



**T.C.
İSTANBUL UNIVERSITY
INSTITUTE OF GRADUATE STUDIES IN
SCIENCE AND ENGINEERING**



Ph.D. THESIS

**EVALUATING THE TECHNICAL AND SENSORY PROPERTIES,
ANTIOXIDANT ACTIVITY AND BIOACCESSIBILITY OF
PHENOLICS IN FIG, APRICOT AND QUINCE POWDERS**

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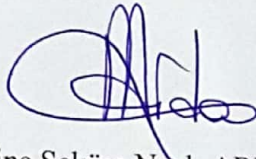
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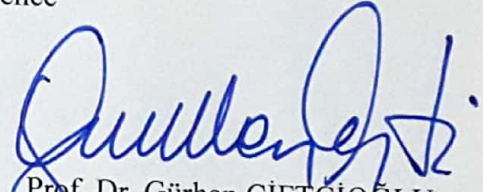
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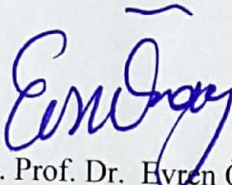
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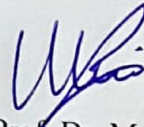
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To my family and to all science buffs,

FOREWORD

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol	Explanation
L*	: Lightness/darkness (color parameter)
C	: Chroma
a*	: Red/green (color parameter)
b*	: Blue/yellow (color parameter)
ϵ	: Molar extinction coefficient
°C	: Degrees centigrade
CI	: Carr Index
H°	: Hue angle
g	: Gram
kg	: Kilogram
mL	: Milliliter
mm	: Millimeter
R²	: Correlation coefficient (statistical analysis)

Abbreviation	Explanation
F	: Fig
A	: Apricot
Q	: Quince
FA	: Fig and Apricot mixture
FQ	: Fig and Quince mixture
AQ	: Apricot and Quince mixture
FAQ	: Fig, Apricot and Quince mixture
TEAC	: Trolox equivalent antioxidant capacity
ABTS	: 2,2-Azino-bis(3-ethylbenzothiazolin-6-sulfonik asit)
CUPRAC	: Cupric Reducing Antioxidant Capacity
FRAP	: Ferric reducing antioxidant power
DPPH	: 1,1-diphenyl-2-picrylhydrazyl
dw	: Dry weight
SSF	: Initially Simulated Salivary Fluid
SGF	: Simulated Gastric Fluid

SIF : Simulated Intestinal Fluid
IN : Symbolizing the matter which entered into the blood system.
OUT : Symbolizing the matter which stayed in the gastrointestinal system



ÖZET

DOKTORA TEZİ

İNCİR, AYVA VE KAYISI TOZLARINDA TEKNİK VE DUYUSAL ÖZELLİKLER, ANTİOKSİDAN AKTİVİTE VE FENOLİKLERİN BİYOERİŞİLEBİLİRLİĞİNİN DEĞERLENDİRİLMESİ

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Günümüzde sağlık üzerine olumlu etkileri, özellikle de zengin polifenol içerikleri ve antioksidan aktiviteleri nedeniyle meyve tüketimi büyük ilgi görmektedir. İncir, ayva ve kayısı zengin mineral, vitamin ve lif içeriği ile Dünya çapında bilinen, ticari değere sahip önemli Akdeniz meyveleridir. Ülkemiz bu üç meyvenin üretiminde dünyada ilk sıralarda yer almaktadır. Taze veya kurutulmuş olarak tüketilen bu meyvelerden reçel, marmelat, pestil gibi işlenmiş ürünler de üretilmektedir. Ayrıca gıda, kozmetik ve farmasötik endüstrisinde meyve tozu ve meyve tableti şeklinde kullanılma potansiyelleri vardır. Meyve tozları ve meyve tabletleri düşük nem içerikleri nedeniyle mikrobiyolojik bozulmaya karşı dayanıklı olmalarının yanı sıra tüketim, taşıma/depolama kolaylığı ve ürün dozunu standardize etme imkânı sağlamaktadır.

Bu doktora tezinin amacı incir, ayva ve kayısı meyvelerinden katma değeri artırılmış, toz ve tablet şeklinde ürünler geliştirerek, bunların (I) gıda sektörü açısından önemli olan fiziko-kimyasal, tekno-fonksiyonel ve duysal özelliklerini belirlemek, (II) tek tek veya kombinasyon halinde hazırlanan taze, kurutulmuş ve toz haline getirilmiş örneklerin toplam fenolik ve toplam flavonoid madde içerikleri ile antioksidan aktivitelerini karşılaştırmak, (III) *in vitro* mide ve bağırsak sindirim ve emilim simülasyonu kullanarak biyoerişilebilirliklerini değerlendirmektir.

Bu hedeflere ulaşmak için deneyler 4 aşamada gerçekleştirildi. İlk olarak meyveler kurutuldu ve öğütülerek toz haline getirildi; meyve tozlarından da meyve tabletleri üretildi. Sonrasında fiziko-kimyasal özellikleri, tekno-fonksiyonel özellikleri temel kimyasal yöntemlerle ölçüldü.

Duyusal analizlerde panelistlerden ürünlerin görünüm, lezzet ve genel kabul edilebilirlik görüşleri istendi. Daha sonra tek tek veya kombinasyon halinde hazırlanan taze, kurutulmuş ve toz haline getirilmiş örneklerin toplam fenolik ve toplam flavonoid madde içeriği ile antioksidan aktiviteleri spektrofotometrik yöntemlerle belirlendi. Son olarak tüm örneklerle diyaliz membran prosedürü kullanılarak *in vitro* mide ve bağırsak sindirim ve emilim simülasyonu uygulandıktan sonra toplam fenolik ve toplam flavonoid madde içerikleri ile antioksidan aktiviteleri belirlenerek sonuçlar değerlendirildi.

Ürünlerin fiziko-kimyasal özelliklerine bağlı olarak kazandığı en dikkat çeken teknolojik özelliklerden, en yüksek poroziteye incir tozunun, en yüksek su tutma kapasitesine ayva tozunun ve en yüksek yağ tutma kapasitesine kayısı tozunun sahip olduğu belirlendi. Kayısı ve incir tozlarının akışkanlık özelliklerinin birbirine yakın olduğu ve ayva tozuna göre daha iyi olduğu gözlemlendi. Yoğunluk bakımından ayva meyvesinin toz formda kullanım için diğer iki meyveden daha uygun olduğu görüldü.

Baldaki görünüm hariç tüm duysal özellikler bakımından ayva tozu diğer meyve tozlarına göre en yüksek puanları aldı. Ek olarak, meyve tabletlerine duysal analiz uygulandı ve sonuçlar, tabletleme işlemi için bu üç meyve grubunda en uygun meyvenin, en yüksek lezzet ve en yüksek tat yoğunluklarına ve uygun doku profiline sahip kayısı tableti olduğu görüldü.

Taze meyve formunda diğer iki forma, yani meyve kurusu ve meyve tozuna göre daha yüksek oranda toplam fenolik bileşik bulunduğu belirlendi. Benzer şekilde toplam antioksidan aktivite değerleri en yüksek meyve formunda elde edilirken en yüksek toplam flavonoid değeri meyve kurusunda gözlemlendi. Örneklerin orijinal içeriğinden farklı olarak barsaktan emilime uğrayarak kana geçen içeriğini değerlendirebilmek için uygulamış olduğumuz *in vitro* sindirim simülasyonuna göre taze meyvelerde biyoerişilebilirlik değerlerinin meyve kurularına ve meyve tozlarına göre daha yüksek olduğu, meyve tozu ve meyve kurularında biyoerişilebilirlik değerlerinin birbirine yakın değerlere sahip olduğu gözlemlendi.

Bu çalışmada, örneklerin birlikte tüketilmeleri durumunda içerdikleri fenolik bileşiklerin barsaktan emilimi gerçekleşirken oluşabilecek sinerjistik etki de araştırılmış olup geri kazanım oranları hesaplanmıştır. Tüm karışımların toplam fenolik bileşik geri kazanım değerlerinin [kayısı kurusu+ayva kurusu (%94), incir tozu+kayısı tozu+ayva tozu (%95)] hariç yüksek olduğu yani birlikte tüketimin sinerjistik etkiye sahip olduğu gözlenmiştir. Benzer şekilde karışımların antioksidan aktivite geri kazanım değerleri incelendiğinde, tüm meyve örneklerinde önemli miktarlarda düşüş gözlenmiş olsa da meyve tozu ve meyve kurusu karışım örneklerinin [incir kurusu+kayısı kurusu hariç (%61)] tek başına meyvelere göre daha yüksek antioksidan aktiviteye sahip olduğu gözlenmiştir.

Bu tez çalışmasının sonucunda ayva meyvesinin toz formda, kayısı meyvesinin tablet formda kullanım için daha uygun olduğu görülmüştür. Ayrıca meyve tozu üretim aşamaları, taze meyvelerin toplam fenolik ve toplam flavonoid biyoerişilebilirlik değerleri ile toplam antioksidan aktivite değerlerinde kayıba yol açtığı, ancak meyve tozlarının çoğunlukla meyve kurularına yakın biyoerişilebilirlik değerlerine sahip olduğu görülmüştür. Ek olarak, meyve kuruları ve meyve tozlarının karışım halindeyken toplam antioksidan aktivite ve fenoliklerin biyoerişilebilirliği bakımından sinerjistik etki gösterdiği gözlenmiştir.

Ağustos 2019, 96 sayfa.

Anahtar kelimeler: İncir, ayva, kayısı, meyve tozu, sindirim simülasyonu, antioksidan aktivite

SUMMARY

Ph.D. THESIS

EVALUATING THE TECHNICAL AND SENSORY PROPERTIES, ANTIOXIDANT ACTIVITY AND BIOACCESSIBILITY OF PHENOLICS IN FIG, APRICOT AND QUINCE POWDERS

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Today, fruit consumption has received great attention due to its positive effects on health, especially its rich polyphenol content and antioxidant activities. Fig, quince and apricot important crops worldwide are rich in minerals, vitamins and fiber content. Our country is first in the production of these three fruits. Processed products such as jam, marmalade and fruit leather are also produced from these fruits which are consumed fresh or dried. They also have the potential to be used as an additives in the form of fruit powder and fruit tablets in the food, cosmetic and pharmaceutical industries. Fruit powders and fruit tablets are resistant to microbiological deterioration due to their low moisture content, as well as the consumption, handling / storage and easiness of standardizing product dosage.

The aim of this doctoral thesis is (I) to determine the physico-chemical, techno-functional and sensory properties of figs, quince and apricot powders or tablets which are developed as value added product, (II) to compare the total phenolics, total flavonoids and antioxidant activities of fresh, dried and powdered samples prepared individually or in combination, (III) to assess their bioaccessibility by using *in vitro* gastric and small intestinal digestion simulation.

Experiments were carried out in 4 stages to achieve these goals. First, the fruits were dried and grinded to powder; fruit tablets were also produced from fruit powders. Then, physico-chemical properties (moisture content, ash content, color properties, water activity), techno-functional properties (oil holding capacity, water holding capacity, wettability, solubility, density and

flowability) were measured by basic chemical methods. In sensory analyzes, the panelists were asked their opinions about appearance, flavor and general acceptability of fruit powders mixed with yogurt, honey or milk. Then, total phenolics, total flavonoids and antioxidant activities of fresh, dried and powdered samples prepared individually or in combination were determined by spectrophotometric methods. Finally, antioxidant activity and the bioaccessibility of phenolic compounds and flavonoid compounds after *in vitro* digestion simulation were analyzed using the procedures gastrointestinal dialysis membrane.

The most remarkable techno-functional properties obtained due to the physico-chemical properties of the products were determined that fig powder had the highest porosity, quince powder had the highest water holding capacity and apricot powder had the highest oil holding capacity. It was observed that the flow properties of apricot and fig powders were close to each other and were better than quince powder. In terms of density, quince fruit was found to be more suitable for use in powder form than the other two fruits.

In terms of all sensory properties except the appearance of honey, quince powder had the highest scores compared to other fruit powders. Quince powder appearance in yogurt, taste feature in honey, general acceptability feature yoghurt was the highest output. In addition, sensory analysis was performed on the fruit tablets, and the results showed that the most suitable fruit for the tableting process was the apricot tablet with the highest flavor and highest flavor densities and the appropriate tissue profile.

In the fresh fruit form, total phenolic compounds were found to be higher than the other two forms, ie dried fruit and fruit powder. Similarly, total antioxidant activity values were highest in fruit form and total flavonoid values were highest in dried form. In this study, if the samples were consumed together, the synergistic effect that may occur during the absorption of phenolic compounds from the intestine was investigated and the recovery rates were calculated.

It was observed that the total phenolic compound recovery values of all mixtures (apricot dry + quince dry (94%), fig powder + apricot powder + quince powder (95%) except) were high, ie the combined consumption had a synergistic effect. Similarly, when the antioxidant activity recovery values of the mixtures were examined, a significant decrease was observed in all fruit samples, but it was observed that fruit powder and dried fruit mixture samples (except fig dried + apricot dried (61%)) had higher antioxidant activity than the fruits alone.

As a result of this thesis, techno-functional and sensory analysis showed that quince fruit is more suitable for use in powder form and apricot fruit is more suitable for use in tablet form. In addition, fruit powder production process caused loss of total phenolics and total flavonoids bioaccessibility and total antioxidant activity values of fresh fruits, but fruit powders mostly had close bioaccessibility value with dried fruits. Additionally, it was observed that together consumption of fruits (in dried form or powdered form but not in fresh form) had a synergistic effect on bioaccessibility of phenolics and total antioxidant activity value.

-----August 2019, 96 pages.

Keywords: fig, apricot, quince, fruit powder, digestion simulation, antioxidant activity

1. INTRODUCTION

Besides the positive health effects, fruit and vegetable consumption has some protective properties against major disease such as cancer, diabetes, heart and vascular disorders. This effect is generally described by the antioxidant activity of bioactives in the fruits and vegetables. According to their chemical structure, the bioactives are divided four group such as phenolic compounds, vitamin-C, carotenoids and vitamin-E.

Weather conditions and soil structure in our country allows the cultivation of a wide variety of fruit. Especially figs, quince and apricot cultivation in our country is located in the first row. Grown fruit is consumed as dry or wet, marmalade, jam, molasses, are treated like products. In addition, studies on the fruit powder forms for industrial use were applied and good results were obtained. But knowledge about bioactive of powder forms are not present.

Fruit powders have the potential to be used as an additives in the form of fruit powder and fruit tablets in the food, cosmetic and pharmaceutical industries and as a food supplement in the diet of people who have difficulty in swallowing such as patients, children, infants. Also fruit tablets can be used as an antioxidant sources.

Aim of the thesis is “Evaluating the *in vitro* bioaccessibility of bioactives in fig (*Ficus carica*), apricot (*Prunus armeniaca*), quince (*Cydonia vulgaris*) powders and their tablets”. In this study Chemical and Techno Functional properties of samples were investigated. In addition, antioxidant activity and the *in vitro* bioaccessibility of phenolic compounds during digestion were evaluated.

Although bioactive components profile and antioxidant activity value of a fruit provide information about bioavailability, bioaccessibility (the amount to be absorbed by the body) is necessary to get information about benefits of that fruit. Therefore antioxidant activity and the *in vitro* bioaccessibility of bioactives during digestion were evaluated.

Although there are studies that evaluate the chemical and technical characteristics of the single fruit powder, there are no studies evaluating the effect of gastrointestinal digestion on the stability of the bioactives of mixed fruit powder/fruit tablets. Specificity of this thesis is

examination of the powders obtained from a mixture of fruits not only a fruit. By the way synergistic effects of fruit mixtures in Bioaccessibility features was evaluated.

In determining the physico-chemical properties of the fruit powder moisture and ash content, color attributes, water activity; the determining techno functional properties oil / water holding capacity, wettability, solubility, density and flow properties were measured. The sensory analysis were carried out by panel analysis and outcomes were obtained by the panelist evaluation.

CUPRAC method was applied in determining the total antioxidant capacity. Total phenol amount and total flavonoids were determined by spectrophotometric method using respectively, gallic acid and catechin calibration curve. CUPRAC methods was applied and trolox was used as standard in determining the total antioxidant capacity. Antioxidant activity and the *in vitro* bioaccessibility of phenolic compounds during *in vitro* digestion simulation were analyzed using the procedures gastrointestinal dialysis membrane.

1.1. FRUIT PHENOLICS AND HEALTH EFFECTS

There is growing evidence that various phenolic compounds present in the diet may reduce the risk of health disorders due to antioxidant activity. Fruits and vegetables are rich in phenolic acids such as hydroxycinnamic acid conjugates and flavonoids. Phenolics exhibiting a wide range of antioxidant activity have protective effects against cancer and cardiovascular diseases (Procházková et al., 2011). Fruits which can be consumed fresh are consumed dried form or processed in products such as marmalade and jelly. It is thought that dried fruits have high glycemic index and insulin response because they contain plenty of carbohydrates glucose and fructose. However, studies have demonstrated that dried fruits have good glycemic and insulin response comparable to those of fresh fruits due to the presence of phenolic compounds and fibers that are able to moderate the response (Chang et al., 2016)

1.1.1. Fig (*Ficus carica*)

Fig (*Ficus carica* L.), deciduous tree that is native to the eastern Mediterranean and southwest Asia, is a member of Moraceae family and one of the earliest cultivated fruit trees. The *Ficus carica* flowers are located in the fruit receptacle for this reason, fertilization takes place by the fig wasps, *Blastophaga psenes* (Çalışkan, 2012). A ripened fig fruit may have a green, brown,

or purple colour. The fruit contains a large number of whitish seeds. The size of the seeds may be small or large, the number may vary from 30 to 1600. Fruits contain seeds which have characteristic nutty taste of dried figs bound with jelly like flesh (Essids et al., 2015).

Fig's historical roots possibly southern Arabia or Turkey and Iran where the wild forms of fig trees are watched (Ikegami et al., 2008).

Ficus spp. represents an ancient source of food and health; it has importance for Jewish, Christian, and Muslim religions. Its importance for Muslim religion is having been written as a name of a surah in the Holy book Quran. Its importance for Christian religion is to be named in several chapters of Christian sacred texts the Gospels (Barolo et al., 2014). Its importance for Jewish is about a mit (Kurt, 2008). Fig is also important for Buddhist traditions. According to the belief, after the Buddha came to the world, he sat down 49 days near the fig tree, and reached to the nirvan.

In Turkey total fruit production has reached 17 million tons in recent years. According to the 2014 FAO statistics a total of 1.1 million tons of figs are produced in the world and Turkey has an important place with 0,3 millions tons. Our country is the first country in the world for both dried and table fig production and exports. In addition, fruits are processed commercial values such as jam, fruit leather, marmalade, lokum, ice cream and biscuits.

Fig fruit is a major source of anthocyanins and polyphenols. There is a correlation between skin colour and phenolic characteristic of a fig. The figs with green or yellow fruit color have less total phenolic, total anthocyanin and total antioxidant activity (Solomon et al., 2006; Caliskan et al., 2006). Several authors, reported the main anthocyanin to be cyanidin-3-rutinoside and main phenolic acid to be chlorogenic acid (Caliskan et al., 2006; Solomon et al., 2006)

The nutrient composition of dried figs have been indicated on its best nutrient score among the dried fruits, being an important source of minerals and vitamins (Barolo et al., 2014). Fig fruits can be demonstrated to a superior source of minerals such as Fe, Ca, K and vitamins such as B₁ and B₂ (Solomon et al., 2006). Figs have remarkable amount of certain minerals and vitamins and contain approximately 80% water, 1.3% protein, 14% carbohydrate, 0.34% fat, and 2.66% fiber (Based on the Turkish food composition database). (Table 1.1). Traditional name: bursa siyahı and Scientific name: *Ficus carica* L.

