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Enhancing Fresh Pasta Quality: The Impact of Thermal Processing and Innovative Packaging Techniques on Shelf Life and Nutritional Value

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ABSTRACT

This paper aims to investigate the effect of heat treatment and packaging techniques on the qualitative attributes of functionally enriched fresh pasta. Fresh pasta is a type of pasta with a moisture content of more than 24% and thus can be said to be perishable. Fresh pasta typically has an average shelf life of approximately five days. In order to cope with this, in this study various thermal treatments and packaging methods (ambient air packaged and modified atmosphere packaging) were used to prolong shelf life and maintain the quality of pasta. Heat treatment was conducted at 90°C for 60, 120 and 180 seconds. Heat-treated and non-treated fresh pasta samples were packaged both in air and in modified atmosphere packaging conditions. The study shows that the application of a nitrogen-carbon dioxide mixture as packaging media (50/50 N2/CO2) improved the retention of such sensory attributes as color and texture as opposed to air in which pasta degrades rapidly. L* values and phytic acid content of fresh pasta samples demonstrated a corresponding decrease with treatment time. Heat treatment did not affect the antioxidant activity and total phenolic content. Fresh pasta samples packaged with normal air deteriorated and became unconsumable in the first week of storage. Modified atmosphere packaging conditions allowed the samples to last much longer compared to air packaging. The best results were obtained for functionally enriched fresh pasta samples that were both thermally treated for 180 seconds and packaged with modified atmosphere conditions.

Yaş Makarna Kalitesinin Artırılması: Isıl İşlem ve Yenilikçi Paketleme Tekniklerinin Raf Ömrü ve Besin Değeri Üzerindeki Etkisi

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ÖZET

Bu makale, ısıl işlem ve paketleme tekniklerinin fonksiyonel olarak zenginleştirilmiş taze makarnanın bazı özellikleri üzerindeki etkisini araştırmayı amaçlamaktadır. Taze makarna, nem içeriği %24'ün üzerinde olan ve dolayısıyla çabuk bozulabilen bir makarna türüdür. Taze makarnanın ortalama raf ömrü yaklaşık beş gündür. Bu sorunla başa çıkabilmek için bu çalışmada makarnanın raf ömrünü uzatmak ve kalitesini korumak amacıyla ısıl işlem ve paketleme yöntemleri (normal havasıyla paketleme ve modifiye atmosferde paketleme) kullanılmıştır. Isıl işlem 90°C'de 60, 120 ve 180 saniye süreyle gerçekleştirilmiş, ısıl işlem görmüş ve işlem görmemiş taze makarna numuneleri hem havada hem de modifiye atmosfer paketleme koşullarında paketlenmiştir. Çalışma sonucunda, ambalajlama ortamı olarak nitrojen-karbon dioksit karışımının (50/50 N2/CO2) uygulanmasının, makarnanın hızla bozunduğu normal hava koşullarında paketlemeye kıyasla renk ve doku gibi duyusal özelliklerin korunmasını sağladığı ortaya koyulmuştur. Taze makarna örneklerinin L* değerleri ve fitik asit içeriği, işlem süresiyle orantılı bir azalma göstermiştir. Isıl işlem antioksidan aktiviteyi ve toplam fenolik içeriği etkilememiştir. Normal havayla paketlenmiş taze makarna örnekleri depolamanın ilk haftasında bozulmuş ve tüketilemeyecek hale gelmiştir. Modifiye atmosfer paketleme koşulları, hava paketlemesi ile karşılaştırıldığında örneklerin daha uzun süre dayanmasını sağlamıştır. En iyi sonuçlar, hem 180 saniye ısıl işleme tabi tutulan hem de modifiye atmosfer koşullarında paketlenen, fonksiyonel açıdan zenginleştirilmiş taze makarna örneklerinde elde edilmiştir.

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INTRODUCTION

Around the world, pasta is a popular culinary product made from grain. There are many varieties of pasta according to some factors such as composition, shape, color, storage and production methods (Costa et al., 2010). While dry pasta is the more popular type of pasta, fresh pasta has become increasingly consumed worldwide, notably in Italy. Fresh pasta formulations can be easily enriched with various components such as wheat germ (Cankurtaran and Bilgiçli, 2019), buckwheat (Alamprese et al., 2007), amaranth (Del Nobile et al., 2009), flaxseed flour (Manthey et al., 2008), and grape marc (Marinelli et al. 2015). These ingredients enrich the pasta not only with nutrients but also with unique flavors and textures, all contributing positively to the health-conscious consumer use. Flaxseed flour, recognized for its ability to enhance fiber content and α-linolenic acid (ALA) levels (Singh et al., 2011), or buckwheat, which has a unique nutty flavor and is gluten-free (Pandey and Tilara, 2023), contributes to the diversification of dietary options available to individuals. Researchers also study the functional properties of these enriched formulations.

