±1.4^{abc}	0.59±0.06^{cd}
0	8	15.5±0.7^{cde}	0.64±0.08^{abc}
0	12	14.3±0.4^{de}	0.64±0.04^{abc}
0	16	18.9±0.1^{ab}	0.73±0.03^{a}
1	0	15.9±1.3^{bcde}	0.69±0.02^{ab}
1	8	15.1±1.6^{cdeB}	0.65±0.03^{abcA}
1	12	18.2±0.4^{abc}	0.58±0.01^{cde}
1	16	17.4±0.3^{abcd}	0.59±0.01^{cd}
2	0	19.8±1.3^{a}	0.60±0.00^{cd}
2	8	17.7±0.5^{abc}	0.59±0.00^{cd}
2	12	16.3±0.3^{bcde}	0.54±0.00^{de}
2	16	15.3±0.3^{cde}	0.50±0.00^{e}
3	0	15.3±0.0^{cde}	0.49±0.02^{e}
3	8	15.0±0.1^{cde}	0.49±0.01^{e}
3	12	13.6±0.8^{e}	0.49±0.01^{e}
3	16	15.4±1.2^{cde}	0.61±0.05^{bcd}
1†	8	30.4±0.7^{A}	0.64±0.08^{A}

†Represents the conventionally dried sample. Different small letters indicate significant differences ($p<0.05$) within the microwave-vacuum-dried samples, whereas different capital letters indicate significant differences ($p<0.05$) between conventionally dried and microwave-vacuum-dried samples at the same LMP and TP concentration. Errors are represented as standard deviations.

Conventionally dried sample, which contained 1% LMP and 8% TP, had an a_w of 0.64±0.08, and its MC was found to be 30.4±0.7. The MC of conventionally dried snack bar was higher than the one dried in a microwave-vacuum oven (1% LMP, 8% TP). This was possibly due to the crust formation in conventional oven and therefore the moisture was retained inside the snack bar. As the heat transfer takes place from the surface to the inside in a conventional oven, the crust is formed on the surface of the snack bar, which resists to the evaporation of water. In this case, heat and mass transfers are in the opposite direction. However, in microwave-vacuum drying, as the heat and mass transfers are in the same direction, there is no crust formation, and therefore the evaporation of water inside the matrix is easier (Gomez et al., 2020). This situation makes the microwave-oven drying more efficient than the conventional one. Prolonged drying of snack bars in conventional oven to match the same MC with the ones dried in microwave-vacuum resulted in burning of the snack bar surface, which prevented the efficient evaporation of bound water. Therefore, microwave-vacuum-dried samples would have lower moisture content than the conventionally dried ones when the a_w, which can be taken as a measure of the free water content, was of the same value.

It is necessary to determine the sorption isotherm for multicomponent products, such as a tomato snack bar, to gain insight for the moisture distribution and migration and also for packaging design. Figure 3.2 shows the sorption isotherm of tomato snack bar at 25°C. Experimental data fitted well with the GAB model (R^2=0.99). From the linearization of the GAB equation, the estimated constants M_0, K, and C were found to be 0.84, 0.60, and 3.42, respectively. As the value of C>2, the model had a sigmoidal shape and a Type 2 curve was obtained according to the Brunauer's classification (Blahovec & Yanniotis, 2008). Type 2 isotherms are often correlated with high starch composition, such as flour, and they are typical for intermediate MC products (a_w between 0.6 and 0.9) (Al-Muhtaseb et al., 2010). Similar to the behavior of the tomato snack bar, freeze-dried vegetable snack bars, and fruit cereal bars were reported to show Type 2 isotherms previously (Ciurzyńska (Woźnica) et al., 2022;

Pallavi et al., 2013). In a Type 2 curve, at low water activities, polar and hydrophilic components are saturated with water molecules to form the adsorption monolayer. Then, additional water molecules at relatively higher water activities form the multilayer coverage, and water molecules are accumulated in intermolecular free spaces. Particularly protein and pectin inside the tomato snack bar contributed to such kind of sorption behavior.

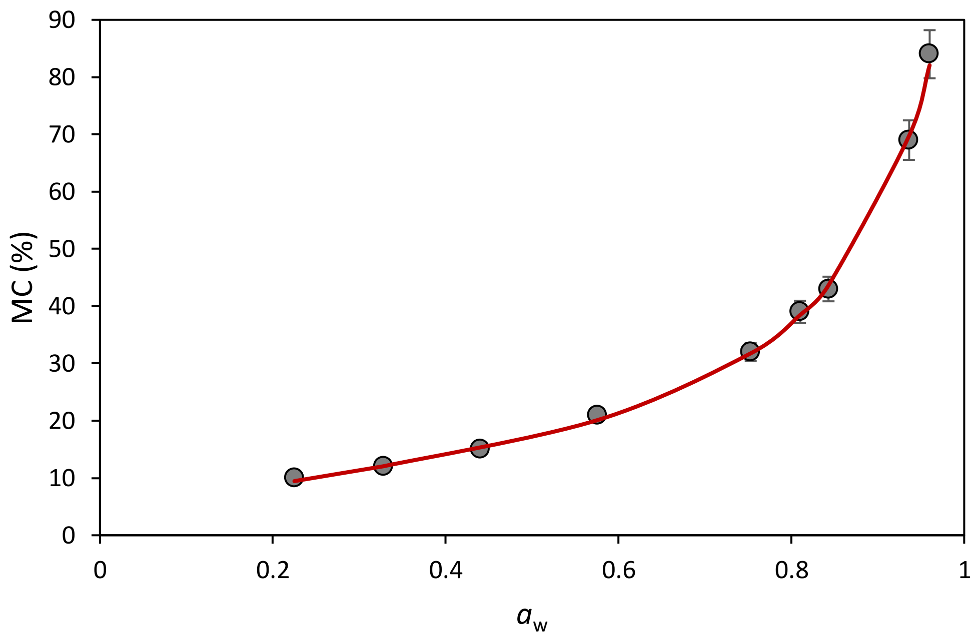

Figure 3.2. Moisture sorption isotherm of the tomato snack bar at 25°C. The solid line represents the GAB model.

3.3 Water distribution within snack bars

To have a better control over the microbial growth and physical stability of a food product, it is desirable that the water distribution be homogeneous within the whole sample. The transverse relaxation behavior of the tomato snack bars was described by a three-component model (Table 3.3). These values and their corresponding weights represented the state and the distribution of water (Hashemi et al., 2010) In a 3-component relaxation model, each proton pool is represented as a with a peak and its corresponding area (or contribution to the signal). The short T_{21} value indicates a strong interaction of water with the other solid components; thus, this transverse relaxation could be attributed to the water in the strongly bound state. Moderate T_{22} indicates weaker interaction of water with the surroundings than the one observed for T_{21}. Thus, this proton population could be related to the transverse relaxation of the tiny water pools that are entrapped within the gaps of the polymer matrix. On the other hand, the T_{23} value represents the water population that interacts the least with the surrounding polymer structure that is mostly acting as bulk water (*but not fully*). However, no correlation was found between the a_w and T_{23} values of the snack bars, which was similar to a previous study on confectionary products (İlhan et al., 2022). This proton population may be associated with distinct and large water populations within the polymer matrix (Mariette, 2009). Changes in peak time and area values suggest that the presence/absence and changes in the concentration of LMP and TP affected the water distribution within the microwave-vacuum-dried samples. T_2 values were mostly dependent on the dry material content, to which TP and PPI contributed greatly. In this case, the effect of TP was higher than the effect of LMP on T_2 values. However, the presence of LMP was expected to contribute to the entrapped water, which was represented by the areas of T_{22} values. Increasing the TP concentration from 0% to 8% changed the water distribution within the samples (both in the presence and in the absence of LMP) abruptly. This change mainly manifested itself with the decrease in the area values represented by T_{21} and the corresponding increase in the area values associated with T_{22} and T_{23}. Beyond the 8% TP concentration (up to 16%), the same peak areas showed an opposite trend to their initial trend between 0% and 8% TP concentration. At 8%, TP particles could not maintain a continuous interaction with the water molecules. However, the interactions between the TP solids and water became more continuous and homogeneous at higher concentrations, thereby bringing the area values closer to their initial values (0% TP concentration). There was no such as trend for the samples prepared with 3% LMP. The reason could be the higher dry material content of these samples.

Table 3.3 T_2 values and their corresponding areas of tomato snack bars

LMP (%)	TP (%)	T_{21} (ms)	Area (%)	T_{22} (ms)	Area (%)	T_{23} (ms)	Area (%)
0	0	1.18 ± 0.08^{b}	65.9^{a}	20.06 ± 1.03^{b}	15^{d}	89.13 ± 1.10^{bc}	19.1^{efg}
0	8	0.63 ± 0.01^{b}	56.3^{abc}	20.37 ± 0.31^{b}	16.9^{cd}	96.99 ± 3.20^{abc}	26.9^{cdefg}
0	12	1.00 ± 0.19^{b}	67.5^{a}	19.31 ± 2.72^{b}	15.3^{d}	94.61 ± 11.17^{abc}	17.3^{fg}
0	16	1.17 ± 0.07^{b}	68.7^{a}	20.48 ± 1.79^{b}	16.4^{d}	91.68 ± 8.41^{bc}	14.9^{g}
1	0	0.75 ± 0.07^{b}	59.4^{abc}	19.3 ± 0.83^{b}	17.3^{bcd}	90.26 ± 6.43^{bc}	23.4^{cdefg}
1	8	0.82 ± 0.08^{bB}	39^{deB}	20.78 ± 0.04^{bA}	26.9^{bA}	97.18 ± 2.64^{abcA}	34.1^{abcA}
1	12	0.75 ± 0.1^{b}	56^{abc}	17.3 ± 0.4^{b}	23^{bcd}	78.37 ± 4.07^{c}	21^{defg}
1	16	0.89 ± 0^{b}	61.4^{ab}	22.35 ± 0.93^{b}	19.5^{bcd}	99.19 ± 4.83^{abc}	19.1^{efg}
2	0	1.05 ± 0.07^{b}	64.8^{a}	19.26 ± 0.75^{b}	17.5^{bcd}	86.30 ± 0.34^{bc}	17.8^{fg}
2	8	0.7 ± 0.07^{b}	45^{bcd}	21.97 ± 1.83^{b}	23.7^{bcd}	101.61 ± 9.46^{ab}	31.4^{bcde}
2	12	0.75 ± 0.16^{b}	55.2^{abcd}	20.85 ± 0.21^{b}	20^{bcd}	99.30 ± 0.69^{abc}	24.8^{cdefg}
2	16	0.63 ± 0.05^{b}	44.6^{cd}	18.43 ± 3.41^{b}	22.2^{bcd}	92.93 ± 5.72^{bc}	33.3^{bcd}
3	0	0.87 ± 0.2^{b}	27.1^{ef}	18.86 ± 2.23^{b}	26.2^{bc}	89.16 ± 5.15^{bc}	46.7^{a}