Table 1.1: Content of *Ficus carica* (values per 100 g edible portion).

Component	Unit	Mean
Energy	kcal	70
Energy	kJ	293
Water	g	90.88
Ash	g	0.69
Protein	g	1.33
Nitrogen	g	0.21
Fat, total	g	0.24
Carbohydrate	g	1410
Fiber, total dietary	g	2.66
Fiber, water soluble	g	0.80
Fiber, water insoluble	g	1.96
Saccharose	g	0,00
Glucose	g	5.97
Fructose	g	5.60
Lactose	g	0.00
Maltose	g	0.00
Salt	mg	10
Iron, Fe	mg	0.41
Phosphorus, P	mg	21
Calcium, Ca	mg	67
Magnesium, Mg	mg	24
Potassium, K	mg	202
Sodium, Na	mg	4
Zinc, Zn	mg	0.19
Vitamin, C	mg	2.1
Thiamin	mg	0.036
Riboflavin	mg	0.038
Niacin, preformed	mg	0.335
Vitamin B-6, total	mg	0.174
Folate, food	µg	8
Vitamin A	RE	11
Beta-carotene	µg	134
Lycopene	µg	0
Lutein	µg	84

1.1.2. Apricot (*Prunus armeniaca*)

In Turkey total fruit production has reached 17 million tons in recent years. According to the 2014 FAO statistics a total of 3.3 million tons of apricots are produced in the world and Turkey has an important place with 0.28 million tons.

Table 1.2: Content of *Prunus armeniaca* (values per 100 g edible portion).

Component	Unit	Mean
Energy	kcal	29
Energy	kJ	117
Water	g	90.90
Ash	g	1.73
Protein	g	0.27
Nitrogen	g	0.04
Fat, total	g	0.21
Carbohydrate	g	5.66
Fiber, total dietary	g	1.24
Fiber, water soluble	g	0.27
Fiber, water insoluble	g	0.96
Saccharose	g	0.70
Glucose	g	1.07
Fructose	g	0.85
Lactose	g	0
Maltose	g	0
Salt	mg	5
Iron, Fe	mg	0.91
Phosphorus, P	mg	19
Calcium, Ca	mg	16
Magnesium, Mg	mg	13
Potassium, K	mg	328
Sodium, Na	mg	2
Zinc, Zn	mg	0.21
Vitamin, C	mg	8.5
Thiamin	mg	0.026
Riboflavin	mg	0.031
Niacin, preformed	mg	0.504
Vitamin B-6, total	mg	0.063
Vitamin A	RE	67
Beta-carotene	µg	808
Lycopene	µg	0
Lutein	µg	20

Apricots fruits contain approximately 90.9% water, 0.27% protein, 5.66% carbohydrate, 0.21% fat, and 1.24% fiber (Based on the Turkish food composition database). Apricots are also remarkable sources of certain minerals and vitamins (Table 1.2). Traditional name: Tyrinthe erkenci sofralık Scientific name: *Prunus armeniaca*.

1.1.3. Quince (*Cydonia vulgaris*)

In Turkey total fruit production has reached 17 million tons in recent years. According to the 2014 FAO statistics a total of 0.65 million tons of quince are produced in the world and Turkey has an important place with 0.1 tons.

Table 1.3: Content of *Cydonie vulgaris* (values per 100 g edible portion).

Component	Unit	Mean
Energy	kcal	29
Energy	kcal	60
Energy	kJ	251
Water	g	81.91
Ash	g	0.45
Protein	g	0.35
Nitrogen	g	0.06
Fat, total	g	0.14
Carbohydrate	g	13.92
Fiber, total dietary	g	3.23
Fiber, water soluble	g	0.47
Fiber, water insoluble	g	2.76
Saccharose	g	0.14
Glucose	g	3.26
Fructose	g	4.68
Lactose	g	0
Sorbitol	g	6.04
Salt	mg	14
Iron, Fe	mg	0.29
Phosphorus, P	mg	14
Calcium, Ca	mg	11
Magnesium, Mg	mg	12
Potassium, K	mg	177
Sodium, Na	mg	6
Zinc, Zn	mg	0.08
Vitamin, C	mg	15.2
Thiamin	mg	0.014
Riboflavin	mg	0.017
Niacin, preformed	mg	0.215
Vitamin B-6, total	mg	0.049
Folate, food	µg	4
Vitamin A	RE	8
Beta-carotene	µg	91
Lutein	µg	10

Quince fruits contain approximately 81.9% water, 0.35% protein, 13.9% carbohydrate, 0.14% fat, and 3.21% fiber (Based on the Turkish food composition database). They have also remarkable amount of certain vitamins and minerals (Table 1.3). Traditional name: Eşme Scientific name: *Cydonie vulgaris P.*

1.1.4. Why this three fruits

Because Turkey ranks first in the world in terms of these fruits production (Figure 1.1). Data was given according to united state food and agriculter organization (FAO) statistics.

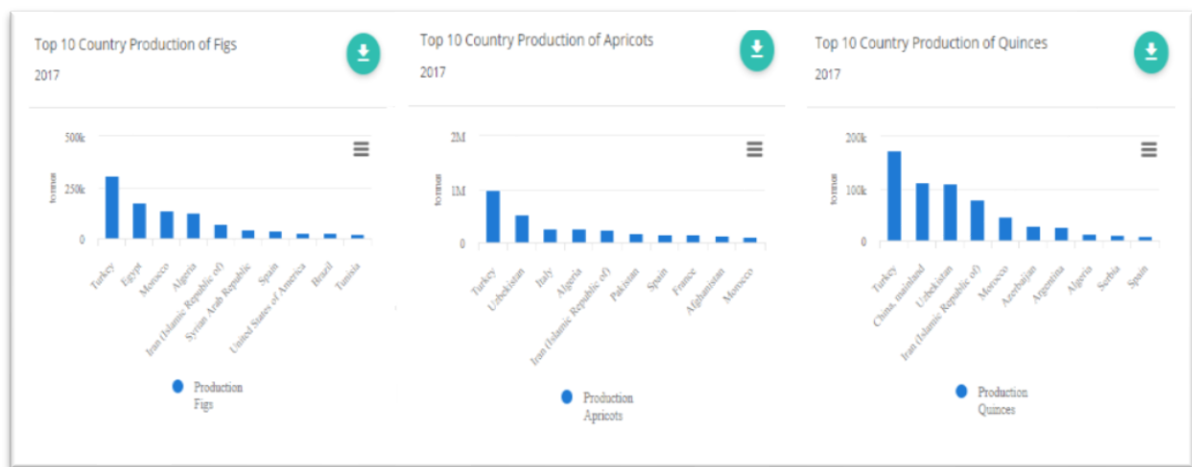


Figure 1.1: The order of the top 10 countries in the world according to production of fig, apricot and quince.

Because they have different type antioxidants. Antioxidants can be categorized into four groups as phenolics, carotenoids, vitamin C and vitamin E. All of the our fruits have phenolics but fig has anthocyanins which is a group of phenolics. Apricot has caretonoids and quince has vitaminC (Table 1.4).

Table 1.4: Antioxidants constituents of fig, apricot and quince.

Antioxidants	Fig	Apricot	Quince
Phenolics	Anthocyanins	√	√
Carotenoids		√	
Vitamin C			√
Vitamin E			

Because these 3 fruits complement to each other in terms of some components. fig is richer than the other fruits in terms of vitamin B6, fructose, calcium, lutein and apricot is richer than the

others in terms of potassium, vitamin A, beta carotene, ash and quince is richer than the other fruits in terms of vitamin C and fibers (Table 1.5).

Table 1.5: Nutritional values of fig, apricot and quince.

Component		Fig	Apricot	Quince
Energy	kcal	70	29	60
Energy	kJ	293	117	251
Carbohydrate	g	14.1	5.66	13.92
Vitamin B-6, total	mg	0.174	0.063	0.049
Fructose	g	5.60	0.85	4.68
Calcium, Ca	mg	67	16	11
Lutein	µg	84	20	10
Potassium, K	mg	202	328	177
Vitamin A	RE	11	67	8
Beta-carotene	µg	134	808	91
Ash	g	0.69	1.73	0.45
Vitamin, C	mg	2.1	8.5	15.2
Fiber, total dietary	g	2.66	1.24	3.23
Fiber, water soluble	g	0.80	0.27	0.47
Fiber, water insoluble	g	1.96	0.96	2.76

The highest values are bold numbers.

1.2. FRUIT POWDERS AND TABLETTING TECHNOLOGY

Fruits are sensitive to deterioration due to high water and sugar content. For this reason, they must be protected against deterioration during their storage and transportation. Drying of the fruit moisture content to a safe level is a worldwide common method. However, the water activity values of dried fruits, a_w :0.70-0.80, are suitable to microbial degradation and the fruits are not resistant to deterioration and can not be stored for a very long time (Victor et al., 2017). According to the Table 1.6, to have a commercial long shelf life, water activity must be below 0.6, but in this case the fruits are so rigid that it needs to be wet before it is consumed such as pestle (Dilbaghi et al., 2007). Another method to consume an advanced dried fruit is consuming after it has been pulverized to powder form.

Powdering of dry fruits is one of the various methods that are used against deterioration in long-term storage of fruits.

Fruit powders in addition to the ease of preserving, transporting and storing properties, are consumed by mixing some foods such as milk, water, yoghurt, honey (Saifullah et al., 2016). Thus allowing to consume fruit for those who are suffering from chewing difficulties such as

the infants and elderly people. Fruit powders are used as a raw material or additive material in the food sector to enhance the color, flavor and nutritional value of the products as well as in the formulation of infant formula (Devatkal et al., 2010; Sudha et al., 2007).

Table 1.6: Water activity relation with food spoilage by microorganisms.

Water activity	Microorganisms grow at this a_w and above	Food examples
1.00 – 0.95	Pseudomonas, E.coli, Proteus, Shigella, Klebsiella, Bacillus, Clostridium perfringens & some yeasts	Highly perishable fresh foods & canned fruits, vegetables, meat, fish, milk, eggs; foods containing up to 40% (w/w) sucrose or 7% NaCl.
0.95 – 0.91	Salmonella, Vibrio parahemolyticus, Clostridium botulinum, Serratia, Lactobacillus, Pediococcus; some molds and yeasts	Some cheeses (cheddar, Swiss), Cured meats; some fruit juice concentrates; bread; high moisture prunes; foods containing 55%(w/w) sucrose or 12% NaCl
0.91 – 0.87	Many yeasts like Candida, Torulopsis, Hansenula; Micrococcus	Fermented sausages; sponge cakes; dry cheese; margarine; foods containing 65%(w/w) sucrose (saturated) or 15% NaCl
0.87 – 0.80	Most molds, Staphylococcus aureus, most Saccharomyces spp., Debaryomyces	Most fruit juice concentrates, sweetened condensed milk, flour, rice. Pulses containing 15 – 17% moisture, salami
0.80 – 0.75	Most halophilic bacteria, Mycotoxigenic Aspergilli	Jam, Marmalade, Glace fruits, Soy sauce
0.75 – 0.65	Xerophilic molds, Saccharomyces bisporus	Rolled oats containing 10% moisture; Fudge; Marshmallows; Jelly; Some dried fruits; Nuts, Peanut Butter
0.65 – 0.60	Osmophilic yeasts, Few molds	Dried fruits containing 15 – 20% moisture; Honey
0.50	No microbial proliferation	Pasta containing 12% moisture; Spices containing 10% moisture
0.40	No microbial proliferation	Whole egg powder containing 5% moisture
0.30	No microbial proliferation	Cookies, biscuits crackers, bread crumbs etc. Containing 3 – 5% moisture
0.20	No microbial proliferation	Whole milk powder containing 2 – 3% moisture, Dried vegetables containing 5% moisture, Corn flakes containing 5% moisture, Instant coffee

Various drying methods are used to obtain fruit powders. Although these methods are determined based on the current state and the nature of the fruit, the selected method affects the physicochemical and nutritional properties of the final product (Saifullah et al., 2016). Convective drying by hot air is low costs and widely used but required long time and high temprature which causes nutrient degradation (Marfi et al., 2008). Freeze drying method can be used to minimize the loss of nutrients and to obtain better quality of final products but is an slow and expensive method which requires high energy consumption (Huang et al., 2008).

There are studies in which the chemical, physico-chemical and technical properties of powders obtained from apricot, fig and quince fruits are examined and used as food additives such as biscuits, muffins and cakes and their positive contributions to product quality are reported (Lee et al., 2002; Devatkal et al., 2010; Khapre et al., 2011; Özbaş et al., 2014; Khapre et al., 2015). In a study, it was explained that apricot kernel powder and apricot-apple mixture powder were used instead of flour at certain ratios in the production of biscuits and they had a positive contribution to product quality with high dietary fiber ratio (Seker et al., 2009).

In another study evaluating the potential for use of powders in the food industry, fig powder co-products have very good chemical, physico-chemical, technical properties and potency to be used as food additive (Viuda et al., 2015).

Tabletting technology is one of the key processes which is used in pharmaceutical industry for the development of solid oral dosage forms. In terms of the food industry, tabletting is a developing technology, but in recent years it has been widely used, especially tabletting of tropical vegetablets and fruits (Yusof et al., 2012). Tabletting process is powdering the fruit after drying in a suitable manner and compressing the fruit powders into tablets. Unlike fruit powders, fruit tablets are compacted so they take up less space and are more resistant to hygroscopicity and oxidation because of smaller surface area.

1.2.1. Food Powders' Properties

When food powders are used as raw materials or additives, knowledge of the particle properties of powders is required in the design of the process flow chart and process equipment. Particle properties include moisture content, activity of water, color, size distribution, shape, density, flow properties, solubility/wettability, water/oil holding capacity.

Color: Color measurements are performed with devices called colorimeter. Color parameters consist of L = 0 (black), L = 100 (white), -a (green), + a (redness), -b (blue) and + b (yellow) Sandaval et al. 2018.

Activity of Water: The powder sample is placed in the sample container of the water activity measuring device and the measurement is performed automatically by the device. Values in the range 0 to 1 are read. 0 is completely dry and 1 is pure water (Victor et al., 2017).

Water/Oil Holding Capacity: They have a critical role on textural quality and functional properties of final product in which the powder is contained (Felli et al., 2018). In the microstructures of the powders, the fiber-fiber interactions cause hydrophobic surface or a hydrophilic surface and result in less oil holding capacity or less water holding capacity (Gouw et al., 2017).

Wettability and Solubility: These properties of powder samples vary depending on the water absorbing property. If it is used in the production of foodstuffs, it is expected that it will be easily dissolved and dispersed in the mixture. The wettability or solubility in a shorter time means that it is more hydrophilic, which facilitates the accessibility of water into the particle. These vary depending on the particle size, porosity, density, surface charge, surface area and moisture content of the particles. (Fitzpatrick et al., 2016).

Density Properties: Density is an important parameter for powdered foods. Firstly, bulk density and tap density are measured and then porosity and apparent density are calculated using these values.

Bulk density is affected by chemical composition, particle size and moisture content. It varies depending on the process and storage conditions of the powders as well as the drying method (shrinkage ratio) (Caparino et al., 2012).

Tap Density: When determining the tap density of powder samples, the weighed sample is taken into the measure. Then pressure is applied to the powder surface (150 strokes at a constant speed). After the pressure the volume of the sample is read and the tap density (g / mL) is calculated by dividing this value by mass (Caparino et al., 2012).

Flow Properties: The flow properties of fruit powders have an important role on processing storage and packaging. The Carr Index or Housner ratio are used to estimate the flowability of powders (Yusof et al., 2015; Kumar et al., 2001; Housner, 1967). The following formulas are used to obtain flow properties.

Housner Ratio = Tap density / Bulk density

Carr Index (%) = (Tap density- Bulk density) / Tap density * 100

The scientists defined ranges for the HR (Hayes et al., 1987; Housner, 1967) and CI (Carr, 1965) for estimating flowability in below.

1.0 < HR < 1.1, for a free-flowing powder;

1.1 < HR < 1.25, for a medium-flowing powder;

1.25 < HR < 1.4, for a difficult-flowing

5% < CI < 15%, for a excellent flowing;

15% < CI < 25%, for a medium-flowing;

25% < CI for a difficult-flowing

1.3. FUNCTIONAL FOOD AND FOOD SUPPLEMENTS REGULATIONS

Due to its desire to be healthier and to develop a higher quality of life, functional food science has recently gained momentum and has become significant branches of science and politics.

Functional foods first appeared in Japan in the 1980s. Food scientists have proved that their foods have “advantageous physiological effects”. Then that foods have labeled with a special FOSHU or Food for Special Health Use label (Kubomuro, 1998). Then countries and scientific organizations tried to create their own functional food definitions. This has led to confusion as to the meaning of functional foods among the public while increasing sales. The lack of a coherent definition between countries has led to a lack of regulation of health claims, a limitation of some of the production of functional food, and a general distrust of the population towards functional food (Martirosyan and Singh, 2015).

Currently, there are no separate regulations for functional foods in the United States and other countries except Japan. The specified regulations are related to the labeling of the product if it is claimed that the product is beneficial for health. The food and dietary supplement regulations may also apply to products marketed as functional foods.

In our country 'Functional foods' entered into our legislation for the first time within the Turkish Food Codex 5179 (Anonymous, 2004). "Functional Food" is defined in this regulation using the following statement:

Functional foods are defined as nutritious foods that contain defined, effective and non-toxic amounts of biologically active compounds that are clinically proven and documented for the prevention, management or treatment of chronic diseases

Fruit powders which were produced in this study might be use as an additives to increase the functional properties of a food product. Additionally the fruit tablets which were produced in this study might be use as an food supplements.

Foods supplements are taken for many purposes such as reinforcing normal nutrition, feeling more energetic, strengthening the immune system by taking vitamins and minerals that cannot be taken adequately, and meeting the needs of the body when not being balanced and healthy.

In the European Union (Directive 2002/46/EC of the European Parliament and of the Council of 10 June 2002) and US legislation (U.S. Food and Drug Administration Center Dietary Supplement Health and Education Act (DSHEA) of 1994) lists of vitamins and minerals that may be contained in food supplements and information on their dosages are detailed. In our country Turkish Food Codex Communiqué on Food Supplements was published in 2013.

1.4. BIOACCESSIBILITY

The knowledge about the content of the bioactive components in the foodstuffs is not sufficient to predict the nutritional efficacy because the compounds which pass into the blood are absorbing after an intense metabolism and may be different from the original compounds that found in original food. Nutritional efficacy of food products may be provided by the evaluation of bioavailability which includes biocessibility and bioactivity (Carbonell-Capella et al., 2014). Bioactivity is the effect of a bioactive compound, such as vitamin, upon a living

organism or on living tissue. The quantity or fraction released from the food matrix in the gastrointestinal system and made available for absorption is called bioaccessibility (Wood, 2005). Figure 1.1 shows the relation between bioavailability, bioaccessibility and bioactivity (Fernandez et al., 2009).

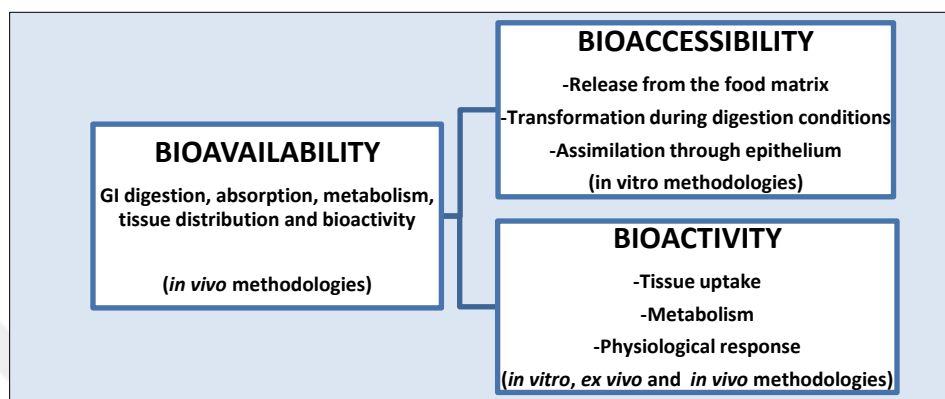


Figure 1.2: The relations between bioavailability, bioaccessibility and bioactivity.