Fresh pasta is subjected to certain sensory and physical characteristics and nutrition profiles with respect to the various ingredients added and the method of heat treatments. For instance, it has been shown that including certain cereal bran enrichments affects the color, cooking properties, and sensory quality of enriched pasta. The incorporation of cereal brans resulted in heightened water absorption and increased cooking losses in pasta (Kaur et al., 2012). Conversely, a study indicated that barley flour high in β-glucan diminished water absorption values (Kosović et al., 2018). These data highlight the complex relationship between ingredients and the overall quality of pasta. Furthermore, the heat treatment process has also been related to changes in antioxidant activity and phenolics, which are, in turn, vital for the nutritional value of pasta. The interplay of moisture content, heat treatment, and packaging underscores the necessity of a comprehensive examination of fresh pasta quality. The rising global demand for fresh pasta has rendered the discovery of suitable preservation technologies very crucial.

The modified formulation of fresh pasta will enable the integration of several functional ingredients (Catzeddu, 2023; Wang et al., 2021; Lux et al., 2023; Sinha et al., 2008; Sant'Anna et al., 2014) to enhance nutritional characteristics and sensory qualities. These components can enhance the nutritional profile of the pasta while offering distinct flavors and textures to cater to diverse consumer preferences. The formulation of fresh pasta is crucial in influencing the quality, nutritional value, and shelf life as compared to dried pasta. Fresh pasta is made with wheat flour as a prime structural element, but for the improvement of nutritional status and functional properties, other valuable additives can be included. Improvements in fresh pasta quality are observed with the addition of antioxidant and dietary fiber-rich ingredients such as flaxseed and oat or barley fiber. The incorporation of alternative flours in fresh pasta formulations, such as wheat germ, buckwheat, and amaranth makes it possible for the product to cater to varying consumer preferences and diet-related needs. Not only do these ingredients contribute to the flavor and texture of pasta, but they also have an impact on its antioxidant capacity and health benefits. Pomegranate seed powder, for example, demonstrates superior antioxidant activity and improves the nutritional content of pasta without notably compromising its cooking, textural, and sensory attributes (Dib et al., 2018).

Fresh pasta comprises around 24% water, rendering it a highly perishable dietary item. Fresh pasta, characterized by its elevated moisture content, is very susceptible to microbial deterioration and may become inedible within around five days (Pagani et al., 2007). The fresh pasta market is growing rapidly, and if products are to be packaged before sale, some additional processes need to be applied to increase microbial resistance. The shelf life of undried pasta varies between 15 and 90 days, depending on heat treatment conditions and packaging techniques (Alamprese et al,. 2008). An injected steam belt pasteurizer is used to perform heat treatment (Sanguinetti et al., 2011). While a single heat treatment is usually preferred, if want a more prolonged shelf life, second heat treatment after the packaging can be performed. Various combinations of treatment time and temperature are used depending on the pasta shape and/or filling materials (Pagani et al., 2007). The effects of different heating methods and treatment conditions on the quality and shelf life of fresh pasta have been thoroughly examined (Alamprese et al., 2008; Sanguinetti et al., 2011; Lucera et al., 2014; Sanguinetti et al., 2015; Scioscia et al., 2016). The modified environment packaging approach enhances food quality and prolongs shelf life. The idea behind modified atmosphere packaging is to use a single gas or a combination of gases in place of the air in the package. Carbon dioxide (CO_2) and nitrogen (N_2) are the two main gases, and they can be used separately or in combination. Additionally, argon and helium may be favored based on the specific product type (Pagani et al., 2007). The rate of CO_2 used in package range from 25% to 100%. Concentration of more than 40% CO_2 in package of fresh pasta can inhibit the fungal activity. N_2, an inert gas, inhibits the proliferation of aerobic bacteria and delays oxidation. Also, it plays a role as filler and preserves the package from collapsing that resulted from the absorption of CO_2 by food. Pagani et al. (2007) reported the suitable ratios of CO_2 and N_2 as 30%-70% or 50%-50% for fresh pasta production. Sanguinetti et al. (2011) packaged the fresh pasta samples under a 50/50 N_2/CO_2 ratio after the thermal treatment and they determined that modified atmosphere packaging protected the samples from mold growth during the 42 days. Del Nobile et al. (2009) indicated that best gas mixture was 30%-70% N_2-CO_2 from among three different gas mixture (30%-70%, 20%-80%, and 0%-100%) for packaging of fresh pasta samples. Processing techniques are greatly affecting the quality and shelf life of fresh pasta, especially those related to heat treatment and the different types of packaging systems. Studies indicate that heat treatment would lessen the microbial load effectively (Scioscia et al., 2016) as well as improve the firmness of pasta (Alamprese et al., 2008), but the exact optimum condition may vary depending on formulation-specific and shelf life considerations. Modified atmosphere packaging emerged as a viable method for enhancing the quality and extending the shelf life of fresh pasta by establishing an optimal environment that prevents rotting while preserving its freshness. Under nitrogen-carbon dioxide mixtures, packaging of fresh pasta demonstrated in studies that it can effectively prevent mold growth while retaining sensory attributes under longer storage (Lee at al., 2001; Marzano et al., 2022).

