

EFFECT OF GELATINIZATION PROPERTIES OF DIFFERENT STARCH
TYPES IN THE PRESENCE OF PSYLLIUM FIBER ON *IN VITRO* DIGESTION

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**EFFECT OF GELATINIZATION PROPERTIES OF DIFFERENT STARCH
TYPES IN THE PRESENCE OF PSYLLIUM FIBER ON *IN VITRO*
DIGESTION**

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ABSTRACT

EFFECT OF GELATINIZATION PROPERTIES OF DIFFERENT STARCH TYPES IN THE PRESENCE OF PSYLLIUM FIBER ON *IN VITRO* DIGESTION

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Starch's digestibility in foods strongly depends on the structure, other ingredients, and processing conditions used. It is essential to understand the relationship between food matrix and starch digestibility. The aim was to investigate the effect of psyllium fiber on gelatinization, crystallinity, and *in vitro* digestibility of starches with different crystalline structures (A, B, and C). Starches from various botanical sources (wheat, potato, and tapioca) with and without added psyllium fiber were heated at 90°C for 10 minutes at three different solid: water (w:v) ratios (1:1, 1:2, and 1:5). The added fiber content was 50% in the solid fraction for the fiber added samples. *In vitro* digestion analyses were conducted after the heating process. Structural changes were observed with Differential Scanning Calorimeter (DSC), X-Ray Diffraction (XRD), Fourier Transform Infrared (FTIR) Spectroscopy and Scanning Electron Microscope (SEM) analysis. Results showed that water content and psyllium fiber addition during cooking affected the structural, morphological, and digestion properties of wheat, potato, and tapioca starches. Psyllium addition decreased the rapidly digestible starch (RDS) fractions while increased the slowly digestible starch (SDS), and resistant starch fractions for

all starch types. The effect of psyllium fiber addition was not limited to restricting the swelling and gelatinization of starch granules during cooking. Psyllium fiber also restricted the mobility of digestive enzymes during digestion. Understanding the relationship between psyllium and starch digestibility could assist in designing food formulations with lower starch digestibility. These *in vitro* data, however, should be confirmed by *in vivo* studies.