Each food has its own complex nutrition profile. If more than one food is consumed as a mixture, the nutrients of different foods may have a synergistic effect on bioavailability (Liu et al., 2013). Similarly, the health benefits of fruits and vegetables depend on the synergy or interactions of bioactive compounds and other nutrients contained there in. For this reason, a balanced diet to live healthy is not made up of nutritional supplements that consist of fruits and vegetables.

In our study, fruit powders and fruit tablets were produced using whole fruits. In addition, fruit mixture have been used to enhance bioavailability of bioactive agents, particularly phenolic compounds.

1.3.1. Methods Used to Assess the Bioaccessibility

In vitro gastrointestinal digestion methods imitate the gastro-intestinal digestion procedure *in vitro* conditions. The first condition for *in vitro* gastrointestinal digestion simulation is the use of a system that produce qualitatively comparable results with *in vivo* results. Main characteristics of a realistic system are temperature, pH, transition time and digestion fluid composition. Generally, these models are categorized as static models and dynamic models (Marze, 2015). Most static digestion simulation is based on continuous mixing with temperature and pH control. Simulated saliva, simulated gastric fluid, and simulated intestinal fluids consist

of physiological electrolytes, while enzymes are generally of animal origin that consists of three steps, mainly oral, gastric and intestinal (Marze, 2017). In the first step which imitate the mastication with enzyme amylase, the food is mixed for several minutes with simulated saliva. In the second step, this bolus is mixed with simulated gastric fluid and mixed for a few hours to obtain chyme. In the last step, the chyme is mixed with artificial intestinal fluid for a few hours to obtain chyle (Marze, 2017). Another static model is cell culture studies using Caco-2 cells and small intestine simulation to provide information on bioavailability. In this study static gastrointestinal digestion simulation model was used.

In the 2000s, many static protocols with differences in physiological parameters were developed, but a European network (INFOGEST) was established to define average values for harmonization of studies (Minekus et al. 2014).

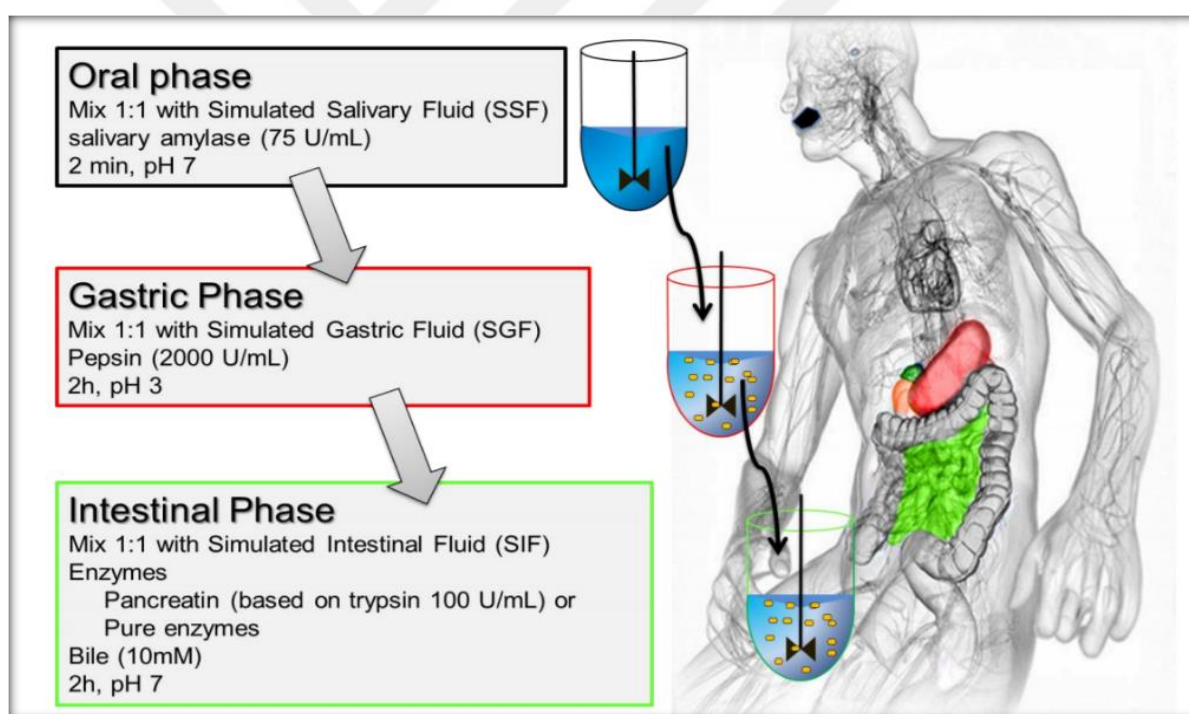


Figure 1.3: *In vitro* gastro-intestinal digestion Consensus INFOGEST protocol (Minekus et al., 2014).

Static systems are generally used for screening techniques, but dynamic systems are being developed to obtain close values to clinical studies. Although research on the development of dynamic systems has started with mastication studies, it has included the rest of the digestive system in recent years.

In addition to having the basic principles of static models, dynamic models dynamic digestion models are systems that simulate gastrointestinal digestion in which foodstuffs are continuously removed, mimicking peristaltic movements, better control and gradual adjustment of pH and enzyme levels. One of the the pioneering systems TNO gastrointestinal model (TIM-1) (Minekus et al., 1995). The TNO model contains four compartments which are stomach, duodenum, jejunum, and ileum. Another pioneering system the simulator of the human intestinal microbial ecosystem (SHIME) (and this model contains three additional colonic compartments (Alander et al., 1999).

SHIME is mainly focused on column microbiology and designed for other parameters except absorption. Therefore, it is more convenient to study gastrointestinal food digestion. In contrast, TIM-1 is designed for use in both pharmacological and nutritional studies. The final version is intended for use in micronutrients or microcomponent bioaccessibility or nutritional digestion for different food systems.

1.5. DESCRIPTIVE SENSORY ANALYSIS

Sensory evaluation of processed products and raw materials is an important part of food quality control in the food industry. All five sensory organs have effects (Seeing, Smell, Taste, Touch, Hearing) in sensory evaluation. Sensory evaluation is directly related to eating quality. When a new product will be available in the food industry, the quality of food needs to be investigated.

Although some objective measurements can be made for individual quality elements, it is not possible to measure the total effects of food on the consumer by any objective analysis or instrument. The overall effect of food on the consumer is based on the results evaluated by panelist with specific properties by descriptive sensory analysis.

There are many different descriptive analysis methods including Flavour Profile Method (the first reported descriptive method, developed in the late 1940s), Texture Profile Method (developed by scientists working for General Foods in the 1960s), Quantitative Descriptive Analysis (developed during the 1970s), The Quantitative Flavour Profiling Technique (developed by Givaudan-Roure in Switzerland during the 1990s), The Spectrum Method (developed by Gail Vance Civille in the 1970s), Generic descriptive analysis, Free-Choice Profiling (developed in the UK during the 1980s). (Murray et al., 2001).

General descriptive analysis is often used to meet specific project objectives in practical applications because it can combine various sensory philosophies and approaches in other methods. Generic descriptive analysis, which allows to define all sensory properties and sensory differences between products, is considered the gold standard in sensory analysis (Heymann et al., 2014).

So far, the descriptive sensory analysis have already been used for Marjoram aroma (Sanchez et al., 2015), sensory attributes of apricots (Fan et al., 2017), effects of packaging materials on the aroma stability (Janija et al., 2017).

1.6. FREE RADICALS AND ANTIOXIDANTS

Free radicals are molecules which have an unpaired electron in the outer orbit. In general, they are very reactive and indecisive molecules such as superoxide and hydroperoxyl ($\text{HO}_2^\cdot$) radicals. Reactive oxygen species (ROS), reactive nitrogen species (RNS), and reactive chlorine species that occur in physiological and pathological conditions in animals and humans are the main free radicals in the organism. (Fang et al., 2002; Valko et al., 2007)

Superoxide, hydroxyl ($\text{OH}^\cdot$), peroxy ($\text{RO}_2^\cdot$), and hydroperoxyl ($\text{HO}_2^\cdot$), hydrogen peroxide (H_2O_2), singlet oxygen (O_2) and peroxyxynitrite ($\text{ONOO}^\cdot$) are the examples of reactive oxygen species and reactive nitrogen species which is involved in interaction with the main macromolecules in food-related systems (Macdonald et al., 2006; Litescu, 2010). These interactions can lead to oxidative damage (stres) which is described as a disorder in pro-oxidative and anti-oxidant equation in an organism. Radicals can damage to cardinal cellular components which can cause to cancer, diabetes and etc. Therefore, production of antioxidants is important to neutralize the free radicals (Kopani et al., 2006; Kopani et al., 2011). They are also important in the area of cosmetics, foods and further fuelling studies by researchers to discover their analogues (Ratnam et al., 2006; Duvvuri et al., 2015).

Antioxidants are substances that significantly prevent or delay the oxidation when they are present in foods at low concentration. Free radicals are toxic substances that can damage the lipids, proteins and nucleic acids which cause diseases and pathologic events. Antioxidants can reduce these toxic substances to the harmless or low toxic substances. Therefore, existence of antioxidants is important (Vassalle et al., 2004).

Antioxidants are substances that can considerably inhibit the negative effect of these reactive species. They can also be taken through foods as they can be produced in the body. When they are found in low concentrations in foods or in body they significantly prevent the oxidation (Zhang et al., 2001). Mainly, vitamins (C, E and A) and phenolic compounds are natural antioxidants which are present in the foods and protect the human body from harmful radicals (Rica et al., 2007).

Antioxidants can be categorized into four groups as polyphenols, carotenoids, vitamin E and vitamin C. Polyphenols and its derivatives are the most important types of antioxidants. Polyphenols are composed of flavonoids and phenolic acids (Ratnam et al., 2006; Duvvuri et al., 2015). They are reducing agents that protect the tissues in the body against the oxidative stress (Scalbert et al 2000; Duenas et al., 2015). They are very strong antioxidants and their activity depends on their structure. Plant polyphenols are multifunctional molecules that they act as reduction agent, hydrogen atom-donor antioxidants and scavengers of oxygen and some as chelators of metal ions capable of catalyzing lipid oxidation (Shahidi et al., 2002; Nayak et al., 2015). Vitamins and carotenoids are the other types of antioxidants (Ratnam et al., 2006; Duvvuri et al., 2015).

1.6.1. Natural Antioxidants

There are many types of different substances with antioxidant potential in the human diet. Vitamin E, vitamin C, carotenoids and polyphenolic substances are significant antioxidants procurators of dietary antioxidants.

Vitamin C, also known as ascorbic acid, is a water soluble vitamin which is mostly found in plants. It is a very strong antioxidant that is abundant especially in orange, strawberry, kiwi, mango, tomato, potato etc. It is a six-carbon lactose synthesized from glucose in the plants and liver of most mammalian species, but not by humans (Padayatty et al., 2003; Liang et al., 2017).

Ascorbic acid is an electron donor and a reducing agent since by donating its electrons, it prohibits other molecules from being oxidized. Besides, it is oxidized itself in the process (Padayatty et al., 2003, Liang et al., 2017). Ascorbic acid avoids the oxidation of low-density lipoprotein (LDL) and fats.

Vitamin E is eight naturally-occurred required fat-soluble food substances. In these eight derivatives, α -tocopherol dominates in many species and it is biologically more active than others (Bjørneboe et al., 1990; El Hadi et al., 2018).

Vitamin E is one of the most important antioxidants because it prohibits the ROS-induced descendants of lipid peroxy radicals, therefore protecting the cells peroxidation of polyunsaturated fatty acids (PUFA), phospholipids and other membrane lipids (Fang et al., 2002). As the admittance of vitamin E increases the immune response is improved. In addition, vitamin E conserves the vitamin A from devastation in the body.

Vitamin E is abundant in vegetable oils and little is available in fish (Horwitt et al. 1986; Raederstorff et al 2015).

Carotenoids are mostly used as natural coloring substances. They are synthesized in plants and have antioxidant activity under light (Podsedeck et al., 2007). Intercellular commutation, cell differentiation and immunoenhancement are some of the acts of carotenoids. The basic structure of many carotenoids is composed of C40 carbon chain and a polyisoprenoid. Lycopene, β -carotene and α -carotene are in the class of carotenoids recognized as carotenes. β -cryptoxanthin, lutein, and zeaxanthin are in the class of carotenoids known as xanthophylls which has oxygenated end groups (Young, 2018).

The main carotenoid molecule can be altered by changes in the double bond structure and also by supplementation of side groups of oxygenated group. In nature, hydroxylated carotenoids are existed as glycosides (Young, 2018).

The enlarged system of conjugated double bonds significantly affects the antioxidant activity of carotenoids. Most of the normal biological mechanisms based on free radicals. Diseases related with oxidative stress are results due to the imbalance between pro-oxidants and antioxidants. Therefore, pro-oxidants or antioxidants activity of carotenoids may be harmful or beneficial in biological system (Young, 2018).

1.6.2. Phenolics

Phenolic compounds are the biggest class of phytochemicals and they are present in most of the plants such as mushrooms, vegetables, nuts and oilseeds (Pokorny, 1991).

The function of phenolics is to provide defense mechanism against pathogens and parasites in the reproduction and growth of the plants and also contributes the color of plants. Moreover, they reduce the risk of chronic diseases, so they are beneficial to health (Liu, 2004).

For polyphenols, it is important to satisfy these two conditions to be described as antioxidants;

- When they are present in low concentration regarding to the molecule that is oxidized, it can detain, postpone and provide auto-oxidation.
- The resulted radical after scavenging must be stable to stop the chain reaction of oxidation.

The largest group of phytochemicals found in a large part of the plants, phenolics have been increasingly popular in recent years because consumption of fruit and vegetables containing these compounds at high levels can reduce the risk of developing various diseases due to their antioxidant properties and potential beneficial health effects. As secondary metabolites, phenolics are found in large quantities in plants and have great significance in defense of a plant against biotic and abiotic stresses (Giada, 2013).

Phenolic compounds consist of molecules having a phenol ring and molecules containing several hydroxyl groups on the aromatic ring. These compounds are thought to have protective effects against certain diseases such as cancer and cardiovascular diseases due to the antioxidant activity. Phenolic compounds are classified according to the number of phenol rings contained and the structure of the elements linking them to each other. The main group of phenolic compounds shown in Figure 1.2 are flavonoids, phenolic acids, tannins, lignans, stilbenes and coumarins (Shahidi and Ambigaipalan, 2015).

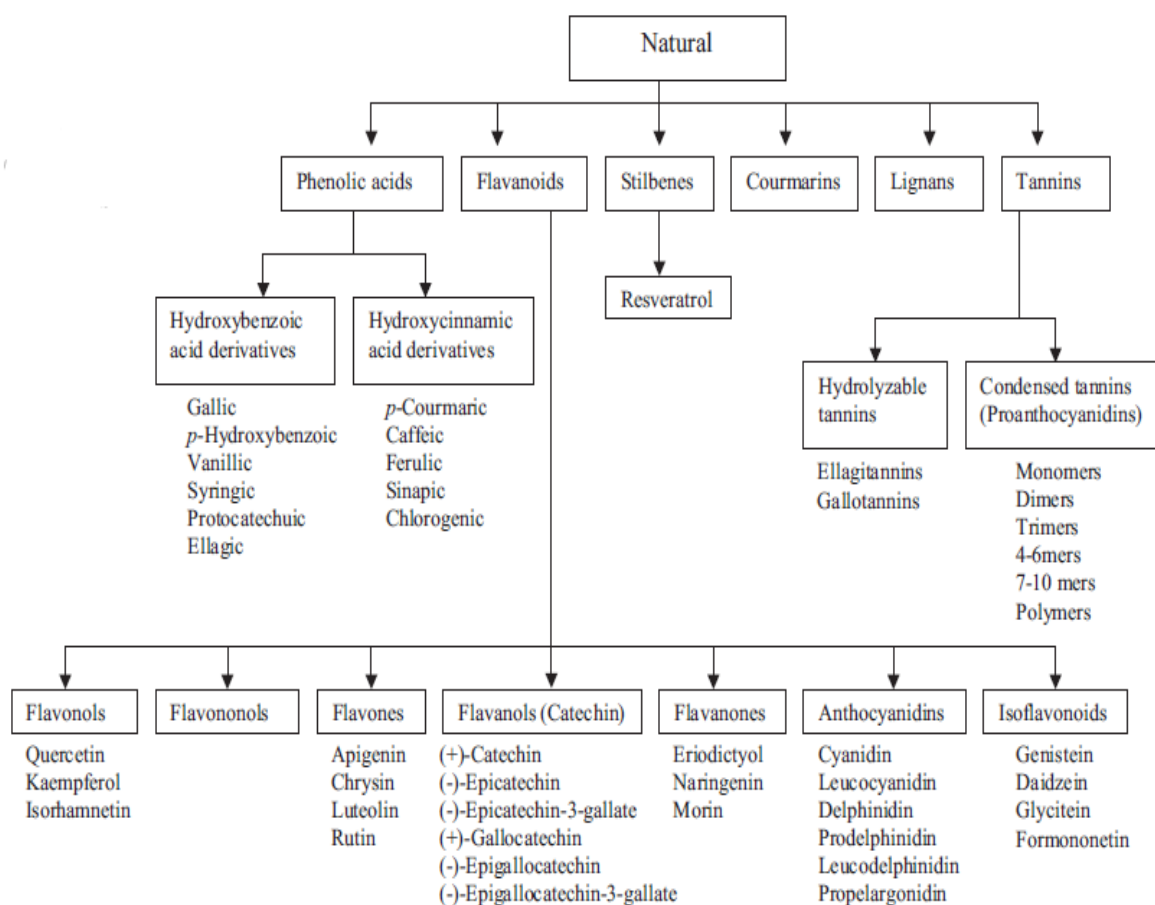


Figure 1.4: Phenolic compounds.

Flavonoids

The most common group of phenolic compounds present in plants is flavonoids because they constitute approximately two-third of the dietary phenols. More than 6,000 flavonoids found in leaves, flowers and roots (Shahidi and Ambigaipalan, 2015). Flavonoids have low molecular weight and show antioxidant and chelating properties. They have aromatic rings of 6 carbons expressed in the form of A and B and heterocyclic rings of 3 carbons in the form of C. Flavonoids are grouped according to the presence of different substituents on the rings and the most common classes shown in the Figure 1.3 are the flavones, flavonols, isoflavones, flavanones, flavanonols and anthocyanidins (Heim et al., 2002).