Table 3.3 (continued)

3	8	0.71±0.04^{b}	43.5^{cde}	19.38±0.78^{b}	24.2^{bcd}	91.25±4.39^{bc}	32.4^{bcd}
3	12	3±0.71^{a}	18.7^{f}	29.93±1.29^{a}	39^{a}	116.55±7.85^{a}	42.3^{ab}
3	16	0.45±0.09^{b}	52.4^{abcd}	16.61±0.35^{b}	18.3^{bcd}	92.06±0.21^{bc}	29.4^{cdefg}
1†	8	2.06±0.17^{A}	71.4^{A}	9.8±1.13^{B}	16.2^{B}	81.02±7.60^{A}	12.5^{B}

†Represents the conventionally dried sample. Different small letters indicate significant differences ($p<0.05$) within the microwave-vacuum-dried samples, whereas different capital letters indicate significant differences ($p<0.05$) between conventionally dried and microwave-vacuum-dried samples at the same LMP and TP concentration. Errors are represented as standard deviations.

Conventional heating (for the samples with 1% LMP and 8% TP) resulted in longer relaxation times and higher contributions for the 1st component and shorter relaxation times and contributions for medium and long components. The longer T_{21} (2.06 ms) and higher peak area (71.4%) of conventionally heated samples suggested that the initial hydration layers around the solid particles were larger than the ones dried in microwave-vacuum oven (Özel et al., 2021). On the other hand, conventionally heated samples showed shorter T_{23} times and area values, 81.02 ms and 12.5%, respectively. Therefore, this reflected a major difference between the conventional and microwave-vacuum drying methods in molecular level since changing the heating type clearly changed the dynamics of polymer-water interactions. There was an interchange between the first and third relaxation peaks. The shorter peak time and area of the conventionally heated samples suggested that the proportion of water that interacted least with the surrounding polymer matrix decreased with respect to the one in the microwave-vacuum-dried samples (Özel et al., 2016). This result was indeed expected due to the surface to inner heating mechanism of conventional drying (Sumnu, 2008). In this way, bulk water was removed from the samples to a greater extent by conventional heating as can be justified with the T_{23} results. On the other hand, microwave-vacuum drying was more successful in removing the proportion of water strongly bound to the solid particles. Consequently, microwave-vacuum-dried samples possessed shorter T_{21} and lower T_{21} peak area than the conventionally dried ones (Table 3.3).

3.4 Lycopene content

The Lycopene content of snack bars is better to be as high as possible, so that the antioxidant content of the product would be high and the color would be bright red, as desired. Lycopene contents of microwave-vacuum-dried samples were found to be between 9.6 and 78.6 mg/ g dry material (Table 3.4). Changing concentrations of both ingredients had a significant effect on the lycopene content of snack bars ($p<0.05$). The highest lycopene amounts were determined in the absence of LMP, whereas the lowest amounts were determined in the presence of 3% LMP, indicating that LMP showed a detrimental effect on the lycopene content. There could be two possible mechanisms for that effect on the lycopene amount. The first one could be that the increasing amount of pectin created a denser pectin network and the lycopene was entrapped in this network (Anese et al., 2013; Lasunon & Sengkhamparn, 2022). In the snack bar matrix, pectin could form a layer around the lycopene molecules and as pectin is water soluble, during the extraction of lycopene in its assay, only a part of the lycopene could have leached to the hexane. The second mechanism suggested the formation of a pectin-lycopene complex in the presence of an amphiphilic compound, such as protein (Jazaeri et al., 2017). In this mechanism, firstly, lycopene attached to the hydrophobic part of protein and formed an intermediate product, and then the polar pectin molecules formed a coating around this intermediate product and thereby limited the extraction of lycopene to the hexane.

Table 3.4 Lycopene concentration (mg/g dry material) of tomato snack bars at different LMP and TP concentrations

	TP (%)			
LMP (%)	0	8	12	16
0	59.1±3.2[c]	71.4±4.1[b]	72.5±1.8[b]	78.6±3.7[a]
1	32.2±1.1[f]	40.4±1.1[eB]	43.2±6.6[d]	39.4±2.0[e]
2	19.5±0.8[h]	33.0±4.8[f]	28.2±1.9[f]	28.5±1.0[f]
3	9.6±1.2[i]	15.4±1.6[hi]	17.1±0.6[h]	21.7±0.1[g]
1[†]		83.4±3.0[A]		

[†]Represents the conventionally dried sample. Different small letters indicate significant differences ($p<0.05$) within the microwave-vacuum-dried samples, whereas different capital letters indicate significant differences ($p<0.05$) between conventionally dried and microwave-vacuum-dried samples at the same LMP and TP concentration. Errors are represented as standard deviations.

The lycopene content of the conventionally dried snack bar was found to be 83.4 ± 3.0 mg/g dry material. This value was higher compared to the lycopene content of the microwave-vacuum-dried sample (with 1% LMP and 8% TP). This was expected since the duration of conventional drying was longer, and the temperature was higher than the microwave-vacuum application. Lycopene is often found as bound to the skin and insoluble fiber in tomatoes, and heat processing enhances the release of lycopene from the cell matrix (Toor & Savage, 2006). In previous studies, the lycopene extraction yield was found to be higher in microwave-assisted techniques, particularly the trans-isomer of lycopene (Ho et al., 2015). Another study reported that the lycopene concentration in fresh tomatoes increased from 2.96 mg/100 g dry material to 25.44 mg/100 g dry material after microwave-vacuum drying (Engmann, 2013). They also reported that high microwave power increased the amount of lycopene extracted due to high temperatures. Therefore, the difference in lycopene content for tomato snack bars prepared in two different methods could be due to the temperature difference. Furthermore, microwave-vacuum oven provided the same amount of lycopene to be obtained in a shorter time than the conventional oven, which was in line with previous studies (Chuyen et al., 2020). Consequently, microwave-vacuum drying demonstrated a higher efficiency in terms of time and energy, as only 5 min of microwave-vacuum drying allowed to obtain almost 85% of the lycopene that could be obtained from conventional drying.

3.5 Investigation of the molecular changes by FTIR spectroscopy

FTIR spectra of LMP, PPI, TP, and snack bars containing 3% LMP and 16% TP were shown in Figure 3.3. Characteristic peaks of the FTIR spectrum observed between 1600 cm^{-1} and 1700 cm^{-1} represent the carbonyl (C=O) stretching of the secondary amide (amide I band) of protein backbone (Wang et al., 2021). The peak around 1500 cm^{-1} observed for PPI and snack bars represents the amide II band (Xu & Dumont, 2015). The peaks between 3000 cm^{-1} and 3500 cm^{-1} were assigned to –OH stretching. On the other hand, the new peak for the tomato snack bar around 2850 cm^{-1} could be an indication of the cross-link between PPI and pectin (Li et al., 2016). Furthermore, the peak at 1590 cm^{-1} of pectin shifted to 1630 cm^{-1} in the snack bar, suggesting the carboxyl groups ($–COO^-$) were cross-linked with Ca^{2+}, which was inherently present in the tomato juice (Ali et al., 2021; Li et al., 2016).

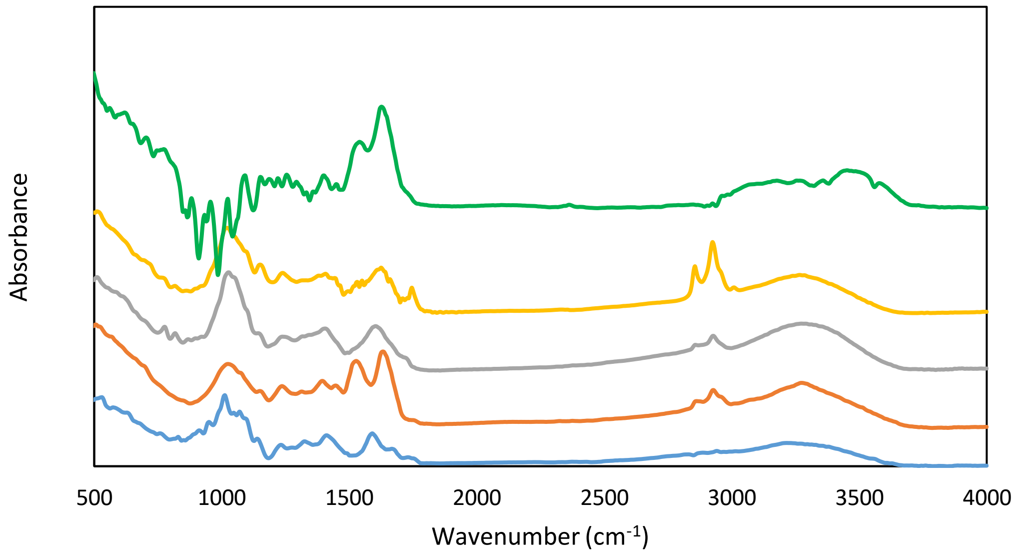

Figure 3.3. FTIR spectra of LMP (blue), PPI (orange), TP (grey), microwave-vacuum-dried (yellow) and conventionally dried (green) tomato snack bar

FTIR spectra of microwave-vacuum-dried and conventionally dried snack bars are different particularly at amide and –OH regions, which corresponded to the bonds formed due to the presence of pectin and protein. This suggested the interactions between pectin and protein occurred differently in a microwave-vacuum oven and a conventional oven. The main factor is temperature, as the temperature in the conventional oven was 120°C, which was higher than the one in the microwave-vacuum oven (max. ~60°C at 150 Torr). With higher temperature and long heating time, proteins were expected to fully denature and more disulfide bonds would have formed (C. Wang et al., 2018). However, at low temperatures and short heating times, denaturation of proteins was not expected to be extensive, and therefore the interaction between pectin and protein should be mainly electrostatic in microwave-vacuum drying (Oduse et al., 2018). Therefore, the type of interaction between pectin and protein was dependent on the duration and temperature of heating as well as the heating mechanism.