In summary, it is essential that fresh pasta be kept using innovative processing methods such as heat treatment and modified atmosphere packaging. These factors significantly impact the quality and shelf life of fresh pasta. This study can act as a reference for optimal preservation methods of fresh pasta, ensuring its continued significance in culinary heritage and contemporary lifestyles. As the project progresses, these insights will drive the advancement of superior formulations and preservation methods to enhance quality and appeal in the fresh pasta market. In this study, various antioxidant-rich (flaxseed and pomegranate seed) and dietary fiber-rich (oat fiber and barley fiber) ingredients were used to enhancing the functional properties of fresh pasta samples. The aim of this study was to assess the impact of functional additives, thermal processing, and packaging techniques on various physical and chemical parameters of fresh pasta.

MATERIAL AND METHODS

In this section, fresh pasta samples preparation and analysis are discussed concerning the effect of heat treatment and modified atmosphere packaging on quality and shelf life.

Raw materials

Durum semolina was sourced from a pasta manufacturing facility (Selva A.Ş.). Antioxidant sources were obtained from a local market and they were ground (<500 µm) in a grinder (Sinbo, SCM2934) before pasta production. Dietary fibers were supplied by Shaanxi Ciyuan Biotech Co.

(Shaanxi, China).

Production of samples

The samples were generated using the methodology outlined by Brennan and Tudorica (2008). To shape them, a low-capacity pasta machine (Dolly, La Monferrina, Moncalieri, Italy) and a penne die were used. The pasta machine and the die used are shown in Picture 1 and Picture 2. Antioxidant (5%) and dietary fiber (15%) rich ingredients were combined in a 20% ratio to make prepare fresh pasta samples (FSOF: 5% flaxseed + 15% oat fiber, FSBF: 5% flaxseed + 15% barley fiber, PSOF: 5% pomegranate seed + 15% oat fiber). The way of selecting the antioxidant and dietary fiber sources and their properties was broadly explained in a previous study (Madenci et al. 2018). Heat treatment was carried out via injecting steam by a pilot type of pasta pasteurization machine (PS150, Pama Macchine, Italy). Three different times (60, 120 and 180 seconds at 90°C) were applied for heat treatment. Heat-treated and non-treated samples were packaged both in ambient air and in a protective atmosphere by a modified atmosphere packaging machine (MAP 25 Apack, Turkey). Pasta pasteurization and modified atmosphere packaging machines are shown in the Picture 3 and Picture 4. A special plastic container (210 x 315 mm, PP/EVOH/PP) and high barrier plastic film (OPA15-LLDPE70 peel) were used for MAP (Pictures 5 and 6). A combination of 50/50 of N_2/CO_2 was used a gas mixture in the packaging as stated in the research of Sanguinetti et al. (2011).

Picture 2
Pasta die

Packaged samples were maintained at 4°C and some properties of the samples were followed at weekly intervals. In the first week of storage, packaged samples both in air and modified atmosphere packaging conditions were investigated. Samples packaged in air condition were affected by microorganisms after the first week of storage, so analyses were continued after first week with samples in modified atmosphere packaging condition. After 21 days of storage, some samples exceeded the maximum microbiological acceptability limits. Heat treatment and packaging conditions used for production of samples stored during the first week and 21 days were summarized in Table 1.