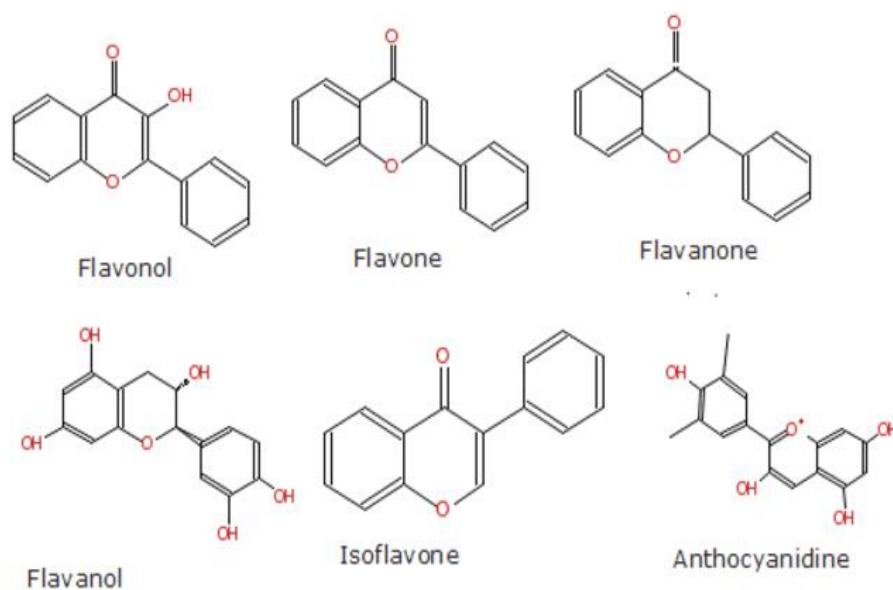


Figure 1.5: Flavonoids.

Flavonoids in plants are mostly present as glycosides. Even in different plants, the composition of flavonoids is different. There are two types of flavonoids; (i) anthocyanins (ii) anthoxantins. Anthocyanins are the most important type of water-soluble plant pigments. They are glycosides of anthocyanidin. They give red, blue and purple colors of flowers and also fruits. The anthoxantins are colorless substances and involve flavones, flavonols, isoflavones, flavanols and flavanones (Kunwar, 2011).

Phenolic Acids

There are two main types of phenolic acids; (i) hydroxybenzoic acids (ii) hydroxycinnamic acids. Ellagic and gallic acid are two basis hydroxybenzoic acids. They usually present as hydrolysable tannins and can be present in the form of sugar derivatives in plant foods.

The main types of hydroxycinnamic acids are caffeic and ferulic acids. They are present pretty much in all plants and play an important role in the phenolic metabolism of plants. Because they are the precursor of the flavonoids, they participate to cell-wall components through the ester bonds (Liu, 2004).

Tannins

Tannins are compounds with a high molecular weight. They react with mouth proteins which causes the sensation in the taste, known as astringency. Tannins can be grouped as condensed and hydrolysable. Condensed tannins are abundant in fruits, grains and legumes. They are polymers of catechins and they gather in the outer stage of plants.

Polymers of gallic or ellagic acids are called as hydrolysable tannins. They are mostly present in nuts, berries etc (King et al., 1999; Saxena et al., 2013).

1.7. TOTAL ANTIOXIDANT CAPACITY METHODS

Until now, many methods have been developed to determine the antioxidant capacity. CUPRAC, ABTS, TEAC, FRAP, FOLIN CIOCALTEU and DPPH tests are some of the most known and used methods.

1.7.1. CUPRAC

CUPRAC is a method which was developed by Apak and his group. Copper (II)-neocuproine is used as the chromogenic oxidizing agent to calculate the antioxidant capacity of polyphenols, vitamin C and vitamin E.

In this method, Cu(II) chloride solution, a neocuproine alcoholic solution and an ammonium acetate solution with a pH 7 are mixed and then added the determined antioxidant solution. The resulted solution gets absorbance at 450 nm in 30-60 minutes. In ascorbic acid, gallic acid and quercetin, the growing of color is fast but not in naringin and naringenin. They are assayed after incubation at 50 °C to complete the oxidation (Apak et al., 2004).

1.7.2. Folin Ciocalteu

Folin-Ciocalteu (FC) assay is a very old method suggested to determine total content of phenolics, however it evaluates the reducing capacity of the sample.

Folin-Ciocalteu method is not just for phenolic compounds it can also be reduced by non-phenolic compounds. The important point is that phenolic compounds can only be reduced under basic conditions because disassociation of phenolic proton only leads to a phenolate anion

in basic medium. Therefore, Folin-Ciocalteu method is based on electron transfer reaction (Roginsky, 2005).

1.7.3. Other Methods

Another method ABTS (2,2-Azino-bis3-etilbenzotiyazolin-6-sülfonik asit) was first suggested by Miller and his group. This method is ground on inhibition of the absorbance of ABTS⁺ (2,2-Azino-bis3-etilbenzotiyazolin-6-sülfonik asit) by antioxidants. In the presence of antioxidants, the total antioxidant capacity is obtained as trolox by taking advantage of decrease in the absorption of ABTS⁺ (2,2-Azino-bis3-etilbenzotiyazolin-6-sülfonik asit) for a short period of time. Its simplicity is the main advantage of TEAC because it can be applied for routine determinations in any laboratory (Roginsky, 2005).

The FRAP (Ferric reducing antioxidant power) assay is first suggested by Benzie and Strain (1996). This method is based on the ferric-to-ferrous iron reduction in the presence of antioxidants. If the reduction occurs in the presence of 2,4,6-trypyridil-s-triazine, a colored complex of Fe²⁺ is formed (Fe²⁺-TPTZ) at low pH. The differences between TEAC and FRAP (Ferric reducing antioxidant power) is that FRAC need acidic conditions whereas TEAC occurs at neutral conditions (Prior et al., 2001; Roginsky et al., 2005). In the food extract, other Fe³⁺ species contained mixture can lead some problems since they can bind to chelators. These molecules can react with antioxidants. Many studies demonstrate that there isn't a proportional relationship between the number of electrons which can be donated by antioxidant and FRAP (Ferric reducing antioxidant power) value (MacDonald et al., 2006).

The DPPH (1,1-diphenyl-2-picrylhydrazyl) test is first suggested to explore H-donors in natural materials. In time, it is quantified to state the antioxidant potential of food, individual phenolics and biological relevant materials. This method is ground on the capability of 2,2-diphenyl-1-picrylhydrazyl to react with H-donors which includes phenolics. DPPH (1,1-diphenyl-2-picrylhydrazyl) gives an intense absorption in the visible region and it can also be easily stated by UV-visible spectroscopy. In the reaction with H-donors, DPPH (1,1-diphenyl-2-picrylhydrazyl) method is more selective than TEAC test. However, in opposite to TEAC, DPPH (1,1-diphenyl-2-picrylhydrazyl) doesn't react with aromatic acids with one OH group, flavonoids and B-ring without OH group (Roginsky, 2005, Foti, 2015).

2. MATERIALS AND METHODS

2.1. CHEMICALS AND REAGENTS

For the simulation of *in vitro* gastrointestinal digestion system, dialysis bags (Dialysis tubing cellulose membrane, avg. flat with 33 mm (1.3 in.)), pancreatin (from porcine pancreas), pepsin (from porcine gastric mucosa), bile salt were purchased. For total phenolic, total flavonoid and total antioxidant activity measurements gallic acid, catechin and trolox were used as a standard, respectively. All chemicals and reagents used for the analyses were of analytical grade and obtained from Sigma Aldrich Chemie GmbH & Co. KG (Steinheim, Germany).

2.2. SAMPLE PREPARATION

Fresh fruits (figs, apricots, quinces) used in this study were purchased from local markets and were stored at -18 °C until drying process less than a month.

Fig fruits were dried at 60 ± 5 °C during 24-48 hour (Viuda et al., 2015). Vacuum oven was used to dry whole quince fruits without seeds at 55 °C (Dziki et al., 2012) and to dry whole apricots without seeds at 70 °C during 24-36 hour (Madrau et al., 2009). Lab scale grinder was employed at maximum speed to obtain powder. 300µm stainless sieve was used to obtain homogeneous particle size. The tableting of the fruit powders was performed by direct compaction method and tablet machine (3atm 30scnd) was used to press fruit powders (Yusof et al., 2012). All powder and tablet samples were stored at -18 °C before analysis less than 3 months.

2.3. PHYSICO-CHEMICAL PROPERTIES

2.3.1. Moisture and Ash Contents

The moisture content of samples were obtained by the official TS 1129-ISO 1026 method. Briefly, 5 g of fruit samples were weighed in a porcelain crucible and dried in an oven by using

a vacuum oven at 70 °C (Turkish Standard, 1998). Average values of samples analyzed in triplicate were given as percentage.

The ash content of samples were determined at 550-590 °C using an ash oven (Dagtekin et al., 2014). Average values of samples analyzed in triplicate were given as percentage

2.3.2. Color Features

Chroma Meter CR-400 (Konica Minolta Sensing Colorimeter, Japan) was used to measure color properties of fresh fruit and powder samples by putting the sample on a plastic petri dish. (Gouw et al., 2017). A standard white plate was used to calibrate the colorimeter. The targeted parameters were L^* (lightness/darkness), b^* (yellow/blue) and a^* (red/green). Following equations were used to calculate color intensity Chroma (C) and hue angle (H°), visual color appearance: where 0° or 360° = red-purple, 90° = yellow, 180° = green, 270° = blue.

$$C = (a^*2 + b^*2)^{1/2}$$

$$H^\circ = \tan^{-1}(b^*/a^*)$$

2.3.3. Activity of Water

Water activity of fruit powder samples were measured using a Lab Touch water activity meter (Novasina, Switzerland) by filling the half of a sample cup with the prepared fruit powder (Gouw et al., 2017). All samples were analyzed in triplicate and average values were reported as percentage.

2.4. TECHNO-FUNCTIONAL PROPERTIES

2.4.1. Oil / Water Holding Capacity

Oil holding capacity was measured in a falcon tube; 0.5 g of fruit powder sample was mixed with 10 mL of olive oil and left overnight at room temperature. Then centrifuged at 1500 g for 5 min, and decanted the excess oil. The fruit powder with adsorbed oil was reweighed, and oil holding capacity was expressed as g oil/g dry weight (Gouw et al., 2017). Average values of samples analyzed in triplicate were given as percentage.

Water holding capacity was measured in a falcon tube; 1 g of fruit powder sample was mixed with 50 mL of distilled water vigorously for 1 min and then centrifuged at 10,000 g for 5 min

(20°C), and decanted the excess water. The fruit powder with adsorbed water was reweighed, and water holding capacity was expressed as g water /g dry weight (Sudha et al., 2007). All samples were analyzed in triplicate and average values were reported as percentage.

2.4.2. Wettability and Solubility

A glass beaker having an internal diameter of 80 mm with a volume of 250 mL was charged with 100 mL of 20 °C water. 10 g of powder was poured onto water and the time required for the powder to sink and disappear from the water surface using a timer was measured in seconds as wetting time (Fitzpatrick et al., 2016).

In the determination of the solubility properties of the powders, the method used by Dirim and friends (2017) was revised. A glass beaker having an internal diameter of 80 mm with a volume of 250 mL was charged with 100 mL of 30 °C water under continuous stirring using a magnetic stirrer. 5 g of powder was mixed and the time required to dissolve the powder completely using a timer was measured in seconds as solubility time

2.4.3. Density and Flow Properties

Bulk Density

Bulk density was measured according to the method used Fazaeli and friends. In a 10 mL graduated cylinder, 2 g of powder was placed and vortexed for 1 minute. Bulk density value was determined by the ratio of the mass of the powder and the volume occupied in the cylinder (Fazaeli et al., 2012). The measurements were carried out in three replicates at room temperature for all samples.

Tap Density

10 mL cylinder with 2 g of sample was tapped 100 times manually at a height of 14 ± 2 mm under its own weight (Caparino et al., 2012). The use of 100 taps was sufficient to get the

minimum volume of the powder bed (Kaialy et al., 2012). Bulk density value was determined by the ratio of powder mass and volume occupied.

True Density (Particle Density)

To measure particle density liquid displacement method was used (Rayo et al., 2015). 2 g of powder was weighed to a glass pycnometer and filled with ethanol.

Porosity and Apparent Density

Apparent density: $d_{\text{bulk}}/d_{\text{true}}$

Porosity: $1-(d_{\text{bulk}}/d_{\text{true}})$

Flow Properties:

Housner Ratio (HR), widely used to evaluate cohesiveness and flow properties. That was defined as the ratio of the tapped density to bulk density and given by the following equation (Housner, 1967):

Housner Ratio = Tap density / Bulk density

Defined different ranges of HR by Hayes to characterize flowability are as follows:

1.0 $0 < \text{HR} < 1.10$ For a free,

1.10 $< \text{HR} < 1.25$ For a medium

1.25 $< \text{HR} < 1.40$ For a difficult

Carr Index (CI), widely used to evaluate compressibility, was defined as the ratio of the difference between the tapped and bulk density and expressed by the following equation (Carr, 1965):

Carr Index (%) = $(\text{Tap density} - \text{Bulk density}) / \text{Tap density} * 100$

2.5. *IN VITRO* GASTROINTESTINAL DIGESTION SIMULATION

The *in vitro* digestion simulation was performed by *in vitro* gastrointestinal digestion model of Minekus and coworkers and performed in triplicate for each sample (Minekus et al., 2014). Initially Simulated Salivary Fluid (SSF), Simulated Gastric Fluid (SGF) and Simulated Intestinal Fluid (SIF). Recommended concentrations of electrolytes in Simulated fluids based on human *in vivo* data were as shown in the Table 2.1.

Table 2.1: Recommended concentrations of electrolytes.

	<i>SSF mmol L⁻¹</i>	<i>SGF mmol L⁻¹</i>	<i>SIF mmol L⁻¹</i>
<i>K⁺</i>	18.8	7.8	7.6
<i>Na⁺</i>	3.6	72.2	123.4
<i>Cl⁻</i>	19.5	70.2	55.5
<i>H₂PO₄⁻</i>	3.7	0.9	0.8
<i>HCO₃⁻, CO₃²⁻</i>	13.7	25.5	85
<i>Mg²⁺</i>	0.15	0.1	0.33
<i>NH₄⁺</i>	0.12	1.0	-
<i>Ca²⁺</i>	1.5	0.15	0.6

Simulated Salivary Fluid (SSF), Simulated Gastric Fluid (SGF) and Simulated Intestinal Fluid (SIF)

Initially electrolyte solutions were prepared according to the concentration given in the Table 2.3. Then the simulated fluid stock solutions were made up with electrolyte solutions and filled with distilled water to 400 mL. So 1.25 fold concentrated simulated fluid stock solutions were gained and stored at -18 °C until analysis. $\text{CaCl}_2(\text{H}_2\text{O})_2$ was prepared freshly and added to the final mixture of simulated digestion fluid as precipitation may occur in the stock solutions. Enzymes, bile salt, HCl and NaOH were prepared freshly before the simulation.

Table 2.2: Sample/simulated fluid stock solution ratio.

Sample	Simulated fluid stock solutions	Other recipients
5x	4x	x

Five parts of sample liquid was mixed with 4 parts of simulated fluid stock solution to obtain a final ratio of sample to simulated fluid of 50:50 (volume to volume) after additions of other recipients and water.

Table 2.3: The concentration of initial electrolyte solutions.

Electrolyte	SSF (pH 7)			SGF (pH 3)		SIF (pH 7)	
Constituent	Stock Conc. mol L ⁻¹	Vol. of stock mL	Conc. in SSF mmol L ⁻¹	Vol. of stock mL	Conc. in SGF mmol L ⁻¹	Vol. of stock mL	Conc. in SIF mmol L ⁻¹
KCl	0.5	15.1	15.1	6.9	6.9	6.8	6.8
KH ₂ PO ₄	0.5	3.7	3.7	0.9	0.9	0.8	0.8
NaHCO ₃	1	6.8	13.6	12.5	25	42.5	85
NaCl	2	-	-	11.8	47.2	9.6	38.4
MgCl ₂ .6H ₂ O	0.15	0.5	0.15	0.4	0.1	1.1	0.33
(NH ₄) ₂ CO ₃	0.5	0.06	0.06	0.5	0.5	-	-
NaOH	1	-	-	-	-	-	-
HCl	6	0.09	1.1	1.3	15.6	0.7	8.4
CaCl ₂ .2H ₂ O	0.3		1.5		0.15		0.6

Simulated Salivary Fluid (SSF), Simulated Gastric Fluid (SGF) and Simulated Intestinal Fluid (SIF)

Oral Phase:

4.975 mL H₂O were added to the 0.5-2 g sample. Then 4 mL SSF stock solution and 0.025 mL CaCl₂ were added and thoroughly mixed before incubation at 37 °C for 5 minutes.

Gastric Phase:

Initially, porcine pepsin stock solution was prepared in the concentration of 25 000 U mL⁻¹ with SGF stock solution. Then 10 mL of oral bolus was mixed with 7.5 mL of SGF stock solution, 0.005 mL of 0.3 M CaCl₂, 0.4 mL of 1 M HCl to reach pH 3.0 and 0.5 mL of water. Finally 1.6 mL of porcine pepsin stock solution was added and incubated at 37 °C and 150 rpm for 2 hour.

After two hour 10 mL of the postgastric (PG) digestion were taken for each sample that are stored at -18 °C till the analysis.

Intestinal Phase:

Initially, pancreatin stock solution was prepared in the concentration of 800 U/mL⁻¹ with SIF stock solution. Then 10 mL of gastric chyme was mixed with 11 mL of SIF stock solution, 2.5 mL 160 mM fresh bile salt (prepared with H₂O), 0.04 mL of 0.3 M CaCl₂, 0.15 mL of 1 M NaOH to reach pH 7.0 and 1.31 mL of water. Finally 5 mL of pancreatin from porcine pancreas stock solution and dialysis bags filled with sodium bicarbonate were added. The mixture was incubated at 37 °C and 150 rpm for 2 hour. After two hour the solutions in the dialysis bags were taken as the IN sample and the solution outside the dialysis bags were taken as the OUT sample (Gil-Izquierdo et al., 2002). IN samples were symbolizing the matter which entered into the blood system and OUT samples were symbolizing the substances which stayed in the gastrointestinal system. To prepare blanks, same conditions and identical chemicals without sample were used.

2.6. SPECTROPHOTOMETRIC ANALYSIS

2.6.1. Chemical Extraction

Chemical extractions were performed according to the method earlier practiced by Çapanoğlu and friends (Capanoglu et al., 2008). 30-300 mg of each sample extracted in 1 mL of 75% methanol containing 0.1% formic acid in a ultrasonic bath (4 °C for 15 min). The treated samples were centrifuged (4 °C, 10 min 2700 g) then the supernatants were collected. This procedur was repeated and final volume was filled to 2 mL with extraction solution.

2.6.2. Total Phenolics

Folin–Ciocalteu’s method adapted to 96-well plate assay was used to calculate total phenolics (Ainsworth et al., 2007; Kamiloglu et al., 2015). 75% methanol containing 0.1% formic acid were used as chemical extraction solvent and gallic acid was used as a standard.

One hundred microliters of extract was mixed with 200 µL of Folin–Ciocalteu reagent freshly 10% (vol/vol) prepared in a 24-well plate on an orbital shaker. The mixture was waited for 5 min and then 800 µL of 700 mM Na₂CO₃ was added to the mixture. The assay tubes were

incubated for 2 h at room temperature. After 2 hour 200 μ L of sample, blank or standard from the assay tube was transferred to a clear 96-well microplate and read the absorbance of each well at 765 nm using a microplate reader.

Using gallic acid a calibration curve was plotted. The results were given as mg of gallic acid equivalent (GAE) per 100 g of dry weight of sample. All samples were analyzed in triplicate. The calibration curve was plotted by gallic acid which was dissolved in methanol 50% (volume to volume) to concentrations of 5, 15, 20, 40, 80, 160 mg/L.

2.6.3. Total Flavonoids

Total flavonoid contents of the samples were quantified using a spectrophotometric method (Floegel et al., 2011). Chemical extraction solvent (75% methanol containing 0.1% formic acid) and catechin was used as a blank and a standard respectively.