When the amide I and II regions were considered, it was apparent that conventionally dried snack bar sample demonstrated distinct peaks whereas microwave-vacuum-dried one showed multiple indistinct peaks in these regions (Figure 3.3). The peak characteristics of microwave-vacuum-dried sample in the amide region suggested that the secondary structures of the PPI were more disordered (Lefèvre & Subirade, 1999). This result indicated that the transitions between the secondary protein structures (α-helix, β-turn, β-sheet) were still ongoing, which was possibly due to insufficient time and temperature in microwave-vacuum drying for a complete PPI denaturation. –OH band regions also showed differences due to drying type. While microwave-vacuum-dried sample showed a broad and smooth peak, conventionally dried one showed a broad but discontinuous peak formed by the merging of many discrete peaks. The broad and smooth –OH peak of microwave-vacuum-dried sample was the result of the higher number of –OH groups involved in the hydrogen bonding (Fattahi et al., 2013). In contrast, the number of free –OH groups that did not take part in hydrogen bonding was higher for the conventionally dried snack bar. These findings demonstrated that the drying mechanism altered the water-polymer interactions at the molecular level.

3.6 Texture Analysis

Each individual ingredient in tomato snack bar had the ability to modify the texture. For instance, water acts as a plasticizer and helps maintain softness and flexibility. The presence of fibers and hydrocolloids improves the water binding and often minimizes the water migration throughout the proteins or starch in the structure. However, a higher than necessary concentration of such ingredients yields a very hard product that is not preferred. In a snack bar, hardness, gumminess, and chewiness are the most important textural parameters. Therefore, the textural properties of tomato snack bars (*hardness, gumminess, chewiness, and cohesiveness*) at different concentrations of LMP and TP were determined and are shown in Table

3.5. The TPA of samples without any TP could not be measured; therefore, only the results of the samples, including TP, were presented. The hardness values of microwave-vacuum-dried snack bars were found to be between 10.6 N and 86.6 N. Increasing the concentration of LMP had a significant effect on the hardness of samples at the same TP concentration ($p<0.05$). This situation was more prominent in the samples with 2% and 3% LMP, as their hardness values were higher than the samples with 0% and 1% LMP. At high LMP concentrations, a more rigid gel network was formed (Khalid Alqahtani et al., 2022). Additionally, increasing LMP concentration decreased the a_w of samples (Table 3.5). As there was less free water at low a_w, the hardness of the samples became higher. On the other hand, the TP did not show a similar trend with LMP. Hardness values fluctuated with increasing concentrations of TP, which could be due to the interaction of water with different polymers in the matrix.

Table 3.5 Textural properties of tomato snack bars

LMP (%)	TP (%)	Hardness (N)	Gumminess (N)	Chewiness (g.cm)	Cohesiveness
0	8	21.3 ± 3.3^{e}	9.4 ± 0.1^{ef}	142 ± 16.9^{fg}	0.46 ± 0^{b}
0	12	10.6 ± 0.8^{f}	7.0 ± 1.1^{f}	93 ± 2.8^{h}	0.44 ± 0^{b}
0	16	15.1 ± 0.8^{ef}	7.3 ± 0.1^{ef}	129.5 ± 2.1^{g}	0.47 ± 0^{b}
1	8	15.7 ± 0.4^{efB}	9.3 ± 0.2^{efB}	168.5 ± 6.4^{fA}	0.59 ± 0^{aA}
1	12	33.7 ± 0.1^{d}	9.6 ± 1.1^{e}	369 ± 2.8^{e}	0.60 ± 0.01^{a}
1	16	14.2 ± 0.7^{ef}	9.8 ± 0.6^{e}	127.5 ± 2.1^{g}	0.60 ± 0.01^{a}
2	8	47.3 ± 0.3^{c}	26.4 ± 0.5^{c}	489 ± 8.5^{c}	0.56 ± 0^{a}
2	12	74.2 ± 1.0^{b}	38.8 ± 0.9^{a}	675 ± 4.2^{a}	0.57 ± 0.01^{a}
2	16	40.6 ± 3.9^{cd}	20.3 ± 0.8^{d}	441.5 ± 13.4^{d}	0.55 ± 0.01^{a}
3	8	41.6 ± 1.2^{cd}	40.6 ± 0.2^{a}	414 ± 0^{d}	0.57 ± 0.01^{a}
3	12	74.4 ± 4.6^{b}	30.1 ± 0^{b}	606.5 ± 2.1^{b}	0.56 ± 0.05^{a}
3	16	86.6 ± 2.9^{a}	26.9 ± 0.4^{c}	703 ± 11.3^{a}	0.60 ± 0.01^{a}
1[†]	8	28.5 ± 1.9^{A}	13.3 ± 0.9^{A}	195 ± 20^{A}	0.47 ± 0^{B}

[†]Represents the conventionally dried sample. Different small letters indicate significant differences (p<0.05) within the microwave-vacuum-dried samples, whereas different capital letters indicate significant differences (p<0.05) between conventionally dried and microwave-vacuum-dried samples at the same LMP and TP concentration. Errors are represented as standard deviations.

Gumminess of foods is often related to the swallowing action and is mostly dependent on the presence of polysaccharides and proteins (Basmal, 2021). In microwave-vacuum-dried tomato snack bars, the LMP was found to affect the gumminess significantly ($p<0.05$). The strength of interaction between LMP and PPI, which was mainly electrostatic, affected the gumminess (Archut et al., 2022). Therefore, in the presence of sufficient PPI, increasing LMP concentrations increased the gumminess of samples.

Chewiness of a sample could be taken as the energy required to masticate a solid food to prepare for swallowing (X. Wang et al., 2021). The lowest chewiness value for the microwave-vacuum-dried snack bars was found as 93 g.cm when there was no LMP and the highest value was found as 703 g.cm when there was 3% LMP in the formulation. LMP significantly increased the chewiness of tomato snack bars ($p<0.05$). The amount of TP also affected the chewiness possible due to increasing the dry material content; however, the effect of LMP was more dominant.

Cohesiveness physically defines the internal resistance of a food material, formed by the internal bonds in the food matrix (Salehi et al., 2016). It expresses how much the product can resist a second deformation relative to the first one (Guiné, 2022). In microwave-vacuum-dried tomato snack bars, the cohesiveness was affected significantly by the presence of LMP ($p<0.05$); however, the TP addition did not affect the cohesiveness significantly. The presence of pectin was reported to increase cohesiveness in different studies (Abid et al., 2017; Khalid Alqahtani et al., 2022).
Conventionally dried sample had higher hardness, gumminess, and chewiness; but lower cohesiveness compared to the microwave-vacuum-dried one with the same formulation (1% LMP and 8% TP). The higher gumminess and chewiness results may be due to the higher MC of the conventionally dried sample. However, the MC cannot explain the higher hardness of conventionally dried sample, as a snack bar sample with higher MC would be expected to have a lower hardness value. This seemingly contradictory result could be an indication of the uneven heating of the

conventional oven. Faster drying of the surface of the snack bars yielded a crust formation, which increased the hardness of the samples. In addition, the lower cohesiveness value of the conventionally dried snack bar may have indicated the formation of different types of bonds in the structure. Microwave-vacuum heating increased the porous structure of the samples due to the volumetric heating (Monteiro et al., 2018). In this case, as the evaporation of water took place from inside to the surface, snack bars expanded more uniformly, which resulted in uniform and softer textural properties. Cross-linking of pectin and protein was also expected to be different in the microwave heating and conventional heating (Basit et al., 2021). In a previous study, the texture of conventional-dried and microwave-vacuum-dried squid shreds were compared, and the latter was found to be softer (Pankyamma et al., 2019) They also attributed the reason to the puffing effect of microwave-vacuum heating system. The microwave-vacuum-dried snack bars had a porous structure and thus resulted in lower force and deformation values during the compression test compared to the conventionally dried samples.

CHAPTER 4

CONCLUSION AND RECOMMENDATIONS

This study reported the preparation of a health-promoting tomato snack bar and the effect of different ingredients and drying methods on the physical, chemical, and textural properties. Snack bars were produced with a minimal number of ingredients by using microwave-vacuum drying, which was an energy and time-efficient process. The microwave-vacuum process shortened the drying time by 93% and saved energy by 88%.

For color preservation, microwave-vacuum drying was superior to the conventional oven. Textural properties, including hardness, gumminess, chewiness, and cohesiveness, were also affected by the type of drying, and microwave-vacuum drying created higher-quality snack bars. Additionally, the microwave-vacuum process achieved a more homogeneous drying compared to conventional drying. Another important finding of this study was that the increasing LMP amounts reduced the lycopene availability. Interactions between the main structural ingredients have also been demonstrated at the molecular level. TD NMR relaxometry results indicated that the differences between the conventional and microwave-vacuum drying mechanisms could be tracked by transverse relaxation parameters. Changes in the T_2 peak times and relative peak areas suggested that the dynamics of polymer-water interactions were affected by the heating type. For instance, microwave-vacuum drying was more successful than the conventional drying in terms of removing the strongly bound water fraction. Moreover, LMP and TP can be used to alter the textural properties of snack bars. Chewier or harder snack bars can be formulated for general consumption; however, softer snack bars may be preferred for toddlers and elderly people having difficulty in chewing. Overall, the results of this study showed the possibility of health-promoting snack bar production in an economically feasible way.

Further research can be conducted, such as production with different protein types. Also, RSM (response surface methodology) could be applied for optimization of microwave vacuum dryer. This will help to optimize not only the energy consumption but also to find the optimum quality parameters (texture, lycopene content, color, a_w, moisture content, etc.) of the tomato snack bar. In addition to this further analysis, there would be changing ingredient types (i. e. spices) and concentrations in pursuit of finding the best formulation. It can also be planned to conduct some experiments in the future to investigate the impact of packaging on various factors, such as shelf life, microbial analyses, peroxide analyses, antioxidant levels, and total phenolic contents. Specifically, the effects of vacuum packaging and different types of composite packaging materials can be examined. Furthermore, conducting sensory analyses on snack bars with varying formulations can optimize formulation and increase consumer acceptance.