Picture 3

Pasteurization machine

Picture 4

MAP machine

Picture 5

Packaging of samples with plastic container

Picture 6

Packaging of samples with high barrier plastic film

Table 1

*Process conditions for samples**

<table>
<tr><th colspan="3">First week of storage under air and MAP condition</th><th colspan="3">21 days of storage under MAP condition</th></tr>
<tr><th></th><th>Heat treatment time (second)</th><th>Storage (day)</th><th></th><th>Heat treatment time (second)</th><th>Storage (day)</th></tr>
<tr><td rowspan="4">Samples (Control, FSOF, FSBF, PSOF)</td><td>NT</td><td>0
7AP
7MAP</td><td rowspan="4">Samples (Control, FSOF, FSBF, PSOF)</td><td>NT</td><td>0
7
14
21</td></tr>
<tr><td>60</td><td>0
7AP
7MAP</td><td>60</td><td>0
7
14
21</td></tr>
<tr><td>120</td><td>0
7AP
7MAP</td><td>120</td><td>0
7
14
21</td></tr>
<tr><td>180</td><td>0
7AP
7MAP</td><td>180</td><td>0
7
14
21</td></tr>
</table>

*FSOF: %5 flaxseed + %15 oat fiber, FSBF: %5 flaxseed + %15 barley fiber, PSOF: %5 pomegranate seed + %15 oat fiber, NT: Non-treated, AP: Air Packaging, MAP: Modified Atmosphere Packaging.

Physical analyses

The Minolta CR-400 (Minolta Camera) was employed to evaluate the color attributes of samples. The outcomes were reported using Hunter L*, a*, and b* values during the measuring phase. For the purpose of calculating the SI and Hue values of the samples, a* and b* values were used (Francis, 1998). Through the use of a TAXT Plus Texture Analyzer that was fitted with an A/LKB-F blade probe, the values of firmness were acquired (Yeyinli, 2006).

Cooking properties

The study of weight increase, volume increase, and cooking loss value was conducted in accordance with the methodology proposed by Özkaya and Kahveci (1990). Cooking a sample of 25 grams of pasta in 250 milliliters of distilled water allowed for the determination of the weight discrepancies between the uncooked and cooked pasta samples. Samples of both uncooked and cooked pasta were placed in a measuring cylinder along with distilled water, and the volume index was determined. For the purpose of determining the values of cooking loss, the water used to cook fresh pasta samples was evaporated in an oven set at 135 ºC.

Some nutritional analysis

Analyses of antioxidant activity, total phenolic content, and phytic acid concentration were performed on fresh pasta samples that were extracted from both raw and cooked forms. Determining the antioxidant activity of fresh pasta samples, the DPPH (2-2-Diphenyl-2-picrylhydrazyl) technique was used (Beta et al., 2005). Slinkard and Singleton (1977) determined the total phenolic content of fresh pasta samples utilizing a spectrophotometer (Hitachi-U1800, Japan) following the Folin-Ciocalteu method. Analyses were conducted following this manner, and the differences were expressed as milligrams of gallic acid equivalent. The analysis of phytic acid was conducted using a spectrophotometer, following the approach established by Haugh and Lantzsch (1983). Following the extraction of phytic acid from the sample using 0.2 N hydrochloric acid, the sample was precipitated using a solution of Fe (III) (ammonium iron (III) sulfate. 12 H_2O), and lastly, the quantity of iron that was still present in the serum fraction was investigated.

Statistics analysis

The JMP 10 software (SAS Institute Inc., Cary, North Carolina, USA) was utilized to perform statistical analyses. The 0.05 threshold of statistical significance was used to determine whether or not there were differences between the samples.

RESULTS AND DISCUSSION

Physical properties of samples

Table 2 presents the colour values and cooking parameters of fresh pasta samples stored for the initial seven-day period. Table 3 shows the results of fresh pasta samples packed in a modified environment during the 21-day storage period. The addition of a variety of antioxidant and dietary fiber sources led to a noteworthy alteration in the color values of fresh pasta, with a statistically important change ($p<0.05$) as seen in Tables 2 and 3.

Table 2

*Color and cooking properties of samples during the first week of storage under air and MAP conditions **

	n	*L**	*a**	*b**	SI	Hue	Weight increase (%)	Volume increase (%)	Cooking loss (%)	Firmness (g)
Additive										
Control	24	64.51^a	-2.73^d	34.76^a	34.87^a	94.59^a	100.50^a	145.91^a	3.13^c	71.50^c
FSOF	24	48.88^b	7.97^c	22.58^c	23.95^c	70.51^b	94.32^b	131.11^c	4.80^a	81.41^b
FSBF	24	47.77^c	8.54^b	23.18^b	24.71^b	69.72^c	93.58^b	134.25^b	4.79^a	83.92^a
PSOF	24	45.58^d	8.88^a	17.32^d	19.49^d	62.48^d	93.29^b	129.18^d	4.56^b	84.18^a
Heat treatment time (second)										
NT	24	52.75^a	5.63^a	24.49^a	25.76^a	74.45^a	95.67^a	134.55^a	4.42^a	80.26^a
60	24	52.11^b	5.65^a	24.46^a	25.76^a	74.27^b	95.85^a	136.01^a	4.31^b	80.43^a
120	24	51.37^c	5.68^a	24.45^a	25.74^a	74.32^b	95.17^a	135.21^a	4.29^b	79.97^a
180	24	50.52^d	5.69^a	24.40^a	25.75^a	74.28^b	95.00^a	134.69^a	4.25^b	80.34^a
Storage (day)										
0	32	53.13^a	5.89^a	27.25^a	28.46^a	75.55^a	95.65^a	134.84^a	4.29^a	81.04^a
7-AP	32	49.69^c	5.23^b	21.20^c	22.49^c	73.65^c	94.85^a	134.97^a	4.34^a	79.99^a
7-MAP	32	52.24^b	5.88^a	24.93^b	26.30^b	73.78^b	95.75^a	135.54^a	4.30^a	79.73^a