Keywords: Wheat, Potato, Tapioca, RDS, Psyllium



ÖZ

FARKLI NIŞASTA TİPLERİNİN PİSİLYUM LİFİ VARLIĞINDA JELATİNİZASYON ÖZELLİKLERİNİN İN VİTRO SİNDİRİME ETKİSİ

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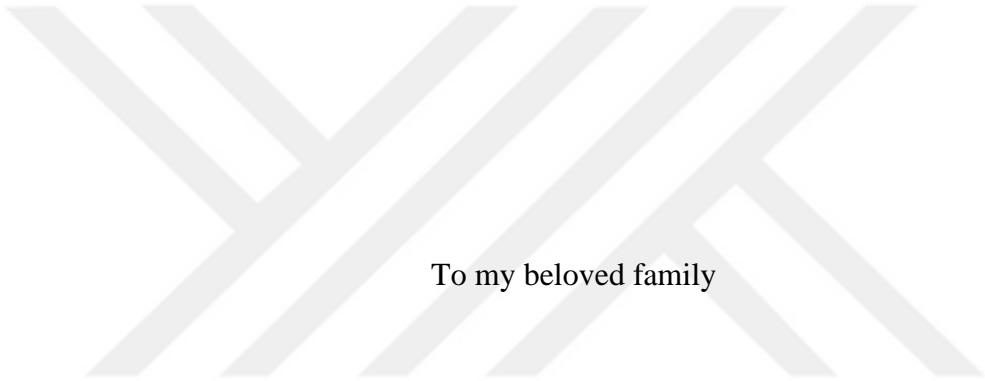
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Nişasta sindirilebilirliğinde en önemli üç faktör nişastanın yapısı, uygulanan proses şartları ve diğer gıda bileşenlerinin (yağlar, şekerler, lifler ve proteinler) sindirilen öğünde bulunmasıdır. Bu sebeple nişasta sindirilebilirliği ve gıda matrisi arasındaki ilişkiyi anlamak önemlidir. Bu çalışmada pisilyum lifinin farklı tipteki nişastaların (A, B ve C) jelatinizasyon, kristallenme ve *in vitro* sindirim davranışlarının incelenmesi hedeflenmiştir. Farklı botanik kaynaktan (buğday, patates ve tapyoka) elde edilmiş nişastalar üç farklı katı madde: su oranında (1:1, 1:2 ve 1:5) pisilyum lifli ve lifsiz olarak 90°C’de 10 dk boyunca ısıtılma tabii tutulmuştur. Lifli örnekler için eklenen lifin katı kütle içindeki miktarı % 50’dir. Yapısal değişimler Diferansiyel Taramalı Kalorimetre (DSC), X-Ray Difraktometre (XRD), Fourier Dönüşümlü Kızılötesi Spektrometresi (FTIR) ve Taramalı Elektron Mikroskobu (SEM) ile analiz edilmiştir. Elde edilen sonuçlar pişirme sırasında su miktarının ve pisilyum lifi varlığının buğday, patates ve tapyoka nişastalarının yapısal, morfolojik ve sindirim özelliklerinin etkilediğini göstermiştir. Pisilyum eklenmesi ile birlikte tüm nişasta tiplerinde hızlı sindirilen nişasta (RDS) miktarı azalırken yavaş sindirilen nişasta (SDS) ve dirençli nişasta miktarlarının arttığı gözlemlenmiştir. Pisilyum lifi yalnızca nişasta granüllerinin şişmesi ve jelatinizasyonunu kısıtlamamıştır, sindirim sırasında sindirim

enzimlerinin hareketliliğini de kısıtladığı da gözlemlenmiştir. Pisilyum ve nişasta sindirilebilirliği arasındaki ilişkiyi anlamak düşük nişasta sindirilebilirliğine sahip gıda formülasyon tasarılarında yardımcı olabilir. Elde edilen *in vitro* verileri *in vivo* çalışmaları ile doğrulanmalıdır.

Anahtar Kelimeler: Buğday, Patates, Tapyoka, RDS, Pisilyum





To my beloved family

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TABLE OF CONTENTS

ABSTRACT.....	v
ÖZ	vii
ACKNOWLEDGMENTS	x
TABLE OF CONTENTS.....	xi
LIST OF TABLES	xiii
LIST OF FIGURES	xiv
CHAPTERS	
1 INTRODUCTION	1
1.1 Starch: History, Importance, Uses	1
1.2 Structures and Morphology of Starch Granules.....	2
1.3 Chemical Composition of Starch Granules.....	2
1.4 Crystalline Structures of Starch Granules.....	3
1.5 Starch Gelatinization.....	7
1.6 Starch Digestion.....	8
1.7 Dietary Fiber	10
1.8 Psyllium	12
1.9 Objective of the Study	14
2 MATERIALS AND METHODS.....	15
2.1 MATERIALS.....	15
2.2 METHODS	16
2.2.1 Preparation of Samples	16
2.2.2 Differential Scanning Calorimetry (DSC)	17

2.2.3	X-ray Diffraction (XRD)	17
2.2.4	Fourier Transform Infrared Spectrometry (FTIR)	18
2.2.5	Scanning Electron Microscopy (SEM)	18
2.2.6	<i>In Vitro</i> Digestion	18
3	RESULTS AND DISCUSSION	23
3.1	Differential Scanning Calorimetry (DSC)	23
3.1.1	Thermal Properties of Starches	23
3.2	X-ray Diffraction Patterns	30
3.3	FTIR Spectroscopy	35
3.4	Scanning Electron Microscopy (SEM)	40
3.5	<i>In vitro</i> Starch Digestibility	45
4	CONCLUSION AND RECOMMENDATIONS	53
	REFERENCES	55
	APPENDICES	
A.	STATISTICAL ANALYSIS	67
B.	FTIR SPECTRA OF STARCH SAMPLES	129