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APPENDICES

A. Statistical Analysis

Table A.1 Two-way ANOVA (LMP-TP), one way ANOVA (microwave-conventional) and Tukey's comparison test for color (L^* value)

General Linear Model

Factor Information

Factor	Type	Levels	Values
LMP	Fixed	4	0, 1, 2, 3
TP	Fixed	4	0, 8, 12, 16

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
LMP	3	61.13	20.377	8.56	0.001
TP	3	101.57	33.857	14.22	0.000
LMP*TP	9	37.98	4.220	1.77	0.152
Error	16	38.09	2.381		
Total	31	238.77			

Comparisons

Tukey Pairwise Comparisons: LMP

Grouping Information Using the Tukey Method and 95% Confidence

LMP	N	Mean	Grouping	
0	8	41.3125	A	
3	8	39.6000	A	B
1	8	38.3000		B
2	8	37.7125		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of LMP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value

Table A.1 (continued)

1 - 0	-3.012	0.771	(-5.222, -0.803)	-3.90	0.006
2 - 0	-3.600	0.771	(-5.809, -1.391)	-4.67	0.001
3 - 0	-1.712	0.771	(-3.922, 0.497)	-2.22	0.160
2 - 1	-0.588	0.771	(-2.797, 1.622)	-0.76	0.870
3 - 1	1.300	0.771	(-0.909, 3.509)	1.69	0.363
3 - 2	1.887	0.771	(-0.322, 4.097)	2.45	0.108

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: TP

Grouping Information Using the Tukey Method and 95% Confidence

TP	N	Mean	Grouping	
16	8	40.6250	A	
8	8	40.1875	A	
12	8	39.9375	A	
0	8	36.1750		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of TP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
8 - 0	4.012	0.771	(1.803, 6.222)	5.20	0.000
12 - 0	3.762	0.771	(1.553, 5.972)	4.88	0.001
16 - 0	4.450	0.771	(2.241, 6.659)	5.77	0.000
12 - 8	-0.250	0.771	(-2.459, 1.959)	-0.32	0.988
16 - 8	0.438	0.771	(-1.772, 2.647)	0.57	0.940
16 - 12	0.688	0.771	(-1.522, 2.897)	0.89	0.809

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: LMP*TP

Grouping Information Using the Tukey Method and 95% Confidence

LMP*TP	N	Mean	Grouping	
0 16	2	42.90	A	
0 8	2	41.95	A	
1 16	2	41.75	A	
0 12	2	41.65	A	
3 12	2	40.75	A	B

Table A.1 (continued)

3 16	2	40.50	A	B	
1 8	2	40.45	A	B	
2 12	2	39.60	A	B	
3 8	2	39.55	A	B	
2 8	2	38.80	A	B	C
0 0	2	38.75	A	B	C
1 12	2	37.75	A	B	C
3 0	2	37.60	A	B	C
2 16	2	37.35	A	B	C
2 0	2	35.10		B	C
1 0	2	33.25			C

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: DRYING METHOD

Grouping Information Using the Tukey Method and 95% Confidence

DRYING METHOD	N	Mean	Grouping	
1	2	40.45	A	
2	2	26.55		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of DRYING METHOD Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
2 - 1	-13.900	0.752	(-17.134, -10.666)	-18.49	0.003

Individual confidence level = 95.00%

Table A.2 Two-way ANOVA (LMP-TP), one way ANOVA (microwave-conventional) and Tukey's comparison test for color (*a** value)

Factor Information

Factor	Type	Levels	Values
LMP	Fixed	4	0, 1, 2, 3
TP	Fixed	4	0, 8, 12, 16

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
LMP	3	5.538	1.8461	2.06	0.146
TP	3	139.306	46.4353	51.76	0.000
LMP*TP	9	56.458	6.2731	6.99	0.000
Error	16	14.355	0.8972		
Total	31	215.657			

Tukey Pairwise Comparisons: LMP

Grouping Information Using the Tukey Method and 95% Confidence

LMP	N	Mean	Grouping
3	8	20.2000	A
2	8	19.8000	A
1	8	19.5000	A
0	8	19.0625	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of LMP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
1 - 0	0.438	0.474	(-0.919, 1.794)	0.92	0.793
2 - 0	0.738	0.474	(-0.619, 2.094)	1.56	0.429
3 - 0	1.137	0.474	(-0.219, 2.494)	2.40	0.117
2 - 1	0.300	0.474	(-1.056, 1.656)	0.63	0.920
3 - 1	0.700	0.474	(-0.656, 2.056)	1.48	0.473
3 - 2	0.400	0.474	(-0.956, 1.756)	0.84	0.833

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: TP

Grouping Information Using the Tukey Method and 95% Confidence

Table A.2 (continued)

TP	N	Mean	Grouping	
12	8	21.2250	A	
16	8	21.0375	A	
8	8	20.2125	A	
0	8	16.0875		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of TP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
8 - 0	4.125	0.474	(2.769, 5.481)	8.71	0.000
12 - 0	5.137	0.474	(3.781, 6.494)	10.85	0.000
16 - 0	4.950	0.474	(3.594, 6.306)	10.45	0.000
12 - 8	1.012	0.474	(-0.344, 2.369)	2.14	0.183
16 - 8	0.825	0.474	(-0.531, 2.181)	1.74	0.336
16 - 12	-0.188	0.474	(-1.544, 1.169)	-0.40	0.978

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: LMP*TP

Grouping Information Using the Tukey Method and 95% Confidence

LMP*TP	N	Mean	Grouping		
1 16	2	22.75	A		
0 16	2	21.95	A		
3 12	2	21.85	A		
1 12	2	21.65	A		
2 8	2	20.85	A	B	
0 12	2	20.80	A	B	
3 8	2	20.70	A	B	
2 12	2	20.60	A	B	
2 16	2	20.20	A	B	
0 8	2	20.05	A	B	
1 8	2	19.25	A	B	
3 16	2	19.25	A	B	
3 0	2	19.00	A	B	
2 0	2	17.55		B	C

Table A.2 (continued)

1 0	2	14.35	C D
0 0	2	13.45	D

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: DRYING METHOD

Grouping Information Using the Tukey Method and 95% Confidence

DRYING METHOD	N	Mean	Grouping
1	2	19.25	A
2	2	12.70	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of DRYING METHOD Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
2 - 1	-6.55	1.55	(-13.23, 0.13)	-4.22	0.052

Individual confidence level = 95.00%

Table A.3 Two-way ANOVA (LMP-TP), one way ANOVA (microwave-conventional) and Tukey's comparison test for color ($b*$ value)

Factor Information

Factor	Type	Levels	Values
LMP	Fixed	4	0, 1, 2, 3
TP	Fixed	4	0, 8, 12, 16

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
LMP	3	33.44	11.1461	16.74	0.000
TP	3	291.28	97.0936	145.80	0.000
LMP*TP	9	65.83	7.3145	10.98	0.000
Error	16	10.65	0.6659		
Total	31	401.20			

Tukey Pairwise Comparisons: LMP

Grouping Information Using the Tukey Method and 95% Confidence

LMP	N	Mean	Grouping

Table A.3 (continued)

0	8	30.1375	A	
3	8	28.6875		B
1	8	27.6500		B
2	8	27.6375		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of LMP Levels	**Difference of Means**	**SE of Difference**	**Simultaneous 95% CI**	**T-Value**	**Adjusted P-Value**
1 - 0	-2.487	0.408	(-3.656, -1.319)	-6.10	0.000
2 - 0	-2.500	0.408	(-3.668, -1.332)	-6.13	0.000
3 - 0	-1.450	0.408	(-2.618, -0.282)	-3.55	0.013
2 - 1	-0.013	0.408	(-1.181, 1.156)	-0.03	1.000
3 - 1	1.037	0.408	(-0.131, 2.206)	2.54	0.091
3 - 2	1.050	0.408	(-0.118, 2.218)	2.57	0.086

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: TP

Grouping Information Using the Tukey Method and 95% Confidence

TP	**N**	**Mean**	**Grouping**	
16	8	30.8250	A	
12	8	30.0250	A	
8	8	29.9250	A	
0	8	23.3375		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of TP Levels	**Difference of Means**	**SE of Difference**	**Simultaneous 95% CI**	**T-Value**	**Adjusted P-Value**
8 - 0	6.587	0.408	(5.419, 7.756)	16.14	0.000
12 - 0	6.687	0.408	(5.519, 7.856)	16.39	0.000
16 - 0	7.487	0.408	(6.319, 8.656)	18.35	0.000
12 - 8	0.100	0.408	(-1.068, 1.268)	0.25	0.995
16 - 8	0.900	0.408	(-0.268, 2.068)	2.21	0.164
16 - 12	0.800	0.408	(-0.368, 1.968)	1.96	0.243

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: LMP*TP

Table A.3 (continued)

Grouping Information Using the Tukey Method and 95% Confidence

LMP*TP	N	Mean	Grouping						
1 16	2	33.25	A						
0 16	2	32.85	A						
0 12	2	32.65	A	B					
0 8	2	31.30	A	B	C				
3 12	2	30.60	A	B	C	D			
2 8	2	30.20	A	B	C	D			
3 8	2	29.55		B	C	D			
3 16	2	29.25			C	D			
1 8	2	28.65			C	D			
2 12	2	28.60			C	D	E		
1 12	2	28.25			C	D	E		
2 16	2	27.95				D	E		
3 0	2	25.35					E	F	
2 0	2	23.80						F	
0 0	2	23.75						F	
1 0	2	20.45							G

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: DRYING METHOD

Grouping Information Using the Tukey Method and 95% Confidence

DRYING METHOD	N	Mean	Grouping	
1	2	28.65	A	
2	2	15.55		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of DRYING METHOD Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
2 - 1	-13.100	0.791	(-16.502, -9.698)	-16.57	0.004

Individual confidence level = 95.00%

Table A.4 Two-way ANOVA (LMP-TP), one way ANOVA (microwave-conventional) and Tukey's comparison test for color (MC value)