* There is no significant difference between means with the same letter within the column ($p<0.05$), FSOF: %5 flaxseed + %15 oat fiber, FSBF: %5 flaxseed + %15 barley fiber, PSOF: %5 pomegranate seed + %15 oat fiber, NT: Non-treated, AP: Air Packaging, MAP: Modified Atmosphere Packaging.

Table 3

*Color and cooking properties of fresh pasta samples during the 21 days of storage under MAP conditions**

	n	*L**	*a**	*b**	SI	Hue	Weight increase (%)	Volume increase (%)	Cooking loss (%)	Firmness (g)
Additive										
Control	32	65.09^{a}	-2.62^{d}	35.76^{a}	35.85^{a}	94.20^{a}	101.95^{a}	146.27^{a}	3.14^{c}	70.83^{c}
FSOF	32	49.13^{b}	8.17^{c}	22.38^{c}	23.83^{c}	69.88^{b}	94.36^{b}	131.36^{c}	4.78^{a}	80.98^{b}
FSBF	32	47.90^{c}	8.80^{b}	22.85^{b}	24.49^{b}	68.85^{c}	94.07^{bc}	134.25^{b}	4.83^{a}	83.24^{a}
PSOF	32	45.21^{d}	9.12^{a}	16.45^{d}	18.86^{d}	60.46^{d}	93.37^{c}	129.32^{d}	4.59^{b}	83.25^{a}
Heat treatment time (second)										
NT	32	52.82^{a}	5.88^{a}	24.36^{a}	25.78^{a}	73.13^{c}	95.97^{a}	135.22^{a}	4.40^{a}	79.55^{a}
60	32	52.33^{b}	5.86^{a}	24.34^{a}	25.75^{a}	73.28^{b}	96.13^{a}	135.65^{a}	4.33^{b}	79.84^{a}
120	32	51.54^{c}	5.87^{a}	24.38^{a}	25.76^{a}	73.47^{a}	95.86^{a}	135.11^{a}	4.32^{b}	79.63^{a}
180	32	50.63^{d}	5.86^{a}	24.35^{a}	25.74^{a}	73.49^{a}	95.78^{a}	135.22^{a}	4.29^{b}	79.29^{a}
Storage (day)										
0	32	53.13^{a}	5.89^{a}	27.25^{a}	28.47^{a}	75.55^{a}	95.65^{a}	134.84^{a}	4.30^{b}	81.04^{a}
7	32	52.24^{b}	5.88^{a}	24.93^{b}	26.30^{b}	73.78^{b}	95.75^{a}	135.54^{a}	4.30^{b}	79.99^{ab}
14	32	51.33^{c}	5.85^{a}	23.12^{c}	24.58^{c}	72.60^{c}	96.13^{a}	135.19^{a}	4.36^{a}	78.98^{bc}
21	32	50.63^{d}	5.85^{a}	22.13^{d}	23.69^{d}	71.45^{d}	96.21^{a}	135.64^{a}	4.37^{a}	78.29^{c}

*There is no significant difference between means with the same letter within the column (p<0.05), FSOF: %5 flaxseed + %15 oat fiber, FSBF: %5 flaxseed + %15 barley fiber, PSOF: %5 pomegranate seed + %15 oat fiber, NT: Non-treated.