LIST OF TABLES

TABLES

Table 2.1 Experimental Design.....	16
Table 2.2 Moisture contents of raw ingredients.....	17
Table 3.1 Thermal properties of wheat starch with and without psyllium fiber	26
Table 3.2 Thermal properties of potato starch with and without psyllium fiber	27
Table 3.3 Thermal properties of tapioca starch with and without psyllium fiber...	28
Table 3.4 IR ratios of 1043 cm ⁻¹ / 1016 cm ⁻¹ of raw starches & psyllium determined by FTIR.....	36
Table 3.5 IR ratios of 1043 cm ⁻¹ / 1016 cm ⁻¹ of wheat starch with and without added psyllium fiber determined by FTIR.....	37
Table 3.6 IR ratios of 1043 cm ⁻¹ / 1016 cm ⁻¹ of potato starch with and without added psyllium fiber determined by FTIR.....	38
Table 3.7 IR ratios of 1043 cm ⁻¹ / 1016 cm ⁻¹ of tapioca starch with and without added psyllium fiber determined by FTIR.....	39
Table 3.8 The amount of wheat starch nutritional fractions with and without added psyllium fiber (RDS/TS, SDS/TS and RS/TS).	50
Table 3.9 The amount of potato starch nutritional fractions with and without added psyllium fiber (RDS/TS, SDS/TS and RS/TS).	51
Table 3.10 The amount of tapioca starch nutritional fractions with and without added psyllium fiber (RDS/TS, SDS/TS and RS/TS).....	52

LIST OF FIGURES

FIGURES

Figure 1.1. Basic structural segments of (a) glucose units, (b) amylose and (c) amylopectin (Pérez & Bertoft, 2010)	3
Figure 1.2. (a) The starch granule structure, (b) the lamellae structure (Jenkins & Donald, 1995)	5
Figure 1.3. Amylopectin crystalline structure of A and B type starches (Zobel, 1988).....	6
Figure 3.1 XRD profiles of raw starches (wheat, potato, tapioca) and psyllium fiber.....	31
Figure 3.2 XRD profiles of raw and cooked wheat starch (A-type) with or without psyllium	32
Figure 3.3 XRD profiles of raw and cooked potato starch (B-type) with or without psyllium	33
Figure 3.4 XRD profiles of raw and cooked tapioca starch (C-type) with or without psyllium	34
Figure 3.5 SEM images of a) wheat starch, b) potato starch, c) tapioca starch,d) psyllium	40
Figure 3.6 SEM images of wheat starches: a)Cooked 1:5 WS; b) Cooked 1:5 WS+P; c) Cooked 1:2 WS; d) Cooked 1:2 WS+P; e) Cooked 1:1 WS; f) Cooked 1:1 WS+P; g) Raw WS; h) Raw WS+P (WS: Wheat Starch; P: Psyllium)	42
Figure 3.7 SEM images of potato starches: a)Cooked 1:5 PS; b) Cooked 1:5 WP+P; c) Cooked 1:2 PS; d) Cooked 1:2 PS+P; e) Cooked 1:1 PS; f) Cooked 1:1 PS+P; g) Raw PS; h) Raw PS+P (PS: Potato Starch; P: Psyllium)	43
Figure 3.8 SEM images of tapioca starches: a) Cooked 1:5 TS; b) Cooked 1:5 TP+P; c) Cooked 1:2 TS; d) Cooked 1:2 TS+P; e)Cooked 1:1 TS; f) Cooked 1:1 TS+P; g) Raw TS; h) Raw TS+P (TS: Tapioca Starch; P: Psyllium)	44
Figure 3.9 Digestibility Fractions of Wheat, Potato and Tapioca Starches (RDS/TS, SDS/TS, and RS/TS)	49

CHAPTER 1

INTRODUCTION

1.1 Starch: History, Importance, Uses

Historically, starch is of enormous importance for human development. It is estimated that 60–70% of the dietary energy intake of humans comes from starch. The introduction of grain and tuber starch in the diet played a role in the evolution of humans. It has been widely used since the invention of cooking and the evolution of salivary alpha-amylases (Hardy et al., 2015). While starch is used as a nutritional product for food applications, it has also been utilized for non-food applications, especially in the production of pharmaceuticals, cosmetics, paper, packaging, bioplastics products (Desta & Tigabu, 2018).