Two hundreds microliters of sample, blank or standard was mixed with 650 μ L of distilled deionized water in a 24-well plate on an orbital shaker. 30 μ L of 5% (w/v) sodium nitrite (NaNO_2) solution was added at time zero and after 5 min, 30 μ L of 10% (w/v) aluminum chloride (AlCl_3) was added. After 6 min 200 μ L of 1 M sodium hydroxide (NaOH) was added and the absorbance of each well was measured at 510 nm using a microplate reader, immediately.

Using catechin a calibration curve was plotted. The results were given as mg of catechin equivalent per 100 g of dry weight of sample. All samples were analyzed in triplicate. The calibration curve was plotted by catechin which was dissolved in methanol 50% (volume to volume) to concentrations of 5, 25, 50, 100, 200 mg/L.

2.6.4. Total Antioxidant Capacity

Antioxidant activity of samples was measured according to the method developed by Apak and friends (Apak et al., 2004). 75% methanol containing 0.1% formic acid were used as chemical extraction solvent and trolox was used as a standard respectively.

400 μ L of 0.01M copper (II)chloride, 400 μ L of 1 M ammonium acetate buffer (pH 7.0 adjusted with acetic acid) solution, 400 μ L of 0.0075 M neocuproin solution (prepared in 96% EtOH),

200 μL of extracts and 240 μL H_2O were mixed in a 24-well plate on an orbital shaker. After one hour 450 nm absorbance was recorded against a reagent blank.

Antioxidant activity of samples determined by using trolox calibration curve, Trolox equivalent antioxidant capacity (TEAC) value of samples were expressed as mg trolox equivalent per 100 g of dw of sample. Standard trolox was dissolved in 96% (volume/volume) ethanol to eight concentrations between 0.01- 0.0005 mM and all samples were analyzed in triplicate.

2.7. SENSORY ANALYSIS

2.7.1. Fruit Tablets

The sensory evaluation has been conducted to fruit tablets. The panel consisted of 8 trained panelists (4 females and 4 males, aged between 24 and 30 years-old). A numerical scale of 0 to 10 and 0.5 increments was used to determine the intensity of the sample attributes, where 0 represent none and 10 represent extremely strong. This scale is widely used because it is wide enough to cover the full density of sensory features; in addition, it is intuitive and easy to understand (Wojdyło et al., 2016)

The samples (7 parts) were dispensed in disposable, odorless plastic plates in each panel. Samples were taken at room temperature and the test room was held at 22 ± 2 °C with combination of natural and unnatural (fluorescent) light. The panelists have been trained to recognize different intensities of 8 sensory attributes. Moreover to help panelist to recognize the attributes we were created appropriate reference standards (Carus et al., 2017). As shown in the Table 2.4 Pantone colour scale was used as a standard for the color, citric acid for sour flavor, sucrose for sweet flavor, fresh fruits for Fruit ID, shortbread for hardness, fresh strawberry for fiberness and fresh carrot without peeling for crunchiness (Galindo et al., 2015).

Table 2.4: Reference standards for sensory analysis.

Attributes	Defination	References and Intensities
Appearance		
Color	Visual evaluation of the color intensity of the sample	Pantone 113C = 1.0; Pantone 116C =5.0; Pantone 119C =9.0
Flavor		
Sour	The taste stimulated by acids, such as citric	Citric acid $0.8\text{gL}^{-1}=3.5$
Sweet	The taste stimulated by sugars, such as sucrose	Sucrose solution $100\text{gL}^{-1}=6.5$
Fruit ID	A sweet and fruity flavor associated with fruit	Freshly fruits
After Taste	Time in which the specific flavor of the dried fruit flavor remains in the mouth after swallowing the sample	5 second=1 20 second=10
Texture		
Hardness	Force required to bite through	Shortbread=1 Fresh carrots (unpeeled) = 8.5
Fiberness	Stringy particles (size and amount)	Fresh strawberry= 3.0
Crunchiness	The intensity of audible noise at first chew with molars	Fresh carrots (unpeeled)=7.5

2.7.2. Fruit Powders

The sensory evaluation has been conducted to fruit powders, too. The panel conditions were as same as the conditions of fruit tablets panel. But serving of the samples were different. Formulations were prepared by using carriers, three different food products, popular in Turkey: honey, yogurt and milk (Ares et al., 2007). Fruit powder/carrier ratio in the formulations was 20/100 (w/w). Panel participants rated the appearance, taste and overall acceptability of the formulations and a numerical scale of 1 to 5 was used to determine the intensity of the sample attributes, where 0 represent "I did not like" and 5 represent "I like" (Sandri et al., 2017). All participants confirm that there is no component allergen in the products. Between the tests, panel participants drunk water and rinsed their mouths to reduce most of the residual effects. Powder samples with honey (3 part) and yogurt (3 part) were dispensed in disposable plastic

plates and powder samples with milk (3 part) were dispensed in glass cup (Castura et al., 2016). Plastic cups were not used because it release chemicals faster than normal when plastic is heated. All samples were taken at room temperature and the test room was held at 22 ± 2 °C but samples with milk were served at 50 ± 2 °C.

2.8. STATISTICAL ANALYSIS

All analyses were performed with three replicates. GraphPad Prism (version 7.00; GraphPad Software, San Diego, CA, USA) was used for statistical analysis and $p < 0.05$ was considered significant. The data was compared using ANOVA (one-way analysis of variance) followed by a Tukey post hoc test. Additionaly microsoft Office Excel 2011 software (Microsoft Co., Redmond, WA, USA) was used to calculate R², slope, intercept, LOD, and LOQ of the standards.

3. RESULTS

3.1. CHEMICAL FEATURES

3.1.1. Moisture and Ash Contents

The moisture content in another words the amount of water is used to measure the quantity of water present within the sample. The ash content is used to measure the quantity of mineral content which is a measure of the amount of specific inorganic components, present within the samples. Both of the ash contents and moisture contents are used to measure the quantity contained in a unit mass of bulk sample as a percentage of fraction by mass.

Table 3.1: Moisture content of the samples.

Moisture	Fig	Apricot	Quince
Fruit	81 ± 3	91 ± 3	83 ± 4
Dried	17 ± 2	13 ± 2	28 ± 4
Powder	7 ± 2	6 ± 2	14 ± 2

The presented data in this table consist of average values ± standard deviation of three independent replicates and expressed unit mass of bulk sample as a percentage of fraction by mass

Fruits have high water content, more than 80% of weights come from water, eating them contribute to your daily water intake. However the high water content makes them vulnerable to microbiological deterioration, so it becomes difficult to store and carry. Dried fruits, which had most of the water content removed through drying techniques, less than 30% of weights come from water. In this study after drying process the moisture content of dried fruits were decreased from 81%, 91% and 83% to 17%, 13% and 28% for fig, apricot and quince, respectively.

The low water content protects dried fruit from deterioration but is still not enough to long time storage. In order to make the fruits more resistant to microbiological deterioration, they need to be dried at lower water rates, but this causes hardening. Fruit powders can be an option that provides ease of consumption. In other words, powder technology makes them more resistant to microbiological spoilage due to low water content, and it provides ease of transportation and long time storage.

Moisture content of fruit powder varies according to the physical and chemical structure of the fruit. In this study, fig, apricot and quince fruit has reached the suitable form for powder technology at 15%, 7% and 6% moisture content respectively.

Table 3.2: Ash content of the samples.

Ash Content (%)	Fig	Apricot	Quince
Fruit	0.69 ± 0.04	1.74 ± 0.08	0.44 ± 0.07
Dried	3.00 ± 0.15	7.62 ± 0.16	1.85 ± 0.19
Powder	3.36 ± 0.17	8.53 ± 0.19	2.21 ± 0.14

The presented data in this table consist of average values ± standard deviation of three independent replicates and expressed unit mass of bulk sample as a percentage of fraction by mass

The ash contents of all fruits exhibit similarity to the ash content of the same fruit found in the Turkey national food composition database. The apricot fruit ash content is higher than the other two fruits, just like the dried forms. Nevertheless the powder form is even higher because of the less of moisture.

3.1.2. Color Features

Color measurement, is an important analysis to determine the the quality of fruits and the drying efficiency (Lazara et al., 2019). For this purpose, CIELAB color measurment method was used to determine the color parameters of fresh and dried fruits and the obtained data are given in Table 3.3. The color coordinates (L^* , a^* and b^*) were used to determine the location of any color in the CIELAB color space (Sandaval et al.,2018; Gouw et al., 2017).

L^* value in the CIELAB color space is defined as the lightness and it ranges from 0 (black) to 100 (white). a^* value in the CIELAB color space ranges from 0 to 60, positive a^* values are red, negative a^* values are green color. b^* value in the CIELAB color space ranges from 0 to 60; positive b^* values are yellow, negative b^* values are blue color. The 0 values of a^* and b^* show that they are colorless. The C^* (chroma) value is a parameter calculated by using color coordinates a^* and b^* from CIELAB color space.

C^* value is defined as the saturation ranges from 0 (mat, dull tones) to 60 (bright vivid tones). Similarly H^* (hue) value, color related property, is a parameter calculated by using color coordinates a^* and b^* from CIELAB color space. It is ranges between 0° to 360° where 0° and

360° is red-purple, 90° is yellow, 180° is green and 270° is blue (Sandaval et al., 2018; Gouw et al., 2017).

Table 3.3: Color feature of the samples.

<u>Colour</u>		Fig	Apricot	Quince
Fruit (skin)	<i>L</i>	33.03 ± 0,76	65.97 ± 0,38	76.55 ± 0,69
	<i>a*</i>	5.87 ± 0,46	22.24 ± 0,53	-2.06 ± 0,08
	<i>b*</i>	-4.85 ± 0,25	49.85 ± 0,04	33.05 ± 0,83
	<i>C</i>	7,62 ± 0,46	54,59 ± 0,21	33,12 ± 0,83
	<i>H</i>	320,38 ± 1,82	65,95 ± 0,51	273,57 ± 0,15
Dried (skin)	<i>L</i>	25.75 ± 0,52	49.85 ± 0,65	59.08 ± 1,07
	<i>a*</i>	10.23 ± 0,58	38.93 ± 0,23	6.33 ± 0,48
	<i>b*</i>	-3.75 ± 0,28	22.22 ± 0,46	32.24 ± 0,44
	<i>C</i>	10,89 ± 0,63	47,15 ± 0,50	34,82 ± 0,52
	<i>H</i>	339,90 ± 0,38	61,88 ± 0,18	199,54 ± 0,63
Powder	<i>L</i>	46.06 ± 0,87	48.58 ± 0,86	55.43 ± 0,87
	<i>a*</i>	9.45 ± 0,16	12.01 ± 0,40	12.09 ± 0,05
	<i>b*</i>	10.26 ± 0,62	17.52 ± 0,09	22.07 ± 1,36
	<i>C</i>	13,95 ± 0,56	21,25 ± 0,22	25,17 ± 1,20
	<i>H±</i>	47,31 ± 1,28	55,57 ± 0,95	61,24 ± 1,50

The presented data in this table consist of average values ± standard deviation of three independent replicates. *L**, *a**, *b**, *C* and *H°* are color parameters: lightness/darkness, red/green, yellow/blue, chroma, and hue angle, respectively.

According to the result we can see *a** values are positive. So we can say that red color is more dominant than green color in all of the dried and powdered products. Similarly *b** values are positive and we can say that yellow color is more dominant than blue color in all of the dried and powdered products. But *b** value of dried fig is negative and it means blue color is dominant

then yellow color. Probably anticyonins in fig skin caused the negative "b" value and blue color. Additionally because of the grinding process fig powder has positive "b" value.

3.1.3. Activity of Water

Undoubtedly, drying is one of the oldest methods of protecting food against chemical and microbiological spoilage. The determination of the water content in the food during the drying process gives information about the stability of the food product studied but is not sufficient. Water activity (aw) can provide direct information on microorganism proliferation.

In this study aw value of the samples were measured and indicated below. Dried fruits have water activity value under 80 and powder forms have under 50.

Table 3.4: Water activity of the samples.

Water Activity	Fig	Apricot	Quince
Fruit	0.951 ± 0.0006	0.979 ± 0.0006	0.945 ± 0.0006
Dried	0.712 ± 0.0006	0.706 ± 0.0012	0.711 ± 0.0006
Powder	0.261 ± 0.0006	0.273 ± 0.0006	0.383 ± 0.0006

The presented data in this table consist of average values ± standard deviation of three independent replicates.

3.2. TECHNO-FUNCTIONAL FEATURES OF POWDERS

3.2.1. Oil / Water Holding Capacity

The water holding capacity is ability of holding the water added to the mixture in which the powder is contained or its own water. Similarly, oil holding capacity is ability of holding the oil added to the mixture in which the powder is contained. In this study water and oil holding capacity of the samples were measured and indicated below.

These values were in accordance with Gouv and friends (2017), where fruit and vegetables (apple, pomace, orange, and yellow pea) had oil holding capacity less than 2 g oil/g.

The water holding capacity of quince in the study found 7.82 g water/g matter and was higher as compared to oat bran (2.10 g), rice bran (4.89 g), wheat bran (5.03 g) and soy flour (6.75 g) (Felli et al., 2018)

Table 3.5: Water holding capacity and oil holding capacity of powder samples.

	Fig	Apricot	Quince
Water Holding Capacity (g water /g dry weight)	3.17 ± 0.06	1.53 ± 0.02	7.82± 0.07
Oil Holding Capacity (g oil /g dry weight)	1.13 ± 0.02	1.42 ± 0.02	0.99 ± 0.02

The presented data in this table consist of average values ± standard deviation of three independent replicates.

3.2.2. Wettability and Solubility

Reconstitution of powder products is important and is desirable to dissolve rapidly for ease of use. For this purpose, the wettability and the solubility features of powder products were measured and shown in Table3.6.

Table 3.6: Wettability and solubility values of the samples.

	Fig	Apricot	Quince
Wettability (Second)	117 ± 2.52	157 ± 5.29	113 ± 2.00
Solubility (Second)	113 ± 3.06	261 ± 2.00	58 ± 5.00

The presented data in this table consist of average values ± standard deviation of three independent replicates.

3.2.3. Density and Flow Features

The density and flow features of fruit powders have an important role on tableting, storage and packaging. The density features of the fruit powders include bulk density, tapped density and true density (particle size) depend on the particle features of the product. In this study density features of the samples were measured and indicated below (Table 3.7).

Table 3.7: Density feature of samples.

	Fig	Apricot	Quince
Bulk Density (kgm⁻³)	667 ± 22	714 ± 25	461 ± 16
Tap Density (kgm⁻³)	910 ± 41	968 ± 27	858 ± 44
True Density (Particle Density)	1442 ± 24	1456 ± 24	883 ± 43
Apparent Density	0.46 ± 0.01	0.49± 0.03	0.52± 0.03
Porosity	0.54± 0.01	0.51± 0.03	0.48± 0.03

The presented data in this table consist of average values ± standard deviation of three independent replicates.

Dirim and friends (2015) obtained higher density value for quince then our quince values but they expressed close value for flow features (Table 3.8).

Table 3.8: Flow feature of samples.

	Fig	Apricot	Quince
Housner Ratio (HR)	1.37 ± 0.09	1.36 ± 0.08	1.86 ± 0.16
Carr Index (CI)	26.60 ± 5.13	26.09 ± 4.51	46.05 ± 4.47

The presented data in this table consist of average values $\pm$ standard deviation of three independent replicates

3.3. SPECTROPHOTOMETRIC ANALYSIS

The average moisture content in fresh fruits were decreased from 85 % to 20 % and 4 % for dried fruits and powdered fruits, respectively. The results in current study were expressed on dry weight basis to eliminate the differences in moisture contents.

3.3.1. Total Phenolics

The total phenolics of the all samples in the current study was given as mg gallic acid equivalent in 100 g dry weight sample.

Table 3.9: Total phenolics of the substances symbolizing the matter before digestion.

INITIAL	F	A	Q	F/A	F/Q	AQ	FAQ
Fruit	700 ± 21	837 ± 22	786 ± 13	736 ± 22	815 ± 17	959 ± 18	848 ± 19
Dried	515 ± 16	722 ± 27	470 ± 85	705 ± 26	773 ± 26	851 ± 26	817 ± 26
Powder	625 ± 10	735 ± 14	597 ± 10	729 ± 13	685 ± 18	768 ± 15	703 ± 16

All contents are expressed as mg gallic acid equivalent in 100 g dry weight sample. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

The total phenolics obtained for fresh fig (700 ± 21 mg GAE/100 g dw) was higher than the literature, however Oguzhan (2015) measured 1090-1110 (mg GAE/100 g dw). Kamiloglu and friends (2014) expressed close total phenolics (493 ± 59 mg GAE/100 g dw) for purple figs (Table 3.9). Purple figs are richer then yellow figs when compared in phenolic material (Kamiloglu et al., 2015).

The total phenolics obtained in this study for fresh apricot was 837 (mg GAE/100 g dw) shown at Table 3.9 and it was higher than most of the results reported in the literature. But Polat (2018), Kamiloglu and friends (2014) measured close total phenolics 175-307, 211 mg gallic acid for 100 g fresh weight, respectively. The concentrations of bioactive compounds in fruits and vegetables vary according to the factors before/after harvest and genetic factors.

The total phenolics obtained in this study for fresh quince was 786 (mg GAE/100 g dw) shown at Table 3.9 and it was higher than most of the results reported in the literature (Torres et al., 2019). Legua and friends (2013) expressed close total phenolic concentration ranged from 40 to 100 mg in 100 g flesh and from 200 to 430 mg in 100 g skin, respectively.

Table 3.10: Total phenolics of the substances symbolizing the matter after gastric digestion.

GI	F	A	Q	F/A	F/Q	AQ	FAQ
Fruit	3138 ± 67	14950 ± 374	5699 ± 112	6675 ± 166	4648 ± 155	8706 ± 226	7805 ± 152
Dried	2602 ± 414	2443 ± 91	2355 ± 716	1325 ± 322	1614 ± 340	1985 ± 216	2231 ± 205
Powder	1218 ± 197	2536 ± 442	3586 ± 627	2875 ± 573	2715 ± 261	3317 ± 589	4036 ± 598

All contents are expressed as mg gallic acid equivalent in 100 g dry weight sample. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

The total phenolics of all fruits were increased after gastro intestinal phase shown in Table 3.10. Phenolic glycosides could be acidic hydrolysis and their aglycone might be occurred during digestion and result in this increasing (Kamiloglu et al., 2014).

Table 3.11: Total phenolics of the substances symbolizing the matter which entered into the blood system.

IN	F	A	Q	F/A	F/Q	AQ	FAQ
Fruit	496 ± 31	895 ± 59	443 ± 30	1147 ± 83	717 ± 82	1652 ± 38	799 ± 26
Dried	327 ± 31	616 ± 46	500 ± 47	867 ± 253	1013 ± 266	522 ± 130	957 ± 253
Powder	312 ± 6	409 ± 8	427 ± 4	692 ± 23	792 ± 26	724 ± 19	364 ± 71

All contents are expressed as mg gallic acid equivalent in 100 g dry weight sample. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

The total phenolics of Out phase were larger than the Post gastric phase and In phase (Table 3.11). The pancreatin enzyme which was used in intestinal digestion may have facilitated the release of phenolic compounds bound to the food matrix (Goncalves et al., 2019).

Table 3.12: Total phenolics of the substances symbolizing the matter which stayed in the gastrointestinal system.

OUT	F	A	Q	F/A	F/Q	AQ	FAQ
Fruit	2818 ± 185	31981 ± 786	15806 ± 857	24288 ± 862	9545 ± 420	20691 ± 753	13621 ± 793
Dried	2765 ± 99	3196 ± 63	3927 ± 188	2614 ± 86	2844 ± 118	8170 ± 75	2958 ± 96
Powder	2084 ± 215	2189 ± 170	1411 ± 12	1246 ± 73	1365 ± 147	2395 ± 104	2406 ± 208

All contents are expressed as mg gallic acid equivalent in 100 g dry weight sample. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

The difference between phases (Initial, Post gastric, In and Out) in phenolic behavior which varies according to many different factors such as temperature, acidity, enzyme presence, is due to different phenolic profiles in different fruits which have distinctive phenolic profile (Wani et al., 2017).