While the lowest L*, b*, SI and Hue values were determined in PSOF, the same sample revealed the highest a* value. Usage of pomegranate seed in the formulation of PSOF caused a substantial increase in the a* value due to the fact that pomegranate seed presented a more reddish color compared to the other raw materials (data not shown). Increasing heat treatment time resulted in a decrement in the L* value of samples compared to the control (p<0.05) (Tables 2 and 3). Similarly, Sanguinetti et al. (2015) found a reduction in the L* value of fresh pasta. a*, b* and SI values did not show any significant differences with increasing heat treatment time. Important effects of packaging techniques and storage time were found on the color parameters of fresh pasta samples (p<0.05) (Tables 2 and 3). The darkness of samples packaged both in air and MAP conditions increased during the first week of storage; in addition to this, more increments was determined in air packaging (Table 2). Similar results were reported by De Camargo Andrade-Molina et al. (2013) and Khouryieh et al. (2006). It was thought that change in the L* value can be related to the retrogradation of starch. Majzoobi et al. (2011) investigated the shelf life of flatbread and concluded that the reduction in L* value during storage appears to be associated with the retrogradation of starch on the sample's surface. No difference was seen in the a* value of samples packaged in MAP conditions during the first week of storage, but packaging in air caused an important decrement (Tables 2 and 3). A significant decline in b* values of the samples packaged both air and MAP conditions was determined during the storage. Similarly, Khouryieh et al. (2006) found a reduction in b* value with storage. Packaging under the MAP condition resulted in a higher b* value compared to packaging in air (Table 2). It was thought that a great decrease in the yellowness of samples packaged in air condition during storage may cause lipoxygenase activity that could remain after the heat treatment. During 21 days of storage L*, b*, SI and Hue values of samples packaged with MAP conditions decreased. Khouryieh et al. (2006) examined the impact of storage on the characteristics of undried noodle samples, revealing a reduction in L* and b* values throughout a 30-day storage period.

Cooking properties and firmness values of fresh pasta samples showed significant changes as a function of additive factor ($p<0.05$) (Tables 2 and 3). Functionally enriched fresh pasta samples revealed lower weight increase and volume increase values than the control sample, however, an increment was determined in the cooking loss values of the samples with the use of various antioxidant and dietary fiber sources. The use of various components in pasta formulation can result in different effects on weight increase values. Aydın and Göçmen (2011) determined an increment in weight increase values of pasta samples with the addition of barley flour, conversely, Bagdi et al. (2014) showed that increasing levels of aleuron-rich flours in formulations reduced the weight increase values of pasta samples. In the literature, it has been stated that cooking loss values of pasta formulations were higher than control pasta samples as a result of the use of various dietary fiber-rich sources (Foschia et al., 2015; Aydın and Göçmen 2011). Similarly to cooking loss, the firmness values of functionally enriched fresh pasta samples were higher than the control (Tables 2 and 3). It was thought that an increase in the fresh pasta firmness related to the enrichment with dietary fiber sources at 15%. Dietary fibers can reveal different effects on the pasta structure. Foschia et al. (2015) reported that using oat bran in pasta production reasoned an increment in the firmness value, conversely addition of inulin showed a significant reduction in pasta firmness. Also, significant variation in firmness values of pasta samples fortified with different dietary fiber sources has been reported by Rakhesh et al. (2015). Except for cooking loss, other cooking properties were not affected by increasing heat treatment times. However, no statistical difference was observed in the firmness values of the samples. (Tables 2 and 3). It was observed that cooking loss values declined only after 60 seconds of treatment, no further decrease occurred with increasing heat treatment time (Tables 2 and 3). Previous studies indicated that increasing severity of heat treatment caused changes in cooking properties and firmness values of fresh pasta, but effects of single heat treatment were limited (Alamprese et al. 2005; 2008). Cooking properties and firmness values of fresh pasta samples packaged both in air and MAP conditions did not change during the first week of storage (Table 2). Cooking loss values of samples packaged under MAP conditions were raised beginning from 14 days of storage period (Table 3). Our results are in consistent with Manthey et al. (2008). They stated that enzymes such as amylase and endoxylanase may be responsible for the increment in cooking loss during storage. In the current study, it was determined that firmness values declined in the same storage days. Similarly, Khouryieh et al. (2006) found a reduction in the firmness values of pasta stored during the 15 days compared to the beginning of storage.

Some nutritional contents of samples

Table 4 displays the findings of an analysis regarding the antioxidant activity, total phenolic content, and phytic acid concentration of samples that were either raw or cooked and stored for one week. The results of the antioxidant activity, total phenolic content, and phytic acid concentration of raw and cooked samples are summarized in Table 5. These results were determined after the samples were stored for 21 days under MAP conditions.