Starch is the primary energy reserve in plants and, therefore, one of the most abundant materials on earth. Starch is considerably low in price and an essential carbohydrate source in the human diet (Robyt, 2008). In addition to their nutritional value, starches are used as gelling, thickening, adhesion, moisture-retention, film-forming, texturizing and surface-coating agents in the food industry (P. Guo et al., 2018; Laguna et al., 2011; Zeng et al., 2018).

Today, potato, wheat, tapioca, maize, and cassava are the primary sources of starch worldwide, mainly depending on the availability and economics in a given region. Europe, with cold environmental conditions, dominantly produces potato starch while the USA produces starch from corn. Likewise, Asian countries are the hubs of tapioca starch (Desta & Tigabu, 2018).

1.2 Structures and Morphology of Starch Granules

Starch is a crucial macronutrient of many foods and the essential energy supply for humans. It is the main carbohydrate reserve in higher plants, being found in cereals, rhizomes, roots, and tubers (Englyst et al., 2006).

The endosperm is the primary site for the synthesis and storage of starch in cereals. The morphology, composition, and crystalline structure of granules in each plant tissue are unique for each species (Smith, 2001). These structural characteristics specify the physical properties of starch. Starch granules from different plants vary greatly in shapes and sizes. The granules have diverse forms, including spherical, polygonal, oval, lenticular (disk), kidney, and elongated (Alcázar-Alay & Meireles, 2015; Pérez & Bertoft, 2010). Sizes of starch granules vary between submicron (e.g., quinoa starch) to more than 100 μm (e.g., canna starch) (Bertoft, 2017). Size distribution can be uni-, bi-, or polymodal (Pérez & Bertoft, 2010).

1.3 Chemical Composition of Starch Granules

Starch is stored in plants as semi-crystalline granules and is composed of two major D-glucose polymers, amylose and amylopectin. They are formed and radially positioned from the hilum to the periphery of the starch granule. Amylose is mostly linear polymer with mainly α -(1-4)-linked D-glucosidic bonds, whereas amylopectin, which is the major component, is a branched polymer α -(1-4)-linked D-glucosidic bonds with α -(1-6)-linkages at the intervals of approximately 20 unit (Jiang et al., 2013; Karim et al., 2000). These two kinds of molecules form amorphous and crystalline areas in granules.

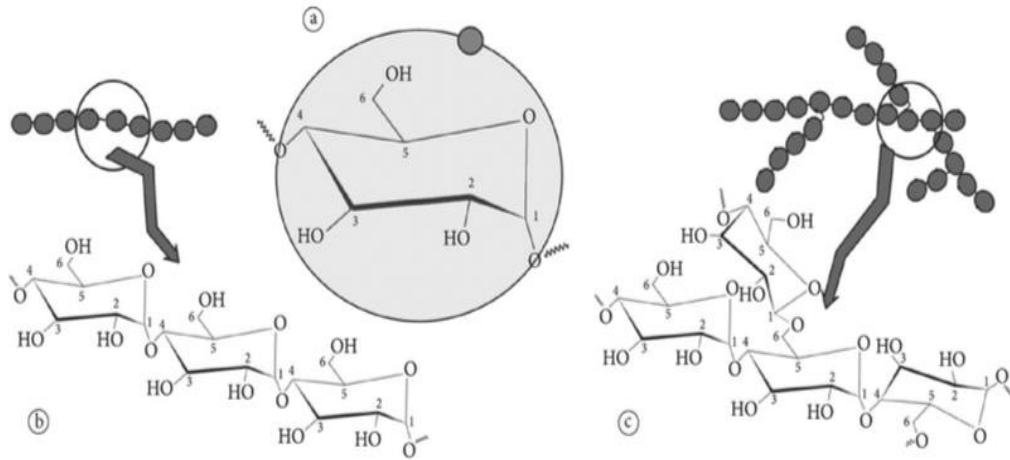


Figure 1.1. Basic structural segments of (a) glucose units, (b) amylose and (c) amylopectin (Pérez & Bertoft, 2010)