3.3.2. Total Flavonoids

The total flavonoids of the all samples in the current study was expressed as mg catechin equivalent/100 g dry weight sample.

Table 3.13: Total flavonoids of the the substances symbolizing the matter before digestion.

INITIAL	F	A	Q	F/A	F/Q	AQ	FAQ
Fruit	35 ± 0.63	72 ± 1.13	206 ± 3.91	85 ± 0.96	69 ± 0.83	117 ± 0.71	81 ± 0.87
Dried	67 ± 0.01	178 ± 0.68	257 ± 4.20	152 ± 0.31	167 ± 0.01	265 ± 1.42	237 ± 0.63
Powder	81 ± 0.47	90 ± 0.01	94 ± 0.47	98 ± 0.31	99 ± 0.01	96 ± 0.31	83 ± 0.01

All contents are expressed as mg catechin equivalent in 100 g dry weight sample. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

The total flavonoids of fig fruits in this study measured 35 mg CE in 100 g dw (Table 3.13) and Kamiloglu and friends (2014) measured close total flavonoids in fruit pulp (44 ± 13 mg CE/100 g dw) for purple figs.

The total flavonoids of apricot fruits in this study measured 72 mg CE in 100 g dw (Table 3.13) and Wani and friends measured total flavonoid content in 14 apricot varieties grown in north India and obtained different values ranges 12 to 36 mg in 100 g fresh fruit.

Table 3.14: Total flavonoids of the substances symbolizing the matter after gastric digestion.

GI	F	A	Q	F/A	F/Q	AQ	FAQ
Fruit	71 ± 0.42	87 ± 0.74	67 ± 3.80	156 ± 2.57	47 ± 2.40	83 ± 0.01	72 ± 1.33
Dried	46 ± 2.18	73 ± 2.75	8 ± 0.67	4 ± 0.63	5 ± 0.47	19 ± 0.42	121 ± 4.69
Powder	101 ± 2.16	81 ± 0.50	52 ± 2.02	76 ± 0.42	77 ± 1.15	57 ± 0.50	105 ± 0.50

All contents are expressed as mg catechin equivalent in 100 g dry weight sample. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

Although the total flavonoids of all samples were decreased after gastro intestinal phase, the total flavonoids of quince was deeply decrease. The decrease in the amount of quince total flavonoid content, which varies according to many different factors such as temperature, acidity, enzyme presence may be due to the susceptibility of the flavonoid profile of quince fruit to acidic environment.

Table 3.15: Total flavonoids of the substances symbolizing the matter which entered into the blood system.

IN	F	A	Q	F/A	F/Q	AQ	FAQ
Fruit	62 ± 8	223 ± 68	155 ± 33	163 ± 25	157 ± 37	113 ± 19	137 ± 50
Dried	20 ± 0.74	50 ± 1.71	43 ± 2.02	30 ± 1.25	44 ± 2.16	20 ± 1.79	35 ± 1.49
Powder	25 ± 0.50	41 ± 0.50	52 ± 0.01	30 ± 0.79	29 ± 0.50	44 ± 0.01	28 ± 0.01

All contents are expressed as mg gallic acid equivalent in 100 g dry weight sample. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

The total flavonoid values measured in the GI phase were lower than the total flavonoid values measured in the in and out phases, which could be due to the acidic environment.

Table 3.16: Total flavonoids of the substances symbolizing the matter which stayed in the gastrointestinal system.

OUT	F	A	Q	F/A	F/Q	AQ	FAQ
Fruit	131 ± 42.34	456 ± 33.47	94 ± 16.73	230 ± 32.91	71 ± 21.98	266 ± 35.13	204 ± 46.37
Dried	47 ± 1.93	62 ± 4.78	139 ± 9.37	94 ± 3.75	126 ± 1.69	32 ± 1.94	70 ± 0.42
Powder	60 ± 0.01	95 ± 2.16	81 ± 0.50	111 ± 1.15	69 ± 0.01	137 ± 0.01	65 ± 0.79

All contents are expressed as mg gallic acid equivalent in 100 g dry weight sample. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

3.3.3. Total Antioxidant Capacity

The total antioxidant capacity of the all samples in the current study was expressed as mg trolox equivalent/100 g dry weight sample.

Table 3.17: Total antioxidant capacity of the substances symbolizing the matter before digestion.

INITIAL	F	A	Q	F/A	F/Q	AQ	FAQ
Fruit	1146 ± 145	1978 ± 173	1679 ± 144	928 ± 103	949 ± 85	1144 ± 103	943 ± 122
Dried	1025 ± 48	1228 ± 39	1105 ± 24	651 ± 30	745 ± 31	1194 ± 42	1047 ± 32
Powder	960 ± 38	959 ± 22	880 ± 32	980 ± 120	1110 ± 42	1244 ± 42	1321 ± 44

All contents are expressed as mg trolox equivalent in 100 g dry weight sample. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

The total antioxidant capacity of fig fruit and apricot fruit were 1146 mg TE in 100 g dry weight and 1978 mg TE in 100 g dry weight, respectively (Table 3.17). The total antioxidant capacity of dried fig fruit and apricot fruit were 1025 mg TE in 100 g dry weight and 1228 mg TE in 100 g dry weight, respectively. Kamiloglu and friends (2014) measured close to this value 152 mg TE in 100 g fresh weight for dried purple figs and 374 mg TE in 100 g fresh weight for dried apricots.

Table 3.18: Total antioxidant capacity of the substances symbolizing the matter after gastric digestion.

GI	F	A	Q	F/A	F/Q	AQ	FAQ
Fruit	3766 ± 100	9170± 595	5760 ±831	3946± 819	2874 ± 609	2859± 602	2639± 229
Dried	1231 ± 109	1273 ± 493	621 ± 59	705 ± 138	1434 ± 294	1083± 128	678± 191
Powder	1012 ± 129	1071 ± 188	1076± 316	1106 ± 90	1389 ± 323	1046± 226	1442± 246

All contents are expressed as mg trolox equivalent in 100 g dry weight sample. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

Table 3.19: Total antioxidant capacity of the substances symbolizing the matter which entered into the blood system.

IN	F	A	Q	F/A	F/Q	AQ	FAQ
Fruit	843 ± 142	3455 ± 511	2312 ± 447	922 ± 167	1122± 154	856± 143	458± 123
Dried	696 ± 129	927± 212	837 ± 33	497 ± 194	840 ± 195	979 ± 105	962 ± 204
Powder	399 ± 222	517 ± 180	666 ± 55	961 ± 91	919 ± 122	1181 ± 138	880 ± 115

All contents are expressed as mg trolox equivalent in 100 g dry weight sample. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures

The difference between phases (Initial, Post gastric, In and Out) in antioxidant behavior which varies according to many different factors such as temperature, acidity, enzyme presence, is due to different antioxidant profiles in different fruits which have distinctive antioxidant profile (Wani et al, 2017).

Table 3.20: Total antioxidant capacity of the substances symbolizing the matter which stayed in the gastrointestinal system.

OUT	F	A	Q	F/A	F/Q	AQ	FAQ
Fruit	7136± 948	12281± 1021	6520± 883	6254± 823	7550± 8884	6228± 801	7394± 482
Dried	1491 ± 147	1568± 238	837± 52	989± 90	1576± 157	1183± 201	1561± 172
Powder	1464± 59	1569± 294	888± 119	2552± 416	1582± 319	2058 ± 153	1683± 168

All contents are expressed as mg trolox equivalent in 100 g dry weight sample. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures

3.4. SENSORY ANALYSIS

3.4.1. Fruit Tablets

Sensory analysis is a scientific method for measuring and analyzing the responses to the features of foodstuffs sensed by sensory organs. In this study sensory analysis of fruit tablet was performed and the results are expressed below.

Table 3.21: Descriptive sensory analysis of fruit tablets.

	F	A	Q	FA	FQ	AQ	FAQ
Color	6.4 ± 0.7	7.1 ± 0.7	4.6 ± 0.5	7.4 ± 0.8	5.6 ± 0.6	6.4 ± 0.7	6.4 ± 0.7
Sour	5.6 ± 0.6	7.4 ± 0.8	6.4 ± 0.7	6.4 ± 0.7	5.6 ± 0.6	5.6 ± 0.6	6.4 ± 0.7
Sweet	3.6 ± 0.4	4.6 ± 0.5	2.9 ± 0.3	4.6 ± 0.5	3.6 ± 0.4	3.6 ± 0.4	3.6 ± 0.4
Fruit ID	7.4 ± 0.8	5.6 ± 0.6	6.4 ± 0.7	7.4 ± 0.8	7.4 ± 0.8	7.4 ± 0.8	6.5 ± 0.8
After Taste	6.4 ± 0.7	7.4 ± 0.8	4.6 ± 0.5	6.4 ± 0.7	5.6 ± 0.6	6.4 ± 0.7	6.4 ± 0.7
Hardness	5.6 ± 0.6	4.6 ± 0.5	5.6 ± 0.6	4.6 ± 0.5	5.6 ± 0.6	5.6 ± 0.6	4.6 ± 0.5
Fiberness	7.4 ± 0.8	5.6 ± 0.6	7.6 ± 0.6	6.4 ± 0.7	7.4 ± 0.8	6.4 ± 0.7	7.4 ± 0.8
Crunchiness	2.9 ± 0.3	4.6 ± 0.5	3.6 ± 0.4	3.8 ± 0.6	4.3 ± 0.5	5.1 ± 1.0	3.7 ± 0.4

F, A, Q are fruit names: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

A numerical scale of 0 to 10 and 0.5 increments was used to determine the intensity of the sample attributes, where 0 represent none and 10 represent extremely strong

The samples (7 parts) were dispensed in disposable, odorless plastic plates in each panel. Samples were taken at room temperature and the test room was held at 22 ± 2 °C with combination of natural and unnatural (fluorescent) light. The panelists have been trained to recognize different intensities of 8 sensory attributes.

3.4.2. Fruit Powders

The sensory evaluation of fruit powders was conducted and at the panel scale of 1 to 5 was used to determine the intensity of the sample attributes, where 0 represent "I did not like" and 5 represent "I like". The questions and the results are below.

Question 1 is “Mark the score that best describes your feeling about the appearance of the product you are given”.

Question 2 is “Mark the score that best describes your feeling about the taste of the product you are given”.

Question 3 is “Mark the score that best describes your feeling about the overall acceptability of the product you are given”

Table 3.22: Descriptive sensory analysis of fruit powders with yogurt.

	Fig	Apricot	Quince
Question 1	2.5 ± 0.5	2.1 ± 0.4	3.5 ± 0.5
Question 2	1.7 ± 0.4	1.1 ± 0.0	2.3 ± 0.4
Question 3	3.5 ± 0.5	3.1 ± 0.5	4.3 ± 0.7

Table 3.23: Descriptive sensory analysis of fruit powders with honey.

	Fig	Apricot	Quince
Question 1	4.3 ± 0.7	3.5 ± 0.5	4.1 ± 0.7
Question 2	3.5 ± 0.5	3.5 ± 0.5	4.1 ± 0.7
Question 3	3.5 ± 0.5	2.5 ± 0.3	4.1 ± 0.7

Table 3.24: Descriptive sensory analysis of fruit powders with milk.

	Fig	Apricot	Quince
Question 1	2.5 ± 0.5	2.0 ± 0.4	3.0 ± 0.50
Question 2	2.5 ± 0.5	3.0 ± 0.5	3.0 ± 0.37
Question 3	2.5 ± 0.5	2.0 ± 0.3	3.0 ± 0.50

Between the tests, panel participants drunk water and rinsed their mouths to reduce most of the residual effects. Powder samples with honey (3 part) and yogurt (3 part) were dispensed in disposable plastic plates and powder samples with milk (3 part) were dispensed in glass cup (Castura et al., 2016).



4. DISCUSSION

4.1. CHEMICAL FEATURES

4.1.1. Moisture and Ash Contents

Fruits have high water content, more than 80% of weights come from water, eating them contribute to your daily water intake. However the high water content makes them vulnerable to microbiological deterioration, so it becomes difficult to store and carry. Dried fruits, which had most of the water content removed through drying techniques, less than 30% of weights come from water.

The low water content protects dried fruit from deterioration but is still not enough to long time storage. In order to make the fruits more resistant to microbiological deterioration, they need to be dried at lower water rates, but this causes hardening. Fruit powders can be an option that provides ease of consumption. In other words, powder technology makes them more resistant to microbiological spoilage due to low water content, and it provides ease of transportation and long time storage.

4.1.2. Color Features

Fruits contain considerable amount of sugars which have the ability to interact with amino acids which is the non-enzymatic browning reaction. Drying process triggers the reaction by which occurs brown colored compound. Oxidation is the other reaction which has an effect on color of drying fruits (Desa et al., 2019).

Color measurement was performed to analysis drying effects on fruits (Lazara et al., 2019). For this purpose, CIELAB color measurement method was used. Shown in the Table 3.3, all of the L^* values (lightness) of dried fruits were decreased because of the drying process, due to the direct contact of heat with the skin and oxidation with the air during drying. Similarly the a^* values (positive a^* values are red, negative a^* values are green) of dried fruits increased because of the non-enzymatic browning reaction. However, the a^* value of fruit powders except for quince powder decreased because of the grinding process by which lighter pulp color mixed with the skin color. a^* value of the quince powder increased because of the second drying process which was continued after pregrinding was applied to the quince powder. The color of

apricot and quince fruits were yellow so that result in positive b value which decreased because of the non-enzymatic browning reaction by drying process. Although the b* value of fig was negative because of the huge amount of anthocyanin in the skin, it increased after grinding process by which pulp color mixed with the skin color. The C* (chroma) value gives the saturation of the color. A decrease in C* value means that the brightness of the color becomes dull. Water found in fruits has a positive effect on the brightness of the fruit color. Depending on the loss of water, there was also a loss of color.

4.1.3. Activity of Water

In this study aw value of the samples were measured and indicated below. Dried fruits have water activity value under 80 and powder forms have under 50. The growth of pathogenic bacteria reduces under water activity 80 but should be below 50 to be microbiologically stable (Victor et al.,2017). So powder form are more stable then dried form against microorganism proliferation.

4.2. TECHNO-FUNCTIONAL FEATURES

4.2.1. Oil / Water Holding Capacity

The water holding capacity which directly affects process efficiency is ability of holding the water added to the mixture in which the powder is contained or its own water. Similarly, oil holding capacity of powder is ability of holding the oil which is added to the mixture. Both water holding capacity and oil holding capacity has a critical role on textural quality and functional features of final product in which the powder is contained (Felli et al., 2018).

In this study, water holding capacity of quince powder (7.82 g/g) is larger then the fig powder water holding capacity (3.17 g/g) which is larger then the apricot powder water holding capacity (1.53 g/g).

When the oil holding capacities are examined, apricot powder value (1.42 g/g) is larger then the fig powder value (1.13 g/g), and fig powder value is larger then the quince powder value (0.99 g/g)

When the relationship between fiber quantity and water holding capacity is examined, it is seen that there is positive correlation (Figure 4.1). The high fiber ratio resulted in many voids in which water could be held, resulting in a high-water holding capacity (Gorecka et al., 2010).

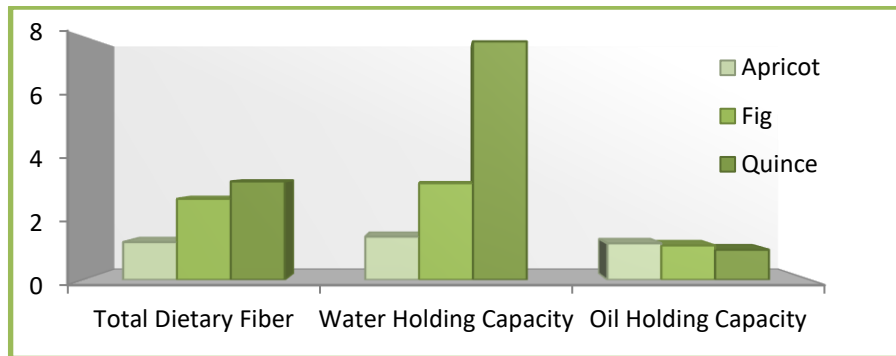


Figure 4.1: Comparison of the dietary content, water holding capacity and oil holding capacity.

In the microstructures of the fruit powders, the fiber may closely compact, and many bundles of fiber matrix may have formed in the powders, which may result from the interaction of fiber-fiber interactions through hydrogen bonds, van der Waals forces or coulomb interactions (Gouw et al., 2017). These fiber-fiber interactions can create a hydrophobic surface or a hidrofiliic surface and result in less oil holding capacity or less water holding capacity.

Table 4.1: Dietary content of the fruits (values per 100 g edible portion).

	Fiber, Total Dietary	Fiber Total Soluble	Fiber Total insoluble
Fig	2,66	0,80	1,86
Apricot	1,24	0,27	0,96
Quince	3,23	0,47	2,76

As a result, quince powder has a high-water holding capacity and at future doh water holding capacity may evaluate by using farinograpf (Sudha et al., 2007). On the other hand, apricot powder has a high oil holding capacity and it can be used for industrial production of fried product (Felli et al., 2018).

4.2.2. Wettability and Solubility

Wettability may be change due to its physical structure of powder such as particle size, density, porosity, surface tension, surface area and surface activity of the particle, as well as its carbohydrate, fat and protein composition on its surface (Dirim et al., 2017). The moisture content of the powder also influences wettability and dissolution (Goula and Adamopoulos, 2008). For this reason, quince powder has the highest moisture content and has been shown to be wettability and solubility for shorter. However, apricot powder has the lowest moisture content and has been shown to be wettability and solubility for longer.

4.2.3. Density and Flow Features

The density features of fruit powders have an important role on tableting, storage and packaging. The density features of the fruit powders include bulk density, tapped density and true density (particle size) depend on the particle features of the product.

Low bulk density powders, which have less air with, are desirable because it decreases oxidation reaxtion because of the lack of air. Furthe rmore high bulk density increases package volume (Elmas et al., 2019). Fig powder density features are similar to apricot powder, on the other hand quince powder has a lower density property than the others. Bulk density propertie is affected by drying process (Krokida et al., 2007). Bulk density of quince powders which have applied vacuum drying is lower then fig and apricot powders which have applied conventional drying tehnique. The large difference between the bulk density and the tapped density indicates that the product have lower flowability (Elmas et al., 2019). Quince powder, has larger difference between the bulk density and the tapped density, is not expected to have better flow features then the others.

Porosity of fruit powders are an important criterion for flowability. Regular shape of the powders is desirable because it increases flowability which is related with porosity (Yusof et al., 2015). Figs and apricot powders have high porosity values and are expected to have good flow features.

One of the factors affecting the powder flowability is the moisture content which have a negative effect on flowability. Such that the higher degree can lead to reduced flowability. Quince powder, has higher moister content, is not expected to have better flow features then the others (Yusof et al., 2015).