Factor Information

Factor	Type	Levels	Values
LMP	Fixed	4	0, 1, 2, 3
TP	Fixed	4	0, 8, 12, 16

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
LMP	3	34.520	11.5067	131.80	0.000
TP	3	16.676	5.5587	63.67	0.000
LMP*TP	9	76.270	8.4744	97.07	0.000
Error	16	1.397	0.0873		
Total	31	128.863			

Tukey Pairwise Comparisons: LMP

Grouping Information Using the Tukey Method and 95% Confidence

LMP	N	Mean	Grouping		
2	8	17.4880	A		
0	8	17.0997	A		
1	8	16.2889		B	
3	8	14.7782			C

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of LMP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
1 - 0	-0.811	0.148	(-1.234, -0.388)	-5.49	0.000
2 - 0	0.388	0.148	(-0.035, 0.811)	2.63	0.078
3 - 0	-2.321	0.148	(-2.745, -1.898)	-15.71	0.000
2 - 1	1.199	0.148	(0.776, 1.622)	8.12	0.000
3 - 1	-1.511	0.148	(-1.934, -1.088)	-10.23	0.000
3 - 2	-2.710	0.148	(-3.133, -2.287)	-18.34	0.000

Individual confidence level = 98.87%

Table A.4 (continued)

Tukey Pairwise Comparisons: TP

Grouping Information Using the Tukey Method and 95% Confidence

TP	N	Mean	Grouping	
0	8	17.2571	A	
16	8	16.9919	A	
8	8	15.8226		B
12	8	15.5833		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of TP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
8 - 0	-1.434	0.148	(-1.858, -1.011)	-9.71	0.000
12 - 0	-1.674	0.148	(-2.097, -1.251)	-11.33	0.000
16 - 0	-0.265	0.148	(-0.688, 0.158)	-1.79	0.311
12 - 8	-0.239	0.148	(-0.662, 0.184)	-1.62	0.396
16 - 8	1.169	0.148	(0.746, 1.592)	7.91	0.000
16 - 12	1.409	0.148	(0.986, 1.832)	9.53	0.000

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: LMP*TP

Grouping Information Using the Tukey Method and 95% Confidence

LMP*TP	N	Mean	Grouping						
2 0	2	20.3707	A						
0 16	2	20.3246	A						
1 12	2	18.3448		B					
2 8	2	17.8986		B					
0 0	2	17.3857		B					
1 16	2	17.3053		B	C				
2 12	2	16.1898			C	D			
0 8	2	16.1304			C	D			
3 0	2	15.9764				D	E		
2 16	2	15.4928				D	E	F	
1 0	2	15.2954				D	E	F	G
3 8	2	15.0512				D	E	F	G

Table A.4 (continued)

3 16	2	14.8448	E F G
0 12	2	14.5582	F G
1 8	2	14.2102	G H
3 12	2	13.2405	H

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: DRYING METHOD

Grouping Information Using the Tukey Method and 95% Confidence

DRYING METHOD	N	Mean	Grouping	
2	2	30.9108	A	
1	2	14.2102		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of DRYING METHOD Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
2 - 1	16.701	0.691	(13.728, 19.673)	24.18	0.002

Individual confidence level = 95.00%

Table A.5 Two-way ANOVA (LMP-TP), one way ANOVA (microwave-conventional) and Tukey's comparison test for color (a_w value)

Factor Information

Factor	Type	Levels	Values
LMP	Fixed	4	0, 1, 2, 3
TP	Fixed	4	0, 8, 12, 16

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
LMP	3	0.114000	0.038000	170.80	0.000
TP	3	0.009207	0.003069	13.79	0.000
LMP*TP	9	0.066743	0.007416	33.33	0.000
Error	16	0.003560	0.000222		
Total	31	0.193509			

Tukey Pairwise Comparisons: LMP

Table A.5 (continued)

Grouping Information Using the Tukey Method and 95% Confidence

LMP	N	Mean	Grouping			
0	8	0.680762	A			
1	8	0.628675		B		
2	8	0.556550			C	
3	8	0.529125				D

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of LMP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
1 - 0	-0.05209	0.00746	(-0.07345, -0.03073)	-6.98	0.000
2 - 0	-0.12421	0.00746	(-0.14557, -0.10285)	-16.66	0.000
3 - 0	-0.15164	0.00746	(-0.17300, -0.13028)	-20.33	0.000
2 - 1	-0.07212	0.00746	(-0.09348, -0.05077)	-9.67	0.000
3 - 1	-0.09955	0.00746	(-0.12091, -0.07819)	-13.35	0.000
3 - 2	-0.02743	0.00746	(-0.04878, -0.00607)	-3.68	0.010

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: TP

Grouping Information Using the Tukey Method and 95% Confidence

TP	N	Mean	Grouping	
16	8	0.616275	A	
8	8	0.606350	A	
0	8	0.601625	A	
12	8	0.570862		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of TP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
8 - 0	0.00472	0.00746	(-0.01663, 0.02608)	0.63	0.920
12 - 0	-0.03076	0.00746	(-0.05212, -0.00940)	-4.12	0.004
16 - 0	0.01465	0.00746	(-0.00671, 0.03601)	1.96	0.242
12 - 8	-0.03549	0.00746	(-0.05685, -0.01413)	-4.76	0.001
16 - 8	0.00992	0.00746	(-0.01143, 0.03128)	1.33	0.558

Table A.5 (continued)

16 - 12	0.04541	0.00746	(0.02405, 0.06677)	6.09	0.000

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: LMP*TP

Grouping Information Using the Tukey Method and 95% Confidence

LMP*TP	N	Mean	Grouping						
0 16	2	0.74720	A						
0 8	2	0.68530		B					
1 0	2	0.68290		B					
0 12	2	0.66740		B	C				
1 8	2	0.66175		B	C	D			
3 16	2	0.63605		B	C	D	E		
0 0	2	0.62315			C	D	E		
2 0	2	0.60280				D	E		
2 8	2	0.58695					E	F	
1 16	2	0.58515					E	F	
1 12	2	0.58490					E	F	
2 12	2	0.53975						F	G
3 0	2	0.49765							G
2 16	2	0.49670							G
3 8	2	0.49140							G
3 12	2	0.49140							G

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: DRYING METHOD

Grouping Information Using the Tukey Method and 95% Confidence

DRYING METHOD	N	Mean	Grouping
2	2	0.68870	A
1	2	0.66175	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of DRYING METHOD Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value

Table A.5 (continued)

2 - 1	0.0270	0.0187	(-0.0534, 0.1073)	1.44	0.286

Individual confidence level = 95.00%

Table A.6 Two-way ANOVA (LMP-TP), one way ANOVA (microwave-conventional) and Tukey's comparison test for color (T21 value)

Factor Information

Factor	Type	Levels	Values
LMP	Fixed	4	0, 1, 2, 3
TP	Fixed	4	0, 8, 12, 16

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
LMP	3	1.1792	0.39305	9.48	0.001
TP	3	2.1119	0.70396	16.99	0.000
LMP*TP	9	6.7968	0.75520	18.22	0.000
Error	16	0.6631	0.04145		
Total	31	10.7510			

Tukey Pairwise Comparisons: LMP

Grouping Information Using the Tukey Method and 95% Confidence

LMP	N	Mean	Grouping	
3	8	1.25850	A	
0	8	0.99425	A	B
1	8	0.79925		B
2	8	0.78312		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of LMP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
1 - 0	-0.195	0.102	(-0.487, 0.097)	-1.92	0.261
2 - 0	-0.211	0.102	(-0.503, 0.080)	-2.07	0.203
3 - 0	0.264	0.102	(-0.027, 0.556)	2.60	0.082
2 - 1	-0.016	0.102	(-0.308, 0.275)	-0.16	0.999

Table A.6 (continued)

3 - 1	0.459	0.102	(0.168, 0.751)	4.51	0.002
3 - 2	0.475	0.102	(0.184, 0.767)	4.67	0.001

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: TP

Grouping Information Using the Tukey Method and 95% Confidence

TP	N	Mean	Grouping	
12	8	1.37562	A	
0	8	0.96075		B
16	8	0.78487		B
8	8	0.71388		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of TP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
8 - 0	-0.247	0.102	(-0.538, 0.045)	-2.43	0.112
12 - 0	0.415	0.102	(0.123, 0.706)	4.08	0.004
16 - 0	-0.176	0.102	(-0.467, 0.116)	-1.73	0.342
12 - 8	0.662	0.102	(0.370, 0.953)	6.50	0.000
16 - 8	0.071	0.102	(-0.221, 0.363)	0.70	0.897
16 - 12	-0.591	0.102	(-0.882, -0.299)	-5.80	0.000

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: LMP*TP

Grouping Information Using the Tukey Method and 95% Confidence

LMP*TP	N	Mean	Grouping	
3 12	2	3.0020	A	
0 0	2	1.1795		B
0 16	2	1.1675		B
2 0	2	1.0495		B
0 12	2	1.0000		B
1 16	2	0.8880		B
3 0	2	0.8670		B
1 8	2	0.8160		B
2 12	2	0.7545		B

Table A.6 (continued)

1 0	2	0.7470	B
1 12	2	0.7460	B
3 8	2	0.7140	B
2 8	2	0.6955	B
2 16	2	0.6330	B
0 8	2	0.6300	B
3 16	2	0.4510	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: DRYING METHOD

Grouping Information Using the Tukey Method and 95% Confidence

DRYING METHOD	N	Mean	Grouping	
2	2	2.061	A	
1	2	0.816		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of DRYING METHOD Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
2 - 1	1.245	0.134	(0.670, 1.820)	9.31	0.011

Individual confidence level = 95.00%

Table A.7 Two-way ANOVA (LMP-TP), one way ANOVA (microwave-conventional) and Tukey's comparison test for color (AREA T21 value)

Factor Information

Factor	Type	Levels	Values
LMP	Fixed	4	0, 1, 2, 3
TP	Fixed	4	0, 8, 12, 16

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
LMP	3	3495.0	1164.99	67.67	0.000
TP	3	568.0	189.35	11.00	0.000
LMP*TP	9	2205.5	245.06	14.23	0.000

Table A.7 (continued)