Various botanical source of starch results in the different amylose/amylopectin ratio. The amylose content can range from 17 to 70%, and respectively the amylopectin varies between 83 to 30% (Robyt, 2008). The typical ratio of the two components of starch is 1:3 or ~25% amylose and ~75% amylopectin (Bertoft, 2017; Fredriksson et al., 1998).

However, there are some mutant plants named as waxy because of the waxy appearance of the endosperm, have a much lower content of amylose, or even composed of the 100% amylopectin component (Jane et al., 1999; Pérez & Bertoft, 2010). There are other types of starches that have an increased amylose content (Pérez & Bertoft, 2010).

1.4 Crystalline Structures of Starch Granules

Native starches display semi-crystalline characteristics. The starch granules consist of alternating amorphous and semi-crystalline concentric growth rings of 120-400 nm thick (Buléon et al., 1998; Donald et al., 2001). The amorphous rings are made of disordered conformation of amylose and amylopectin, whereas the semi-

crystalline rings are composed of a regular alternation of crystalline and amorphous lamellae with a repeat distance of 9–10 nm (Blanshard et al., 1984; Pérez & Bertoft, 2010).

Starch granules possess very complex molecular structures resulting from variation in the components of the starch granule. Amylose and amylopectin molecules organize the crystalline and amorphous regions of lamellae in the granule. Starches with a higher proportion of amylopectin show high crystallinity. Short branched amylopectin molecules constitute the crystalline region. On the other hand, amylose with large amylopectin branches builds up the amorphous region of the starch granule (Cheetham & Tao, 1998).



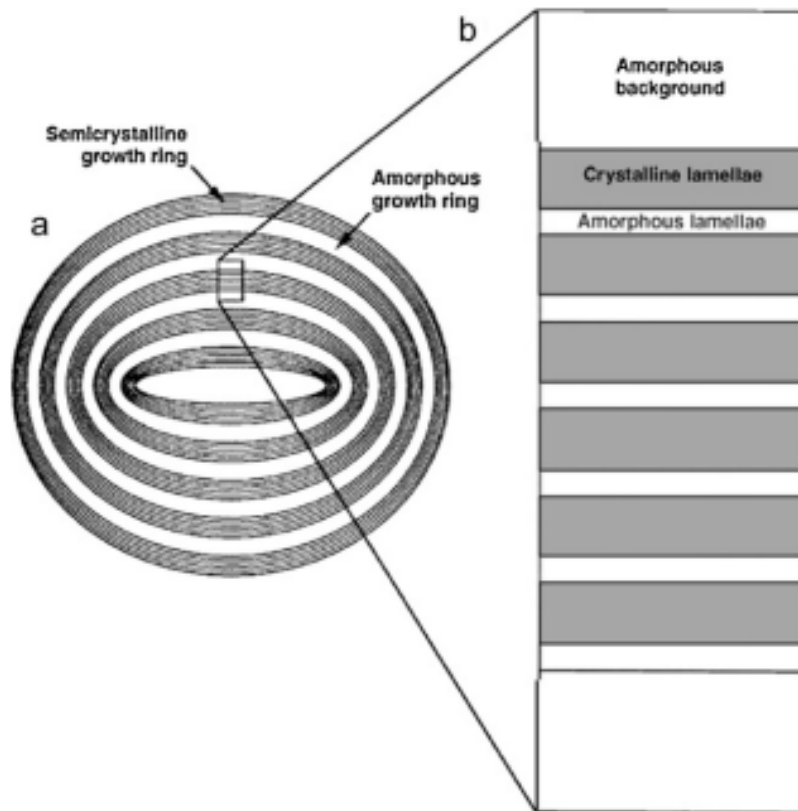


Figure 1.2. (a) The starch granule structure, (b) the lamellae structure (Jenkins & Donald, 1995)