Flowability of powders is estimated with the Carr Index or Housner ratio which are measure powder arch stability, strength and interparticle friction (Yusof et al., 2015; Kumar et al., 2001; Housner, 1967). The scientists defined ranges for the HR for estimating flowability: $1.0 < HR < 1.1$, for a free-flowing powder; $1.1 < HR < 1.25$, for a medium-flowing p; $1.25 < HR < 1.4$, for a difficult-flowing (Hayes et al., 1987; Housner, 1967). Carr who constructed flowability index defined ranges for the CI for estimating flowability: $5\% < CI < 15\%$, for a excellent flowing; $15\% < CI < 25\%$, for a medium-flowing; $25\% < CI$ for a difficult-flowing (Yusof et al., 2015; Carr, 1965)

When Carr Index and Hausner Ratio value are examined, it is observed that fig and apricot powders have better flowabilty than quince powder but all of the powders are diffucult flowing powders. Therefore, it may be necessary to add flow enhancer in industrial production where one of these powder is used.

4.3. SPECTROPHOTOMETRIC ANALYSIS

In these analysis trolox, gallic acid and catechin were used as standard, and standard calibration curves were obtained. In the regression analysis given in Table 4.2, x: concentration, y: absorbance, r: correlation coefficient, % RSD: percentage relative standard deviation value, LOD limit of detection and LOQ means limit of quantification.

Table 4.2: Regression analysis of standards.

Standards	Regression Equations	(r)	% RSD (n=5)	LOD (mol L ⁻¹)	LOQ (mol L ⁻¹)
Trolox	$y = 1.6 \times 10^4 X - 0.005$	0.99	0.29	3.9×10^{-6}	1.2×10^{-5}
Gallic acid	$y = 1 \times 10^3 X + 0.0044$	0.99	0.66	1.6×10^{-5}	5×10^{-5}
Catechin	$y = 4.2 \times 10^3 X - 0.0075$	0.99	1.60	6.5×10^{-5}	1.9×10^{-4}

x: concentration, y: absorbance and r: correlation coefficient; % RSD: percentage relative standard deviation; LOD (Limit of Detection): refers to the lowest amount of substance that can be determined. LOQ (Limit of Quantification): refers to the lowest amount of substance that can be quantified.

4.3.1. Total Phenolics

Fruits are valuable in health and contain a large number of phytochemicals, one of which is phenolic compounds. However, phenolic compounds are sensitive to temperature and oxidation. In this study, figs, apricots and quince fruits were dried and powdered. Figure 4.2 shows the effects of drying and powdering processes on phenolic compounds.

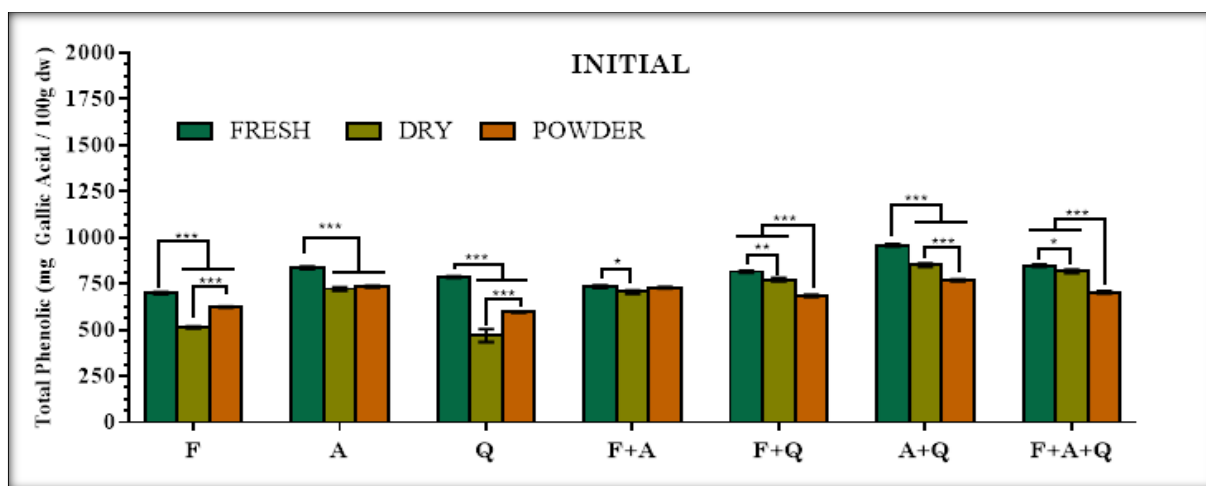


Figure 4.2: Drying effect on total phenolics of fruits. All contents are given as mg gallic acid equivalent in 100 g dry weight sample. Graph represents the average values $\pm$ standard deviation of three independent replicates. Different characters above bars represent statistically significant differences ($p < 0.05$). P values were determined by one-way ANOVA using Tukey's multiple comparison test. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

According to Figure 4.2, the fruits contain higher phenolic compounds than dried and powdered forms. Although the lowest amount of phenolic compound is seen in most of the dried form, they have close values with powder forms. For this reason, dried fruit and fruit powder are close to the phenolic compound content.

When the phenolic content of fruit mixtures is examined, it is seen that the fruit forms are close to dry and powdered forms. This may be due to the oxidation of phenolic compounds by contact with air in the mixing stage.

However, when evaluated in terms of health, the phenolic compound values that the body can benefit from are also important. For this reason, in our study *in vitro* digestion simulations were performed and the phenolic compounds passed from the small intestine to the blood after consumption of the products were compared in Figure 4.3.

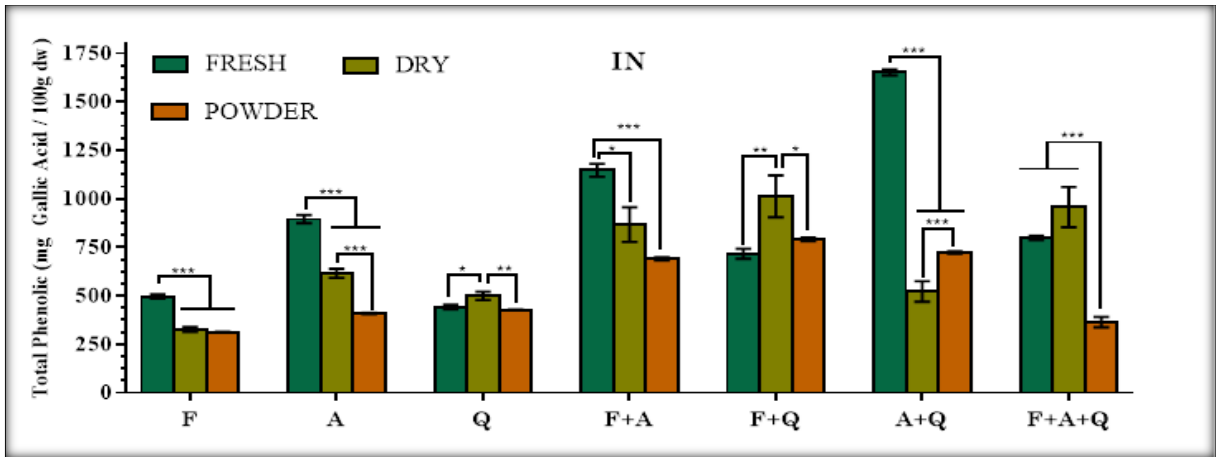


Figure 4.3: Bioaccessibility of total phenolics after drying process All contents are given as mg gallic acid equivalent in 100 g dry weight sample. Graph represents the average values $\pm$ standard deviation of three independent replicates. Different characters above bars represent statistically significant differences ($p < 0.05$). P values were determined by one-way ANOVA using Tukey's multiple comparison test. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

Each fruit has its own complex phenolic compound profile. If fruits are consumed as a mixture, phenolic compounds from different fruits may have a synergistic effect in absorption from the small intestine to the blood. In order to reach more detailed information, recovery values of mixed fruits were calculated and shown in Figure 4.4. The recovery calculation shown in Equation 4.1, the values of two different fruits were collected and divided into two then the % recovery values were calculated by proportioning the values of the mixture product to the two fruits.

$$\% \text{ Recovery of Fruit}_{AB} = \left(\frac{\text{Value}_{AB}}{\frac{\text{Value}_A + \text{Value}_B}{2}} \right) * 100 \quad (4.1)$$

According to the Figure 4.4 all of the fruit mixtures have better bioaccessibility than the alone except dried apricot/quince mixture and powdered fig/apricot/quince mixture. Although the recovery value of the dried apricot/quince mixture and powdered fig/apricot/quince mixture smaller than the one hundred percent, they are close to this value. These results indicate that there is a synergy between fruits in phenolic transport from small intestine to blood.

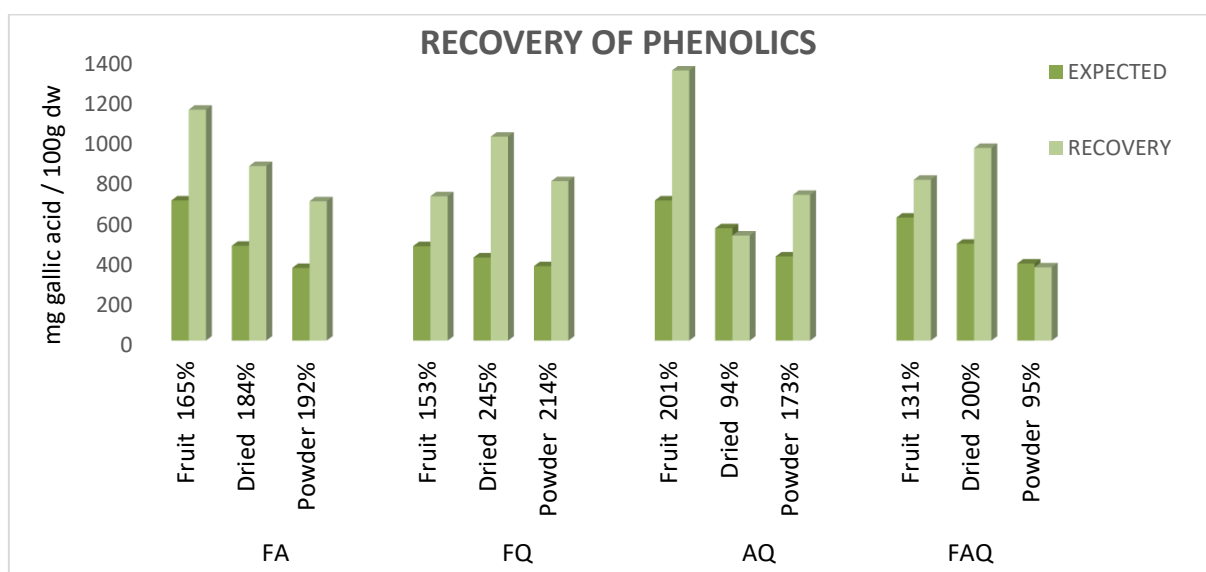


Figure 4.4: Recovery total phenolic compounds of fruit mixtures. All contents are given as mg gallic acid equivalent in 100 g dry weight sample. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

4.3.2. Total Flavonoids

One of the important phytochemicals found in fruits is flavonoids which has a considerable role for a healthy life. In our study, drying and powdering processes were applied to the fruits and the effect of drying method on flavonoids was shown in Figure 4.5

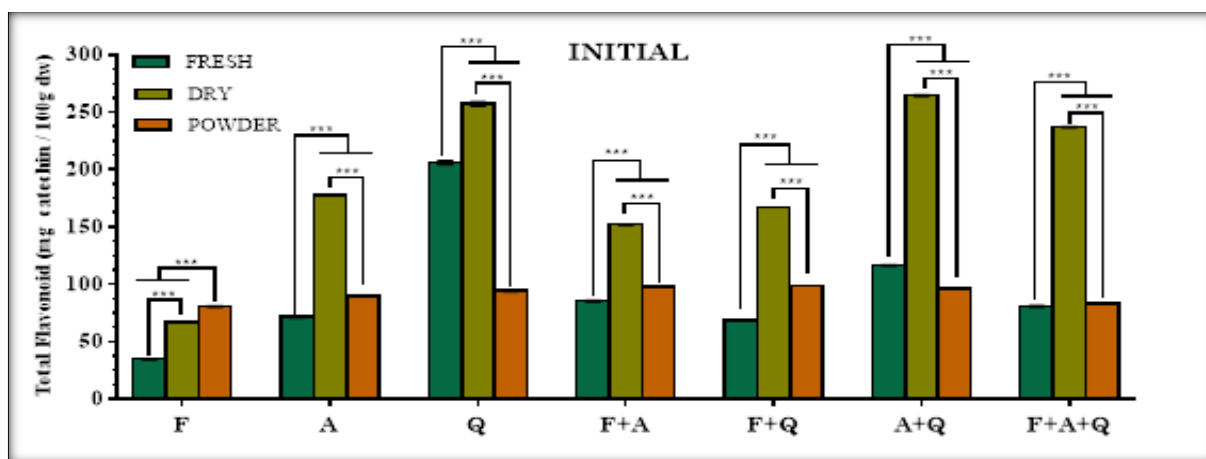


Figure 4.5: Drying effect on total flavonoid content of fruits. All contents are given as mg catechin equivalent in 100 g dry weight sample. Graph represents the average values $\pm$ standard deviation of three independent replicates. Different characters above bars represent statistically significant differences ($p < 0.05$). P values were determined by one-way ANOVA using Tukey's multiple comparison test. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

According to the Figure 4.5 total flavonoids of dry forms (except fig sample) are higher than the other forms in all samples. These results show that the flavonoids are resistant to drying and are concentrated in dried fruit. However, flavonoids are degraded in powder production, which includes longer-term drying and grinding, due to the long-term oxygen contact (Valleja et al., 2012).

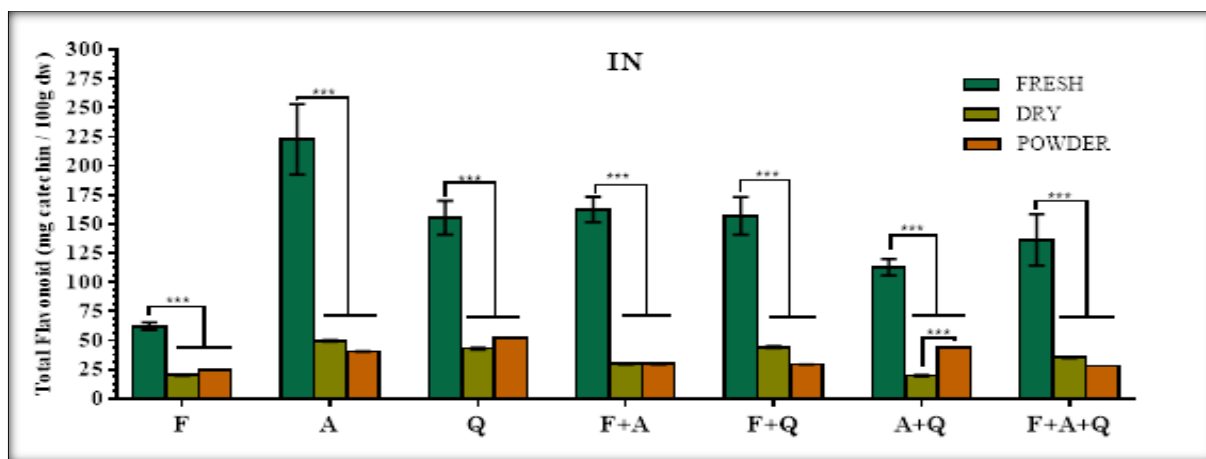


Figure 4.6: Bioaccessibility of total flavonoids after drying process. All contents are given as mg catechin equivalent in 100 g dry weight sample. Graph represents the average values $\pm$ standard deviation of three independent replicates. Different characters above bars represent statistically significant differences ($p < 0.05$). P values were determined by one-way ANOVA using Tukey's multiple comparison test. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

The total flavonoid values obtained by *in vitro* digestion simulations for the total flavonoid values that the body can benefit are shown in Figure 4.6. It is clear from the Figure 4.6 that the drying and powdering processes have caused significant changes in the bioaccessibility of flavonoids. Although these processes did not have a significant effect on the total amount of flavonoids, it may have caused structural changes in flavonoids.

According to figure 4.7, the recovery values of all mixtures (except fig + apricot fruits and fig + quince fruits) are less than one percent, which means that there is no synergistic effect on the bioaccessibility of the flavonoids.

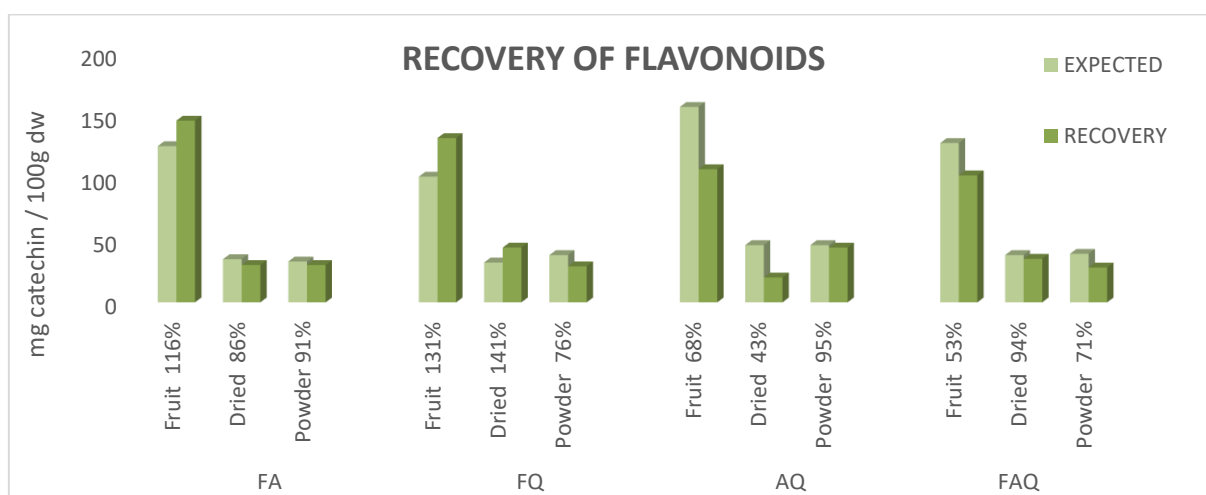


Figure 4.7: Recovery total flavonoids of fruit mixture. All contents are given as mg catechin equivalent in 100 g dry weight sample. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

4.3.3. Total Antioxidant Capacity

Fruits contain different antioxidant substances which are vitamin E, vitamin C, carotenoids and polyphenolic substances. The sensitivity of these four groups of antioxidant agents to food processing conditions such as temperature, oxygen, light, etc. differs. In this study, each of the fig, apricot and quince, which are found in the sample group, unlike the other two fruit contain anthocyanins, carotenoids and vitamin C, respectively.

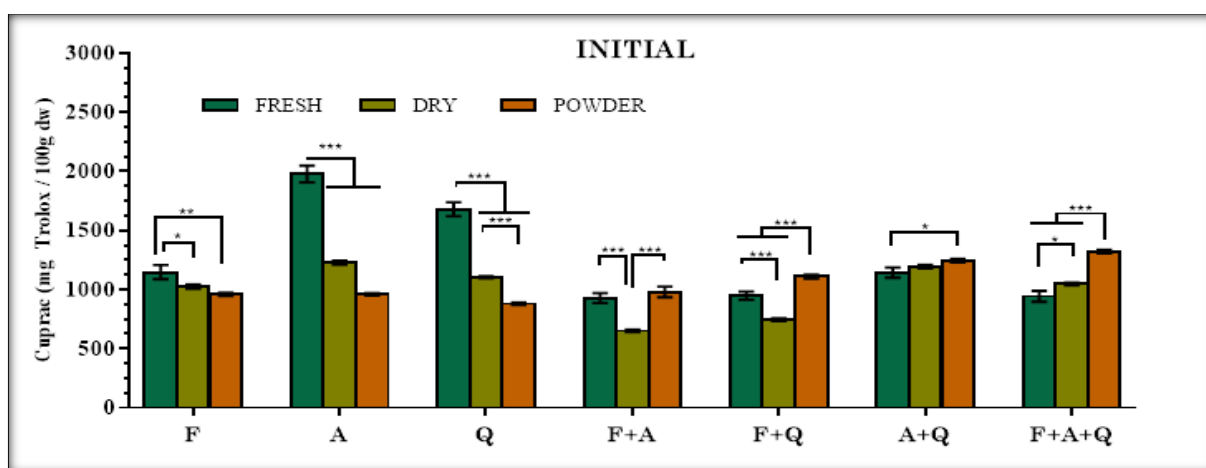


Figure 4.8: Drying effects on total antioxidant activity of fruits. All contents are given as mg trolox equivalent in 100 g dry weight sample. Graph represents the average values $\pm$ standard deviation of three independent replicates. Different characters above bars represent statistically significant differences ($p < 0.05$). P values were determined by one-way ANOVA using Tukey's multiple comparison test. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

The total antioxidant value of fruit forms of whole fruits are higher than the dried and powder form (Figure 4.8). However fruit forms of mixtures are not higher than the dried and powdered form of mixtures. While preparing the fruit mixture, the fruits were first pureed. During mixture preparing process the fruits may be lost in the antioxidant compounds due to their exposure to oxygen and this resulted in a decrease in the antioxidant activity of the fruit mixtures.