Error	16	275.5	17.22
Total	31	6544.0	

Tukey Pairwise Comparisons: LMP

Grouping Information Using the Tukey Method and 95% Confidence

LMP	N	Mean	Grouping		
0	8	64.5750	A		
1	8	53.9375		B	
2	8	52.3875		B	
3	8	35.4000			C

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of LMP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
1 - 0	-10.64	2.07	(-16.58, -4.70)	-5.13	0.001
2 - 0	-12.19	2.07	(-18.13, -6.25)	-5.87	0.000
3 - 0	-29.18	2.07	(-35.12, -23.23)	-14.06	0.000
2 - 1	-1.55	2.07	(-7.49, 4.39)	-0.75	0.877
3 - 1	-18.54	2.07	(-24.48, -12.60)	-8.94	0.000
3 - 2	-16.99	2.07	(-22.93, -11.05)	-8.19	0.000

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: TP

Grouping Information Using the Tukey Method and 95% Confidence

TP	N	Mean	Grouping		
16	8	56.7375	A		
0	8	54.3000	A	B	
12	8	49.3375		B	C
8	8	45.9250			C

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of TP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
8 - 0	-8.37	2.07	(-14.32, -2.43)	-4.04	0.005
12 - 0	-4.96	2.07	(-10.90, 0.98)	-2.39	0.119

Table A.7 (continued)

16 - 0	2.44	2.07	(-3.50, 8.38)	1.17	0.650
12 - 8	3.41	2.07	(-2.53, 9.35)	1.64	0.383
16 - 8	10.81	2.07	(4.87, 16.75)	5.21	0.000
16 - 12	7.40	2.07	(1.46, 13.34)	3.57	0.012

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: LMP*TP

Grouping Information Using the Tukey Method and 95% Confidence

LMP*TP	N	Mean	Grouping					
0 16	2	68.65	A					
0 12	2	67.50	A					
0 0	2	65.90	A					
2 0	2	64.80	A					
1 16	2	61.40	A	B				
1 0	2	59.40	A	B	C			
0 8	2	56.25	A	B	C			
1 12	2	55.95	A	B	C			
2 12	2	55.20	A	B	C	D		
3 16	2	52.35	A	B	C	D		
2 8	2	45.00		B	C	D		
2 16	2	44.55			C	D		
3 8	2	43.45			C	D	E	
1 8	2	39.00				D	E	
3 0	2	27.10					E	F
3 12	2	18.70						F

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: DRYING METHOD

Grouping Information Using the Tukey Method and 95% Confidence

DRYING METHOD	N	Mean	Grouping	
2	2	71.4	A	
1	2	39.0		B

Means that do not share a letter are significantly different.

Table A.7 (continued)

Tukey Simultaneous Tests for Differences of Means

Difference of DRYING METHOD Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
2 - 1	32.40	2.01	(23.74, 41.06)	16.10	0.004

Individual confidence level = 95.00%

Table A.8 Two-way ANOVA (LMP-TP), one way ANOVA (microwave-conventional) and Tukey's comparison test for color (T22 value)

Factor Information

Factor	Type	Levels	Values
LMP	Fixed	4	0, 1, 2, 3
TP	Fixed	4	0, 8, 12, 16

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
LMP	3	8.171	2.724	1.20	0.343
TP	3	32.477	10.826	4.76	0.015
LMP*TP	9	224.278	24.920	10.95	0.000
Error	16	36.407	2.275		
Total	31	301.332			

Tukey Pairwise Comparisons: LMP

Grouping Information Using the Tukey Method and 95% Confidence

LMP	N	Mean	Grouping
3	8	21.1925	A
2	8	20.1263	A
0	8	20.0525	A
1	8	19.9313	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Table A.8 (continued)

Difference of LMP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
1 - 0	-0.121	0.754	(-2.281, 2.039)	-0.16	0.998
2 - 0	0.074	0.754	(-2.086, 2.234)	0.10	1.000
3 - 0	1.140	0.754	(-1.020, 3.300)	1.51	0.454
2 - 1	0.195	0.754	(-1.965, 2.355)	0.26	0.994
3 - 1	1.261	0.754	(-0.899, 3.421)	1.67	0.369
3 - 2	1.066	0.754	(-1.094, 3.226)	1.41	0.509

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: TP

Grouping Information Using the Tukey Method and 95% Confidence

TP	N	Mean	Grouping	
12	8	21.8463	A	
8	8	20.6238	A	B
16	8	19.4638		B
0	8	19.3688		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of TP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
8 - 0	1.255	0.754	(-0.905, 3.415)	1.66	0.373
12 - 0	2.477	0.754	(0.318, 4.637)	3.28	0.022
16 - 0	0.095	0.754	(-2.065, 2.255)	0.13	0.999
12 - 8	1.222	0.754	(-0.937, 3.382)	1.62	0.395
16 - 8	-1.160	0.754	(-3.320, 1.000)	-1.54	0.439
16 - 12	-2.382	0.754	(-4.542, -0.223)	-3.16	0.028

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: LMP*TP

Grouping Information Using the Tukey Method and 95% Confidence

LMP*TP	N	Mean	Grouping	
3 12	2	29.930	A	
1 16	2	22.345		B
2 8	2	21.965		B

Table A.8 (continued)

2 12	2	20.850	B
1 8	2	20.780	B
0 16	2	20.475	B
0 8	2	20.370	B
0 0	2	20.060	B
3 8	2	19.380	B
0 12	2	19.305	B
1 0	2	19.300	B
2 0	2	19.260	B
3 0	2	18.855	B
2 16	2	18.430	B
1 12	2	17.300	B
3 16	2	16.605	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: DRYING METHOD

Grouping Information Using the Tukey Method and 95% Confidence

DRYING METHOD	N	Mean	Grouping	
1	2	20.7800	A	
2	2	9.7985		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of DRYING METHOD Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
2 - 1	-10.981	0.802	(-14.432, -7.531)	-13.69	0.005

Individual confidence level = 95.00%

Table A.9 Two-way ANOVA (LMP-TP), one way ANOVA (microwave-conventional) and Tukey's comparison test for color (AREA T22 value)

Factor Information

Factor	Type	Levels	Values
LMP	Fixed	4	0, 1, 2, 3
TP	Fixed	4	0, 8, 12, 16

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
LMP	3	490.13	163.375	27.65	0.000
TP	3	174.72	58.239	9.86	0.001
LMP*TP	9	436.18	48.464	8.20	0.000
Error	16	94.53	5.908		
Total	31	1195.55			

Tukey Pairwise Comparisons: LMP

Grouping Information Using the Tukey Method and 95% Confidence

LMP	N	Mean	Grouping		
3	8	26.9125	A		
1	8	21.6500		B	
2	8	20.8375		B	
0	8	15.8750			C

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of LMP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
1 - 0	5.77	1.22	(2.29, 9.26)	4.75	0.001
2 - 0	4.96	1.22	(1.48, 8.44)	4.08	0.004
3 - 0	11.04	1.22	(7.56, 14.52)	9.08	0.000
2 - 1	-0.81	1.22	(-4.29, 2.67)	-0.67	0.907
3 - 1	5.26	1.22	(1.78, 8.74)	4.33	0.003
3 - 2	6.08	1.22	(2.59, 9.56)	5.00	0.001

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: TP

Grouping Information Using the Tukey Method and 95% Confidence

Table A.9 (continued)

TP	N	Mean	Grouping	
12	8	24.3125	A	
8	8	22.8875	A	
16	8	19.1000		B
0	8	18.9750		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of TP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
8 - 0	3.91	1.22	(0.43, 7.39)	3.22	0.025
12 - 0	5.34	1.22	(1.86, 8.82)	4.39	0.002
16 - 0	0.12	1.22	(-3.36, 3.61)	0.10	1.000
12 - 8	1.42	1.22	(-2.06, 4.91)	1.17	0.652
16 - 8	-3.79	1.22	(-7.27, -0.31)	-3.12	0.030
16 - 12	-5.21	1.22	(-8.69, -1.73)	-4.29	0.003

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: LMP*TP

Grouping Information Using the Tukey Method and 95% Confidence

LMP*TP	N	Mean	Grouping			
3 12	2	39.00	A			
1 8	2	26.85		B		
3 0	2	26.20		B	C	
3 8	2	24.15		B	C	D
2 8	2	23.65		B	C	D
1 12	2	23.00		B	C	D
2 16	2	22.20		B	C	D
2 12	2	20.00		B	C	D
1 16	2	19.50		B	C	D
3 16	2	18.30		B	C	D
2 0	2	17.50		B	C	D
1 0	2	17.25		B	C	D
0 8	2	16.90			C	D
0 16	2	16.40				D

Table A.9 (continued)

0 12	2	15.25	D
0 0	2	14.95	D

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: DRYING METHOD

Grouping Information Using the Tukey Method and 95% Confidence

DRYING METHOD	N	Mean	Grouping	
1	2	26.85	A	
2	2	16.15		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of DRYING METHOD Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
2 - 1	-10.700	0.474	(-12.741, -8.659)	-22.56	0.002

Individual confidence level = 95.00%

Table A.10 Two-way ANOVA (LMP-TP), one way ANOVA (microwave-conventional) and Tukey's comparison test for color (T23 value)

Factor Information

Factor	Type	Levels	Values
LMP	Fixed	4	0, 1, 2, 3
TP	Fixed	4	0, 8, 12, 16

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
LMP	3	159.5	53.16	1.62	0.224
TP	3	365.9	121.98	3.71	0.034
LMP*TP	9	1521.1	169.01	5.15	0.002
Error	16	525.4	32.84		
Total	31	2571.9			

Tukey Pairwise Comparisons: LMP

Grouping Information Using the Tukey Method and 95% Confidence

LMP	N	Mean	Grouping

Table A.10 (continued)

3	8	97.2525	A
2	8	95.0337	A
0	8	93.1000	A
1	8	91.2475	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of LMP Levels	**Difference of Means**	**SE of Difference**	**Simultaneous 95% CI**	**T-Value**	**Adjusted P-Value**
1 - 0	-1.85	2.87	(-10.06, 6.35)	-0.65	0.915
2 - 0	1.93	2.87	(-6.27, 10.14)	0.67	0.905
3 - 0	4.15	2.87	(-4.05, 12.36)	1.45	0.489
2 - 1	3.79	2.87	(-4.42, 11.99)	1.32	0.563
3 - 1	6.00	2.87	(-2.20, 14.21)	2.10	0.196
3 - 2	2.22	2.87	(-5.99, 10.42)	0.77	0.865