Table 4

*Some nutritional contents of raw and cooked samples during the first week of storage under air and MAP conditions **

	n	Raw samples			Cooked samples		
		Antioxidant activity (%)	Total phenolic content (mgGAE/g)	Phytic acid (mg/100g)	Antioxidant activity (%)	Total phenolic content (mgGAE/g)	Phytic acid (mg/100g)
Additive							
Control	24	13.39[d]	0.43[d]	199.59[d]	12.37[d]	0.41[d]	194.25[d]
FSOF	24	44.93[b]	0.71[b]	783.78[a]	36.32[b]	0.60[b]	753.28[a]
FSBF	24	42.10[c]	0.65[c]	735.27[b]	35.09[c]	0.55[c]	706.94[b]
PSOF	24	46.58[a]	0.77[a]	720.10[c]	37.83[a]	0.67[a]	690.99[c]
Heat treatment time (second)							
NT	24	36.89[a]	0.65[a]	620.53[a]	30.48[a]	0.56[a]	597.19[a]
60	24	36.69[a]	0.64[a]	615.38[a]	30.19[a]	0.56[a]	590.48[b]
120	24	36.54[a]	0.64[a]	607.54[b]	30.56[a]	0.56[a]	583.27[c]
180	24	36.90[a]	0.64[a]	595.28[c]	30.37[a]	0.56[a]	574.52[d]
Storage (day)							
0	32	39.91[a]	0.70[a]	610.86[a]	33.44[a]	0.61[a]	587.18[a]
7-AP	32	32.84[c]	0.59[c]	609.68[a]	28.12[c]	0.51[c]	586.01[a]
7-MAP	32	37.51[b]	0.64[b]	608.50[a]	29.64[b]	0.56[b]	585.91[a]

* There is no significant difference between means with the same letter within the column ($p<0.05$), FSOF: %5 flaxseed + %15 oat fiber, FSBF: %5 flaxseed + %15 barley fiber, PSOF: %5 pomegranate seed + %15 oat fiber, NT: Non-treated, AP: Air Packaging, MAP: Modified Atmosphere Packaging.

Table 5

*Some nutritional content of raw and cooked samples during the 21 days of storage under MAP condition **

	n	Raw samples			Cooked samples		
		Antioxidant activity (%)	Total phenolic content (mgGAE/g)	Phytic acid (mg/100g)	Antioxidant activity (%)	Total phenolic content (mgGAE/g)	Phytic acid (mg/100g)
Additive							
Control	32	13.77[d]	0.43[d]	197.80[d]	12.59[d]	0.42[d]	193.08[d]
FSOF	32	46.82[b]	0.72[b]	782.21[a]	36.21[b]	0.62[b]	752.15[a]
FSBF	32	43.02[c]	0.65[c]	734.26[b]	34.78[c]	0.56[c]	705.85[b]
PSOF	32	47.99[a]	0.78[a]	719.09[c]	37.57[a]	0.67[a]	689.70[c]
Heat treatment time (second)							
NT	32	37.89[a]	0.65[a]	619.52[a]	30.44[a]	0.57[a]	596.27[a]
60	32	38.00[a]	0.64[a]	613.83[b]	30.07[a]	0.57[a]	588.71[b]
120	32	37.69[a]	0.64[a]	606.38[c]	30.38[a]	0.56[a]	582.52[c]
180	32	38.02[a]	0.65[a]	593.64[d]	30.26[a]	0.57[a]	573.27[d]
Storage (day)							
0	32	39.91[a]	0.70[a]	610.86[a]	33.44[a]	0.61[a]	587.18[a]
7	32	37.51[b]	0.64[b]	608.50[a]	29.64[b]	0.56[b]	585.91[a]
14	32	37.40[b]	0.63[b]	607.37[a]	29.23[bc]	0.55[b]	584.45[a]
21	32	36.78[c]	0.62[b]	606.63[a]	28.84[c]	0.54[b]	583.24[a]

* There is no significant difference between means with the same letter within the column ($p<0.05$), FSOF: %5 flaxseed + %15 oat fiber, FSBF: %5 flaxseed + %15 barley fiber, PSOF: %5 pomegranate seed + %15 oat fiber, NT: Non-treated.