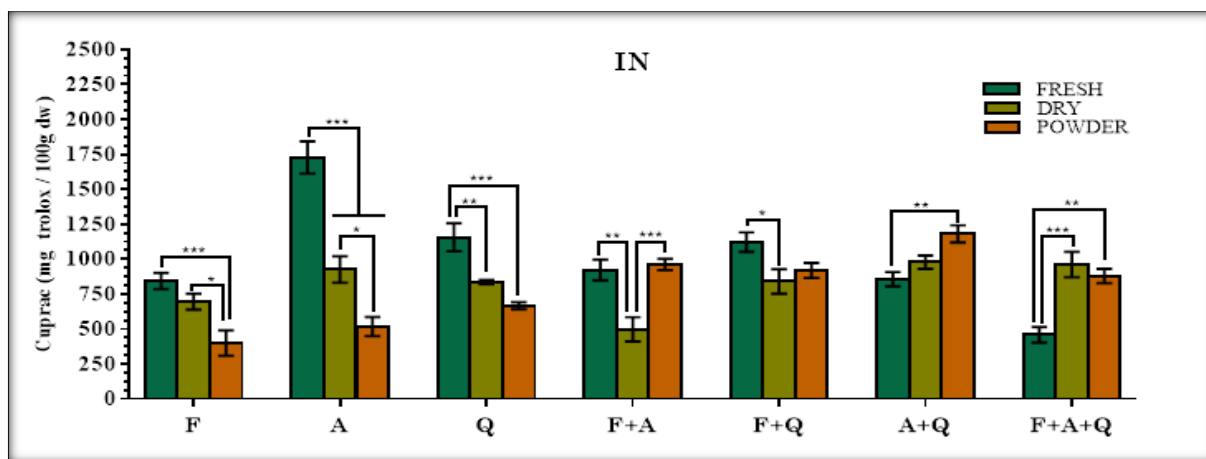


Figure 4.9: Bioaccessibility of antioxidants after drying process. All contents are given as mg trolox equivalent in 100 g dry weight sample. Graph represents the average values $\pm$ standard deviation of three independent replicates. Different characters above bars represent statistically significant differences ($p < 0.05$). P values were determined by one-way ANOVA using Tukey's multiple comparison test. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

Bioaccessibility of antioxidants after drying process was shown at Figure 4.9. All of the fruit forms of whole samples have higher bioaccessibility than dried form and dried forms of whole samples have higher bioaccessibility than powdered form.

According to Figure 4.10, recovery of antioxidant values of powder forms are higher than dry and fresh forms. Similarly, the recovery value of the dry form is greater than the recovery value of the fresh form.

When dried or powdered fruits are consumed together in a mixture, synergy occurs about the bioaccessibility of antioxidant values (except consumption of dried figs / apricots) but does not occur in fresh forms.

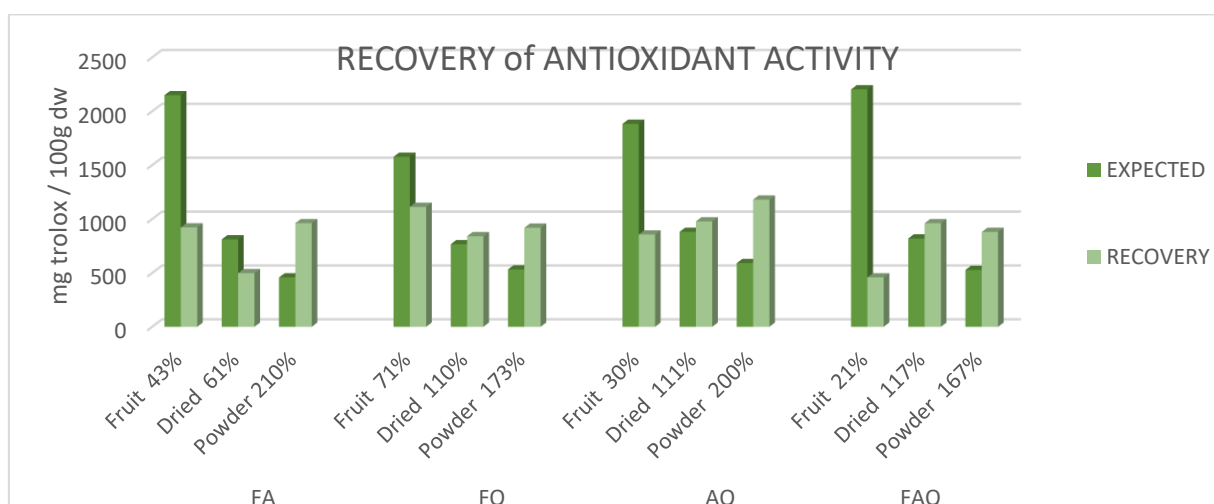


Figure 4.10: Recovery total antioxidant activity of fruit mixtures. All contents are given as mg trolox equivalent in 100 g dry weight sample. F, A, Q are fruits' name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

4.4. SENSORY ANALYSIS

Sensory analysis which is a scientific method for measuring and analyzing the responses to the features of foodstuffs sensed by sensory organs was performed.

4.4.1. Sensory Analysis of Fruit Tablets

When the color characteristics of fruit tablets are examined (Figure 4.11), it is seen that the lightest color belongs to quince tablet and the darkest color belongs to apricot tablets. This results have similarities with L^* values of fruit powders which is a lightness/darkness parameter of color analysis (Table 3.3). Apricot tablet has the highest (4.6) sweetness and highest sour (7.4) which are key taste parameter; however, it has the lowest intensity (5.6) of fruit ID. The sweetness values of the fig tablet and quince tablet are 3.6 and 2.9, respectively. The sour values of them are 5.6 and 6.4.

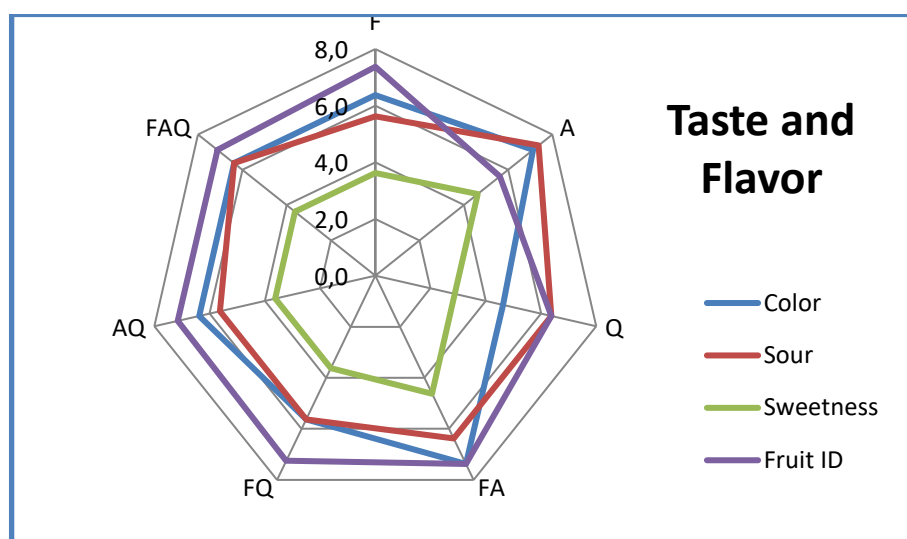


Figure 4.11: Descriptive sensory analysis of “Taste and Flavor” attributes of fruit tablets. F, A, Q are fruits’ name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

Drying of fruits causes increase in the hardness and crunchiness of the samples. The lowest value of hardness which is 4.6, and the highest value of crunchiness which is 4.6 is saved for apricot tablet. Fig tablet and quince tablet have very high intensities of hardness (5.6), and relatively low crunchiness 2.9 and 3.6, respectively

Probably the most important flavor parameter of fruit tablet is fruit-ID, which represents the flavor of freshly harvest fruits. The range of intensity for this parameter is 5.6–7.4, with a mean value of 6.9. The highest value of this essential attribute which is 7.4, is saved for fig tablet.

Another important flavor parameter of fruit tablet is after taste, which represents the taste that a particular food or other substance leaves in your mouth when you have swallowed it. The range of intensity for this parameter is 4.6–7.4, with a mean value of 6.2. The highest value of this essential attribute which is 7.4, is saved for apricot tablet.

It can be concluded that from a sensory point of view, the most suitable fruit in this three fruit group for tableting process is Apricot with highest flavor and taste intensities and suitable texture profile.

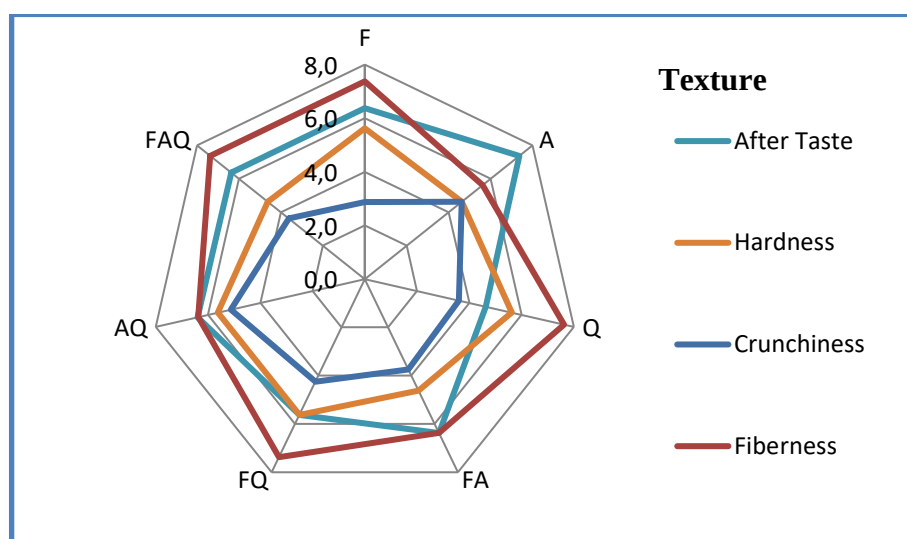


Figure 4.12: Descriptive sensory analysis of “Texture” attributes of fruit tablets. F, A, Q are fruits’ name: fig, apricot, quince, respectively and FA, FQ, AQ, FAQ are fruit mixtures.

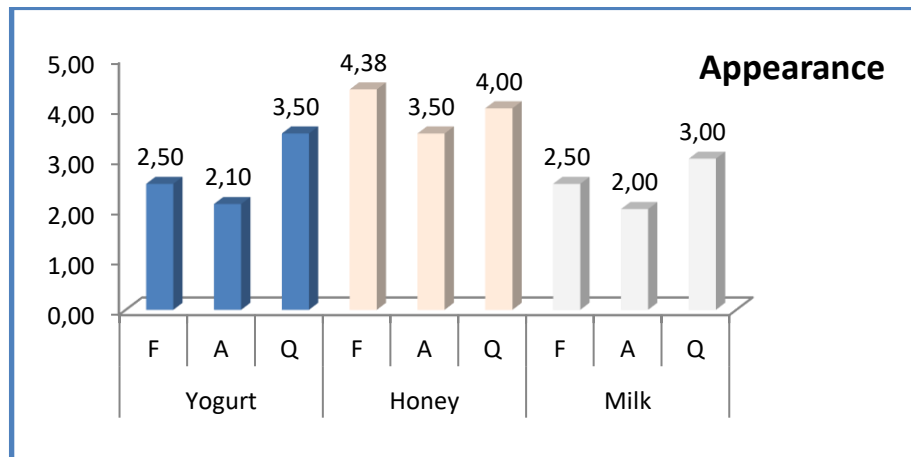
4.4.2. Sensory Analysis of Fruit Powders

Sensory analysis of fruit powders with yogurt, honey and milk were performed. Panelists were asked to evaluate the appearance, taste and general acceptability of the powder mixtures.

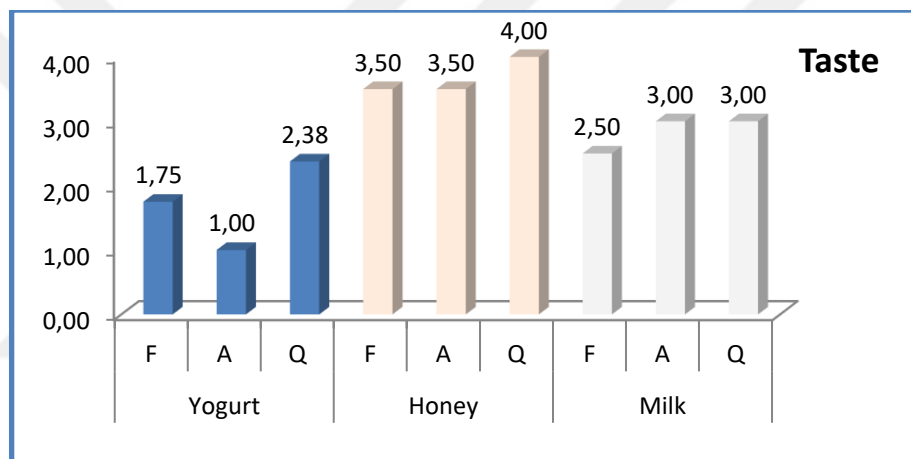
In terms of both of the taste (highest honey+quince) and appearance (highest honey+fig) features, honey and fruit powder mixture were rated higher as shown in Figure 4.13. In terms of general acceptability features, yogurt and fruit powder mixture, especially yogurt and quince powder mixture

In terms of both of the taste (highest honey+quince) and appearance (highest honey+fig) features, honey and fruit powder mixture were rated higher as shown in Figure 4.13. In terms of general acceptability features, yogurt and fruit powder mixture, especially yogurt and quince powder mixture were rated higher as shown. Sensory analysis of fruit powders with yogurt, honey and milk were performed. Panelists were asked to evaluate the appearance, taste and general acceptability of the powder mixtures.

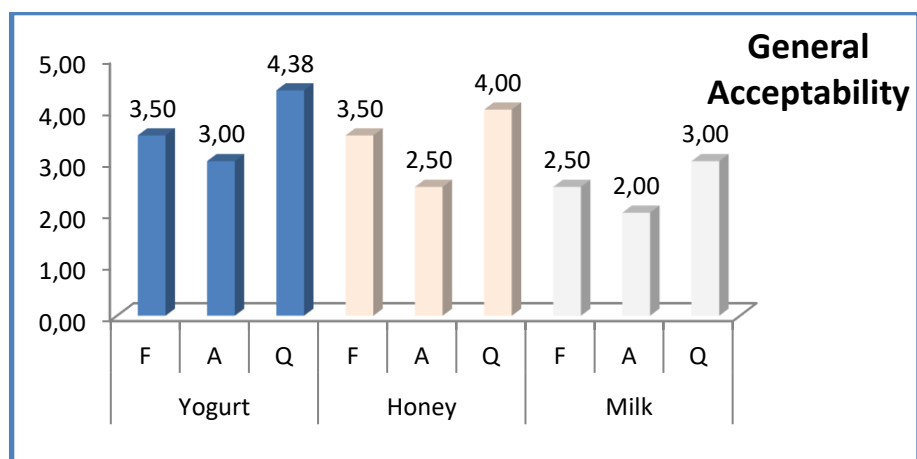
In terms of both of the taste (highest honey+quince) and appearance (highest honey+fig) features, honey and fruit powder mixture were rated higher as shown in Figure 4.13. In terms of general acceptability features, yogurt and fruit powder mixture, especially yogurt and quince powder mixture were rated higher as shown in Figure 4.13.



A



B



C

Figure 4.13: According to the sensory analysis Appearance (A), Taste (B) and General acceptability (C) features of the fruit powders. F, A, Q are fruits' name: fig, apricot, quince, respectively.

5. CONCLUSION AND RECOMMENDATIONS

In this study; figs, apricots and quince fruits were dried and powdered and fruit powders were compressed to produce fruit tablets. The fruit powders, which have been reduced below the water activity value of 50, have become resistant to microbiological deterioration.

The techno-functional analysis of this study showed that quince powder had a high water holding capacity and that the apricot powder had a high oil holding capacity. It was observed that the flowability features of the powders were not sufficient. In addition, density characteristics were examined and it was observed that quince fruit was more suitable for using in powder form than other two fruits.

Sensory analysis of fruit powders with yogurt, honey and milk were performed and their appearance, taste and general acceptability features were evaluated. The results showed that honey is more suitable for consumption with fruit powders in terms of appearance (highest honey+fig) and taste (highest honey+quince) features. On the other hand, yogurt is more suitable for consumption with fruit powders (especially quince and yogurt) in terms of general acceptability features. In addition, sensory analysis was applied to fruit tablets and the results showed that, the most suitable fruit in this three fruit group for tableting process is Apricot with highest flavor and highest taste intensities and suitable texture profile.

The effects of drying and powdering processes on phenolic compounds, flavonoids and total antioxidant activity of fruit samples were examined by using spectrophotometric methods. The result show that the fruits contain higher phenolic compounds than dried and powdered forms (Figure 4.2), but that the dried forms (except fig sample) contain higher total flavonoids than the other forms in all samples (Figure 4.5). Total antioxidant activity values were significantly affected by drying and powdering processes and these values decreased in dried and powder forms (Figure 4.8).

The knowledge about the content of foodstuffs is not sufficient to predict the nutritional efficacy, we need the knowledge about the contents that pass into the blood which may be different from the original content of foodstuffs. Because of that in this study *in vitro* digestion simulation was performed and total phenolic compounds, total flavonoid compounds and the antioxidant activity of digested samples were calculated and compared with initial forms. Fruits

have higher flavonoid bioaccessibility than dried and powdered forms of fruits. In addition bioaccessibility of antioxidants is highest for fruit forms.

In this study, the recovery values of fruit mixtures were calculated and evaluated for absorption of total phenolic compounds, total flavonoid compound and antioxidant activity. As a result, all fruit mixtures, especially fig and quince mixtures, have better phenolic bioaccessibility than fruits alone. However, all fruit mixtures (except fig + apricot fruits and fig + quince fruits) have worst flavonoid bioaccessibility than fruits alone. For the recovery of antioxidant activity result, although fruit mixtures have not better bioaccessibility than fruits alone, fruit powders and dried fruits have better bioaccessibility than fruits alone.



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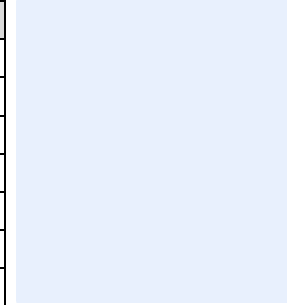
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APPENDICES

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