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: TP

Grouping Information Using the Tukey Method and 95% Confidence

TP	**N**	**Mean**	**Grouping**	
12	8	97.2050	A	
8	8	96.7562	A	B
16	8	93.9612	A	B
0	8	88.7112		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of TP Levels	**Difference of Means**	**SE of Difference**	**Simultaneous 95% CI**	**T-Value**	**Adjusted P-Value**
8 - 0	8.04	2.87	(-0.16, 16.25)	2.81	0.055
12 - 0	8.49	2.87	(0.29, 16.70)	2.96	0.041
16 - 0	5.25	2.87	(-2.96, 13.46)	1.83	0.295
12 - 8	0.45	2.87	(-7.76, 8.65)	0.16	0.999
16 - 8	-2.80	2.87	(-11.00, 5.41)	-0.98	0.765
16 - 12	-3.24	2.87	(-11.45, 4.96)	-1.13	0.676

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: LMP*TP

Table A.10 (continued)

Grouping Information Using the Tukey Method and 95% Confidence

LMP*TP	N	Mean	Grouping		
3 12	2	116.550	A		
2 8	2	101.610	A	B	
2 12	2	99.300	A	B	C
1 16	2	99.185	A	B	C
1 8	2	97.180	A	B	C
0 8	2	96.990	A	B	C
0 12	2	94.605	A	B	C
2 16	2	92.925		B	C
3 16	2	92.055		B	C
0 16	2	91.680		B	C
3 8	2	91.245		B	C
1 0	2	90.260		B	C
3 0	2	89.160		B	C
0 0	2	89.125		B	C
2 0	2	86.300		B	C
1 12	2	78.365			C

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: DRYING METHOD

Grouping Information Using the Tukey Method and 95% Confidence

DRYING METHOD	N	Mean	Grouping
1	2	97.180	A
2	2	81.015	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of DRYING METHOD Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
2 - 1	-16.17	5.69	(-40.65, 8.32)	-2.84	0.105

Individual confidence level = 95.00%

Table A.11 Two-way ANOVA (LMP-TP), one way ANOVA (microwave-conventional) and Tukey’s comparison test for color (AREA T23 value)

Factor Information

Factor	Type	Levels	Values
LMP	Fixed	4	0, 1, 2, 3
TP	Fixed	4	0, 8, 12, 16

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
LMP	3	1411.8	470.61	45.79	0.000
TP	3	208.2	69.39	6.75	0.004
LMP*TP	9	916.4	101.83	9.91	0.000
Error	16	164.5	10.28		
Total	31	2700.9			

Tukey Pairwise Comparisons: LMP

Grouping Information Using the Tukey Method and 95% Confidence

LMP	N	Mean	Grouping		
3	8	37.6750	A		
2	8	26.7875		B	
1	8	24.3875		B	
0	8	19.5375			C

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of LMP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
1 - 0	4.85	1.60	(0.26, 9.44)	3.03	0.036
2 - 0	7.25	1.60	(2.66, 11.84)	4.52	0.002
3 - 0	18.14	1.60	(13.55, 22.73)	11.31	0.000
2 - 1	2.40	1.60	(-2.19, 6.99)	1.50	0.462
3 - 1	13.29	1.60	(8.70, 17.88)	8.29	0.000
3 - 2	10.89	1.60	(6.30, 15.48)	6.79	0.000

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: TP

Grouping Information Using the Tukey Method and 95% Confidence

Table A.11 (continued)

TP	N	Mean	Grouping	
8	8	31.1750	A	
0	8	26.7125	A	B
12	8	26.3500		B
16	8	24.1500		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of TP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
8 - 0	4.46	1.60	(-0.13, 9.05)	2.78	0.058
12 - 0	-0.36	1.60	(-4.95, 4.23)	-0.23	0.996
16 - 0	-2.56	1.60	(-7.15, 2.03)	-1.60	0.407
12 - 8	-4.82	1.60	(-9.42, -0.23)	-3.01	0.037
16 - 8	-7.02	1.60	(-11.62, -2.43)	-4.38	0.002
16 - 12	-2.20	1.60	(-6.79, 2.39)	-1.37	0.533

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: LMP*TP

Grouping Information Using the Tukey Method and 95% Confidence

LMP*TP	N	Mean	Grouping						
3 0	2	46.65	A						
3 12	2	42.30	A	B					
1 8	2	34.10	A	B	C				
2 16	2	33.25		B	C	D			
3 8	2	32.40		B	C	D			
2 8	2	31.35		B	C	D	E		
3 16	2	29.35			C	D	E	F	
0 8	2	26.85			C	D	E	F	G
2 12	2	24.80			C	D	E	F	G
1 0	2	23.35			C	D	E	F	G
1 12	2	21.00				D	E	F	G
1 16	2	19.10					E	F	G
0 0	2	19.10					E	F	G
2 0	2	17.75						F	G

Table A.11 (continued)

0 12	2	17.30	F G
0 16	2	14.90	G

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: DRYING METHOD

Grouping Information Using the Tukey Method and 95% Confidence

DRYING METHOD	N	Mean	Grouping	
1	2	34.10	A	
2	2	12.45		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of DRYING METHOD Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
2 - 1	-21.65	2.32	(-31.65, -11.65)	-9.31	0.011

Individual confidence level = 95.00%

Table A.12 Two-way ANOVA (LMP-TP), one way ANOVA (microwave-conventional) and Tukey's comparison test for color (LYCOPENE value)

Factor Information

Factor	Type	Levels	Values
LMP	Fixed	4	0, 1, 2, 3
TP	Fixed	4	0, 8, 12, 16

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
LMP	3	13680.7	4560.23	3434.40	0.000
TP	3	858.0	286.01	215.40	0.000
LMP*TP	9	272.3	30.26	22.79	0.000
Error	16	21.2	1.33		
Total	31	14832.3			

Tukey Pairwise Comparisons: LMP

Grouping Information Using the Tukey Method and 95% Confidence

LMP	N	Mean	Grouping

Table A.12 (continued)

0	8	71.1500	A			
1	8	39.1125		B		
2	8	26.9375			C	
3	8	15.9125				D

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of LMP Levels	**Difference of Means**	**SE of Difference**	**Simultaneous 95% CI**	**T-Value**	**Adjusted P-Value**
1 - 0	-32.038	0.576	(-33.687, -30.388)	-55.61	0.000
2 - 0	-44.213	0.576	(-45.862, -42.563)	-76.74	0.000
3 - 0	-55.237	0.576	(-56.887, -53.588)	-95.87	0.000
2 - 1	-12.175	0.576	(-13.825, -10.525)	-21.13	0.000
3 - 1	-23.200	0.576	(-24.850, -21.550)	-40.27	0.000
3 - 2	-11.025	0.576	(-12.675, -9.375)	-19.14	0.000

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: TP

Grouping Information Using the Tukey Method and 95% Confidence

TP	**N**	**Mean**	**Grouping**		
16	8	42.4000	A		
12	8	41.7500	A		
8	8	39.4500		B	
0	8	29.5125			C

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of TP Levels	**Difference of Means**	**SE of Difference**	**Simultaneous 95% CI**	**T-Value**	**Adjusted P-Value**
8 - 0	9.937	0.576	(8.288, 11.587)	17.25	0.000
12 - 0	12.237	0.576	(10.588, 13.887)	21.24	0.000
16 - 0	12.887	0.576	(11.238, 14.537)	22.37	0.000
12 - 8	2.300	0.576	(0.650, 3.950)	3.99	0.005
16 - 8	2.950	0.576	(1.300, 4.600)	5.12	0.001
16 - 12	0.650	0.576	(-1.000, 2.300)	1.13	0.678

Individual confidence level = 98.87%

Tukey Pairwise Comparisons: LMP*TP

Table A.12 (continued)

Grouping Information Using the Tukey Method and 95% Confidence

LMP*TP	N	Mean	Grouping								
0 16	2	80.70	A								
0 12	2	73.45		B							
0 8	2	73.20		B							
0 0	2	57.25			C						
1 12	2	46.90				D					
1 8	2	39.75					E				
1 16	2	38.20					E				
1 0	2	31.60						F			
2 8	2	30.30						F			
2 12	2	29.25						F			
2 16	2	29.10						F			
3 16	2	21.60							G		
2 0	2	19.10							G	H	
3 12	2	17.40							G	H	
3 8	2	14.55								H	I
3 0	2	10.10									I

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: DRYING METHOD

Grouping Information Using the Tukey Method and 95% Confidence

DRYING METHOD	N	Mean	Grouping	
2	2	83.35	A	
1	2	39.75		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of DRYING METHOD Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
2 - 1	43.60	2.15	(34.35, 52.85)	20.27	0.002

Individual confidence level = 95.00%

Table A.13 Two-way ANOVA (LMP-TP), one way ANOVA (microwave-conventional) and Tukey's comparison test for color (HARDNESS value)

Factor Information

Factor	Type	Levels	Values
LMP	Fixed	4	0, 1, 2, 3
TP	Fixed	3	8, 12, 16

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
LMP	3	11412.7	3804.22	755.72	0.000
TP	2	1125.4	562.70	111.78	0.000
LMP*TP	6	2893.8	482.30	95.81	0.000
Error	12	60.4	5.03		
Total	23	15492.3			

Tukey Pairwise Comparisons: LMP

Grouping Information Using the Tukey Method and 95% Confidence

LMP	N	Mean	Grouping			
3	6	67.5400	A			
2	6	54.0300		B		
1	6	21.1967			C	
0	6	15.6300				D

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of LMP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
1 - 0	5.57	1.30	(1.72, 9.41)	4.30	0.005
2 - 0	38.40	1.30	(34.55, 42.25)	29.64	0.000
3 - 0	51.91	1.30	(48.06, 55.76)	40.07	0.000
2 - 1	32.83	1.30	(28.99, 36.68)	25.35	0.000
3 - 1	46.34	1.30	(42.50, 50.19)	35.78	0.000
3 - 2	13.51	1.30	(9.66, 17.36)	10.43	0.000

Individual confidence level = 98.83%

Tukey Pairwise Comparisons: TP

Grouping Information Using the Tukey Method and 95% Confidence

Table A.13 (continued)

TP	N	Mean	Grouping		
12	8	48.2175	A		
16	8	39.1150		B	
8	8	31.4650			C

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of TP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
12 - 8	16.75	1.12	(13.76, 19.74)	14.93	0.000
16 - 8	7.65	1.12	(4.66, 10.64)	6.82	0.000
16 - 12	-9.10	1.12	(-12.09, -6.11)	-8.11	0.000

Individual confidence level = 97.94%

Tukey Pairwise Comparisons: LMP*TP

Grouping Information Using the Tukey Method and 95% Confidence

LMP*TP	N	Mean	Grouping					
3 16	2	86.635	A					
3 12	2	74.370		B				
2 12	2	74.180		B				
2 8	2	47.285			C			
3 8	2	41.615			C	D		
2 16	2	40.625			C	D		
1 12	2	33.745				D		
0 8	2	21.265					E	
1 8	2	15.695					E	F
0 16	2	15.050					E	F
1 16	2	14.150					E	F
0 12	2	10.575						F

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: DRYING METHOD

Grouping Information Using the Tukey Method and 95% Confidence

DRYING METHOD	N	Mean	Grouping	
2	2	28.470	A	
1	2	15.695		B

Means that do not share a letter are significantly different.