The branch chains of amylopectin that form double helices are arranged in parallel to form the crystallinity of type A and B (Pérez & Bertoft, 2010). The double-helical structure within the crystalline forms of A and B type is the same (Gidley & Bulpin, 1987). The main differences between A and B types are the packing arrangement of double helices and the water content in the crystal unit cell (Imberty et al., 1988; Takahashi et al., 2004). The A-type crystals are compactly packed with monoclinic unit cells and contain eight water molecules per unit cell. In contrast, B-type crystals are packed in a hexagonal unit with 36 water molecules per unit cell.

The packing of the helices in the A-type crystallites is more compact than in the crystalline structure of B type, which has a more open structure with a hydrated core. Consequently, A-type crystals are considered to be more resistant than B-type crystals to enzymatic digestion (Copeland et al., 2009).

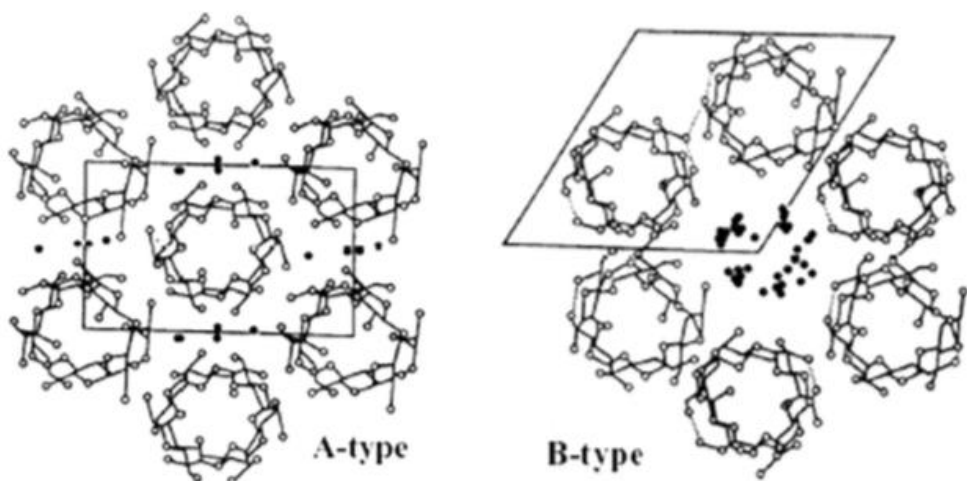


Figure 1.3. Amylopectin crystalline structure of A and B type starches (Zobel, 1988)

Depending on the botanical source, the granule varies in size, shape, and crystal structure. In general, natural starch granules range 15% and 45% crystalline

content. Native starch granules contain A-type, B-type, or mixed (C-type) crystalline polymorphs according to X-ray diffraction patterns (Zobel, 1988). The A-type pattern is mainly found in cereals such as wheat and maize starches, B type pattern usually in tubers such as potato starch, and C type pattern is in some legumes such as pea starch (Bogracheva et al., 2002; Jane et al., 1999).

1.5 Starch Gelatinization

When the starch granule is heated in excess water, granules undergo an irreversible phase transition, known as gelatinization. During gelatinization, the multi-scale structure of starch is destroyed, and its internal structure turns amorphous and becomes digestible (Tester et al., 2004). Starch gelatinization is an endothermic process that corresponds to the collapse of molecular order and the breaking of hydrogen bonds. Therefore irreversible changes are observed, such as granular swelling, melting of crystallites, the unwinding of amylopectin double helices, and solubilization of starch molecules (Waigh et al., 2000).