In both raw and cooked pasta formulations, PSOF exhibited the highest levels of antioxidant activity and total phenolic contents because of the pomegranate seed (Tables 4 and 5). Pomegranate seed was found to be the richest component in antioxidant activity and total phenolic content. Oat fiber presented the highest antioxidant activity after pomegranate seed (data not shown). The amount of phytic acid in samples was raised by enriching it with various types of dietary fiber and antioxidants. (Tables 4 and 5). The formulation of FSOF revealed the highest phytic acid contents and it has 3.92- and 3.87-fold as much phytic acid in the raw and cooked form as compared to raw and cooked control samples, respectively. The cooking process caused a decrease in the antioxidant activity, total phenolic and phytic acid contents. Non-significant effects of heat treatment time were found on the antioxidant activity and total phenolic contents of both raw and cooked samples (Tables 4 and 5). Marinelli et al. (2015) reported similar findings. Heat treatment was found to be a successful method for lowering the amount of phytic acid. In the current study, in the first week of storage, while the phytic acid contents of raw samples were significantly declined after 120 seconds of treatment, in the cooked fresh pasta samples significant decrement started at 60 seconds (Table 4). While the phytic acid level of both samples packaged in air and MAP conditions did not significantly alter over the first week of storage, packaging conditions had a substantial impact on the antioxidant activity and total phenolic contents. The MAP condition presented less loss in the antioxidant activity and total phenolic contents of samples compared to air packaging conditions. Total phenolic contents of raw fresh pasta samples showed a decrease of about 18% for air and 6% for modified atmosphere compared to the beginning of storage, respectively. The antioxidant activity of samples was shown to have significantly decreased over the course of the 21-day storage period. Changes in the total phenolic contents were not important after 7 days of storage. The amounts of phytic acid in samples that were kept for 21 days did not differ significantly. (Table 5). It was thought that there were no noticeable changes in the phytic acid level because the storage process was carried out in a refrigerator and the conditions stayed the same throughout the storage time. Moscoso et al. (1984) stored the kidney beans at different temperatures for 9 months, and they did not determine important changes in the phytic acid content at 2 °C.

CONCLUSION

The quality traits of fresh pasta were evaluated for potential improvements in shelf life and nutritional value, particularly when subjected to heat treatment and packaging techniques. Since fresh pasta is an extremely perishable product with moisture content above 24%, it is well suited for effective preservation beyond the normal five-day shelf life. Thermal treatment and modified atmosphere packaging have shown antimicrobial activity for extended shelf life in quality and safety maintenance. In this research samples enclosed in a modified atmosphere exhibited prolonged shelf life without degradation compared to those packaged under standard environmental conditions, with monitoring conducted over a 21-day period.

Research has demonstrated that packaging is a vital factor in the preservation of fresh pasta, revealing that samples packaged in air experienced significant quality deterioration, particularly in color and texture, after one week of storage, whereas those in modified atmosphere packaging maintained acceptable quality levels. This resulted from reduced oxygen levels in modified atmosphere packaging, which allowed oxidation processes to decelerate spoiling. Once more, a variety of useful components, including antioxidants and dietary fibers, enhanced the nutritional content of fresh pasta while also altering its overall quality and cooking properties.

The pasta formulation with the highest phenolic content and antioxidant activity was prepared using pomegranate seeds. Findings indicate that heat treatment did not result in significant alterations in antioxidant activity and total phenolic content of fresh pasta samples. Irrespective of the cooking technique, it was demonstrated that heat treatment substantially reduced the levels of phytic acid. Additionally, it has been determined that the MAP state is a beneficial packaging method for preserving the chemical and physical characteristics of fresh pasta. The results showed that heat treatment, MAP conditions, and the addition of antioxidant and dietary fiber sources can work in concert to increase the shelf life.

This clearly indicates that time and temperature are important for heat treatment since both affect cooking loss and pasta firmness greatly. It was observed that with a single heat treatment, certain quality attributes could be improved, but in order to obtain the best shelf life, a second treatment would be required. Such complexity is seen with the interaction taking place due to the specific formulation of the pasta concerning the type of flour used and the processing condition against the final product.

As a whole, the advancement of novel packaging technology combined with tailored heat treatment protocols is a phenomenon that holds much potential in developing fresh pasta products safe to eat while possessing good sensory and nutritional qualities. In order to satisfy the growing consumer demand for fresh and superior pasta products, future research should keep focusing on improving these procedures.

Ethical Statement

The research was carried out with financial support from the TÜBİTAK (Project No: 114O383).

Ethics Committee Approval

Ethics committee permission is not required for the research.

Author Contributions

Research Design (CRediT 1) Yazar 1 (%50) – Yazar 2 (%25) – Yazar 3 (%25)

Data Collection (CRediT 2) Yazar 1 (%50) – Yazar 2 (%25) – Yazar 3 (%25)

Research - Data Analysis - Validation (CRediT 3-4-6-11) Yazar 1 (%50) – Yazar 2 (%25) – Yazar 3 (%25)

Writing the Article (CRediT 12-13) Yazar 1 (%50) – Yazar 2 (%25) – Yazar 3 (%25)

Revision and Improvement of the Text (CRediT 14) Yazar 1 (%50) – Yazar 2 (%25) – Yazar 3 (%25)

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Conflict of Interest

There is no conflict of interest for the authors or third parties arising from the study.

Sustainable Development Goals (SDG)

Sustainable Development Goals: 3. Health and Quality of Life

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