Table A.13 (continued)

Tukey Simultaneous Tests for Differences of Means

Difference of DRYING METHOD Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
2 - 1	12.77	1.35	(6.96, 18.59)	9.46	0.011

Individual confidence level = 95.00%

Table A.14 Two-way ANOVA (LMP-TP), one way ANOVA (microwave-conventional) and Tukey's comparison test for color (GUMMINESS value)

Factor Information

Factor	Type	Levels	Values
LMP	Fixed	4	0, 1, 2, 3
TP	Fixed	3	8, 12, 16

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
LMP	3	2909.32	969.772	2476.86	0.000
TP	2	151.71	75.856	193.74	0.000
LMP*TP	6	413.44	68.906	175.99	0.000
Error	12	4.70	0.392		
Total	23	3479.16			

Tukey Pairwise Comparisons: LMP

Grouping Information Using the Tukey Method and 95% Confidence

LMP	N	Mean	Grouping			
3	6	32.5467	A			
2	6	28.4967		B		
1	6	9.5717			C	
0	6	7.8717				D

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Table A.14 (continued)

Difference of LMP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
1 - 0	1.700	0.361	(0.627, 2.773)	4.71	0.002
2 - 0	20.625	0.361	(19.552, 21.698)	57.09	0.000
3 - 0	24.675	0.361	(23.602, 25.748)	68.30	0.000
2 - 1	18.925	0.361	(17.852, 19.998)	52.39	0.000
3 - 1	22.975	0.361	(21.902, 24.048)	63.60	0.000
3 - 2	4.050	0.361	(2.977, 5.123)	11.21	0.000

Individual confidence level = 98.83%

Tukey Pairwise Comparisons: TP

Grouping Information Using the Tukey Method and 95% Confidence

TP	N	Mean	Grouping	
8	8	21.4350	A	
12	8	21.3638	A	
16	8	16.0662		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of TP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
12 - 8	-0.071	0.313	(-0.905, 0.763)	-0.23	0.972
16 - 8	-5.369	0.313	(-6.203, -4.535)	-17.16	0.000
16 - 12	-5.298	0.313	(-6.132, -4.463)	-16.93	0.000

Individual confidence level = 97.94%

Tukey Pairwise Comparisons: LMP*TP

Grouping Information Using the Tukey Method and 95% Confidence

LMP*TP	N	Mean	Grouping				
3 8	2	40.600	A				
2 12	2	38.755	A				
3 12	2	30.100		B			
3 16	2	26.940			C		
2 8	2	26.440			C		
2 16	2	20.295				D	
1 16	2	9.750					E

Table A.14 (continued)

1 12	2	9.645	E
0 8	2	9.380	E F
1 8	2	9.320	E F
0 16	2	7.280	E F
0 12	2	6.955	F

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: DRYING METHOD

Grouping Information Using the Tukey Method and 95% Confidence

DRYING METHOD	N	Mean	Grouping	
2	2	13.33	A	
1	2	9.32		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of DRYING METHOD Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
2 - 1	4.010	0.660	(1.172, 6.848)	6.08	0.026

Individual confidence level = 95.00%

Table A.15 Two-way ANOVA (LMP-TP), one way ANOVA (microwave-conventional) and Tukey's comparison test for color (CHEWINESS value)

Factor Information

Factor	Type	Levels	Values
LMP	Fixed	4	0, 1, 2, 3
TP	Fixed	3	8, 12, 16

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
LMP	3	916025	305342	4843.49	0.000
TP	2	72201	36101	572.65	0.000
LMP*TP	6	144703	24117	382.56	0.000
Error	12	757	63		
Total	23	1133686			

Table A.15 (continued)

Tukey Pairwise Comparisons: LMP

Grouping Information Using the Tukey Method and 95% Confidence

LMP	N	Mean	Grouping			
3	6	574.500	A			
2	6	535.167		B		
1	6	221.667			C	
0	6	121.500				D

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of LMP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
1 - 0	100.17	4.58	(86.55, 113.78)	21.85	0.000
2 - 0	413.67	4.58	(400.05, 427.28)	90.24	0.000
3 - 0	453.00	4.58	(439.39, 466.61)	98.82	0.000
2 - 1	313.50	4.58	(299.89, 327.11)	68.39	0.000
3 - 1	352.83	4.58	(339.22, 366.45)	76.97	0.000
3 - 2	39.33	4.58	(25.72, 52.95)	8.58	0.000

Individual confidence level = 98.83%

Tukey Pairwise Comparisons: TP

Grouping Information Using the Tukey Method and 95% Confidence

TP	N	Mean	Grouping		
12	8	435.875	A		
16	8	350.375		B	
8	8	303.375			C

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of TP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
12 - 8	132.50	3.97	(121.92, 143.08)	33.38	0.000
16 - 8	47.00	3.97	(36.42, 57.58)	11.84	0.000
16 - 12	-85.50	3.97	(-96.08, -74.92)	-21.54	0.000

Individual confidence level = 97.94%

Tukey Pairwise Comparisons: LMP*TP

Grouping Information Using the Tukey Method and 95% Confidence

Table A.15 (continued)

LMP*TP	N	Mean	Grouping							
3 16	2	703.0	A							
2 12	2	675.0	A							
3 12	2	606.5		B						
2 8	2	489.0			C					
2 16	2	441.5				D				
3 8	2	414.0				D				
1 12	2	369.0					E			
1 8	2	168.5						F		
0 8	2	142.0						F	G	
0 16	2	129.5							G	
1 16	2	127.5							G	
0 12	2	93.0								H

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: DRYING METHOD

Grouping Information Using the Tukey Method and 95% Confidence

DRYING METHOD	N	Mean	Grouping
2	2	195.0	A
1	2	168.5	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of DRYING METHOD Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
2 - 1	26.5	14.7	(-36.8, 89.8)	1.80	0.213

Individual confidence level = 95.00%

Table A.16 Two-way ANOVA (LMP-TP), one way ANOVA (microwave-conventional) and Tukey's comparison test for color (COHESIVENESS value)

Factor Information

Factor	Type	Levels	Values
LMP	Fixed	4	0, 1, 2, 3
TP	Fixed	3	8, 12, 16

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
LMP	3	0.061117	0.020372	84.30	0.000
TP	2	0.000175	0.000088	0.36	0.704
LMP*TP	6	0.003858	0.000643	2.66	0.070
Error	12	0.002900	0.000242		
Total	23	0.068050			

Tukey Pairwise Comparisons: LMP

Grouping Information Using the Tukey Method and 95% Confidence

LMP	N	Mean	Grouping		
1	6	0.583333	A		
3	6	0.573333	A	B	
2	6	0.556667		B	
0	6	0.456667			C

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of LMP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
1 - 0	0.12667	0.00898	(0.10001, 0.15332)	14.11	0.000
2 - 0	0.10000	0.00898	(0.07334, 0.12666)	11.14	0.000
3 - 0	0.11667	0.00898	(0.09001, 0.14332)	13.00	0.000
2 - 1	-0.02667	0.00898	(-0.05332, -0.00001)	-2.97	0.050
3 - 1	-0.01000	0.00898	(-0.03666, 0.01666)	-1.11	0.688
3 - 2	0.01667	0.00898	(-0.00999, 0.04332)	1.86	0.296

Individual confidence level = 98.83%

Tukey Pairwise Comparisons: TP

Table A.16 (continued)

Grouping Information Using the Tukey Method and 95% Confidence

TP	N	Mean	Grouping
8	8	0.54500	A
16	8	0.54375	A
12	8	0.53875	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of TP Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
12 - 8	-0.00625	0.00777	(-0.02697, 0.01447)	-0.80	0.708
16 - 8	-0.00125	0.00777	(-0.02197, 0.01947)	-0.16	0.986
16 - 12	0.00500	0.00777	(-0.01572, 0.02572)	0.64	0.800

Individual confidence level = 97.94%

Tukey Pairwise Comparisons: LMP*TP

Grouping Information Using the Tukey Method and 95% Confidence

LMP*TP	N	Mean	Grouping	
3 16	2	0.595	A	
1 12	2	0.595	A	
1 8	2	0.590	A	
3 8	2	0.570	A	
1 16	2	0.565	A	
2 12	2	0.565	A	
2 8	2	0.560	A	
3 12	2	0.555	A	
2 16	2	0.545	A	
0 16	2	0.470		B
0 8	2	0.460		B
0 12	2	0.440		B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: DRYING METHOD

Grouping Information Using the Tukey Method and 95% Confidence

DRYING METHOD	N	Mean	Grouping
1	2	0.59	A

Table A.16 (continued)

2	2	0.47	B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of DRYING METHOD Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-Value	Adjusted P-Value
2 - 1	-0.1200	0.0000	(-0.1200, -0.1200)	*	*

Individual confidence level = 95.00%