The gelatinization process begins from the hilum of the starch granule and then spreads rapidly throughout the periphery. Gelatinization takes place initially in the amorphous region because of weak hydrogen bonds and then extends to the crystalline part of the granule. The presence of amylose reduces the melting temperature of the crystalline area and the amount of energy required to start gelatinization (Sasaki et al., 2000).

The rate and extent of disruption, which is a significant determinant of the starch functional properties, depends on the type of starch, moisture, temperature, heating time, and the presence of other constituents such as lipids, proteins, and fibers. Gelatinization of most starches occurs between 60°C and 80°C. When starch is heated above its gelatinization temperature, the starch granule absorbs water and then swells substantially; eventually, the semi-crystalline nature is lost (Blazek & Gilbert, 2011; Kulkarni, 2006). During gelatinization, the changes in starch are the

main factors determining its functional properties for food processing, during digestion, and in industrial applications (Wang et al., 2015).

1.6 Starch Digestion

In starch digestion, the starch molecules are broken down into smaller oligosaccharides, maltose, and other branched oligosaccharides that are turned into glucose in the small intestine by the pancreatic α -amylases. The rate and extent of digestion of starch result in a wide range of glycemic responses (Magallanes-Cruz et al., 2017).

Starch is digested and absorbed at different rates and to varying extents in the human small intestine, depending on its botanical source, which determines the ratio of amylose to amylopectin and the structural characteristics (Englyst et al., 2006). Other viral factors are affecting the metabolic fate of starch are the presence of other ingredients, formulation of the product, and the processing method used (Englyst et al., 2006; Heaton et al., 1988). Many different factors, like the extent of chewing and the transition time of food in the digestive system, may restrict the enzymatic hydrolysis of starch (Hoover, 2010).

The digestibility of starch has been related to the glycemic index (GI) to value the nutritional aspects of foods. The GI has been used as a measure of postprandial glucose response for starch-based foods to assess the classification of foods on their digestion (Shi et al., 2018). The GI is determined by the area under the glycemic response curve of food containing 50 g of available carbohydrate and defined as a percentage of the response to the same amount of carbohydrate from glucose or white bread as a reference food. Foods are grouped into three levels, which are high ($GI \geq 70$), moderate ($GI 56-69$), or low GI ($GI \leq 55$) according to measured GI values (Passos et al., 2015; Jenkins et al., 1981).

Foods with a high GI are rapidly digested and absorbed, which causes a rapid rise in blood glucose level after consumption. Diets with high GI foods have been

associated as a risk factor for many diseases, including cardiovascular disease, diabetes, obesity, and some cancers (Englyst et al., 2006; Wong & Jenkins, 2007). Due to public health concerns, people in the world have been focused on low glycemic index (GI) foods. Low GI foods are described by the slower rate of glucose absorption in the small intestine resulting in improved glycemic control. Consumption of low GI foods shows benefits in the management of blood glucose control, treatment of diabetes, weight control, improvement of satiety, and prevention of cardiovascular disease (Englyst et al., 2003).

The digestion rate of starch is a primary determinant of the extent of blood glucose and insulin levels after a meal. Food digestion analysis by *in vivo* methods is expensive and complicated because of ethical concerns, necessary facilities, and extensive time needed (Kulkarni, 2006; Magallanes-Cruz et al., 2017). Therefore, *in vitro* methods have been developed to correlate the rate of starch digestion and GI. The *in vitro* methods quantify the carbohydrate digestibility fractions according to the glucose release by enzymatic hydrolysis (Belorio et al., 2020; Chávez-Murillo et al., 2018; Englyst & Hudson, 1996; Kulkarni, 2006).

The magnitude and extent of glycemic response differ depending on starch digestion in the small intestine. A nutritional classification based on an *in vitro* measurement of starch digestion is useful for predicting glycemic response to foods and meals. Dietary starch has been classified into rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS) (Englyst & Hudson, 1996).

RDS is the fraction of starch rapidly and completely digested in the small intestine, while SDS like RDS is thoroughly but slowly digested throughout the small intestine (Englyst & Hudson, 1996; Zou et al., 2015). Resistant starch (RS) refers to the sum of starch and starch degradation products that are not hydrolyzed in the small intestine (S. Liu et al., 2020).

SDS provides sustained glucose release, which is coupled to a low glycemic

response (Englyst & Hudson, 1996; Magallanes-Cruz et al., 2017). It has been recommended that diets rich in slowly digested carbohydrates may reduce several diseases such as type 2 diabetes, obesity, and cancer (Kulkarni, 2006; Magallanes-Cruz et al., 2017). Conversely, diets that comprise high amounts of rapidly digested carbohydrates can have adverse health effects because they are quickly absorbed and led to elevated blood sugar levels.

1.7 Dietary Fiber

Dietary fiber (DF) is described as the parts of plants that are not digested and absorbed in the human small intestine. It includes polysaccharides such as cellulose, hemicelluloses, pectins, gums, and lignin non-carbohydrate components. (DeVries et al., 2001). Dietary fibers have been known for their health benefits with a range of functionalities and have been used in various food applications. Studies have shown that they are beneficial nutrients for constipation, reduction of serum cholesterol levels, glycemic control, and cancer prevention (Oh et al., 2014).

Epidemiologic studies have shown that a diet with a combination of high glycemic load and low dietary fiber causes a higher risk of type 2 diabetes in men and women (Englyst et al., 2003; Wong & Jenkins, 2007). Significantly, many studies have demonstrated the association between increased intake of fiber and decreased glycemic response in people with diabetes (Bae et al., 2016).

According to World Health Organisation (WHO), approximately 2 billion adults were overweight, 650 million adults were obese and, over 340 million children and adolescents aged 5-19 were overweight and obese globally in 2016. It is estimated that by 2025, approximately 2.7 billion adults will be overweight, and more than 1 billion will be obese. Therefore, it is crucial to have a change in food choices, which will be the most effective way to fight obesity. Many studies have shown that individuals with high dietary fiber intake reduce the risk of certain types of

cancer, coronary heart disease, obesity, and diabetes. Health authorities and nutritionist has reached a consensus on the beneficial role of the dietary fiber in human health (Foschia et al., 2015; Fuentes-Zaragoza et al., 2010).

When dietary fibers are added to starch-based foods, they may limit the available water and increase the digesta viscosity. Consequently, dietary fibers in the human digestive system restrict the accessibility of starch granules to digestive enzymes, leading to the reduction of the glycemic index (Oh et al., 2014).

In recent years, dietary fibers have been widely used in various food items, including pasta, biscuits, and bread, to reduce GI values as well as fiber enrichment and reduce caloric intake. Gularte et al. (2012) reported that the estimated glycemic index of gluten-free layer cakes had been reduced 3% and 7% with the incorporation of oat fiber and inulin, respectively. Brennan et al. (2015) have studied the effect of inulin GR, inulin HPX, glucagel, psyllium, and oat fiber on the GI values of pasta and reported that GI had been reduced significantly in pasta with 15% of inulin GR, inulin HPX, glucagel, oat and psyllium when individually added. Agama-Acevedo, Islas-Hernandez, Pacheco-Vargas, Osorio-Diaz, and Bello-Perez (2012) have also found that unripe banana flour as a fiber source reduced starch hydrolysis by 16% in cookie preparations by replacing wheat flour at a level of 50%.

DFs in food applications are directly related to their functional properties (Oh et al., 2014). DFs have been divided into soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) according to their solubility in water (Schneeman, 1987). SDFs have been related to the reduction of cholesterol levels and decrease in the absorption of intestinal glucose, while IDFs have been linked to intestinal regulation (Robyt, 2008). Structural and physical characteristics of SDFs and IDFs affect their physiological properties such as hydration, swelling, and enzymatic attack (Oh et al., 2014).

Both types of fibers have different molecular characteristics and physiological

effects on the digestive tract (Fabek et al., 2014). Insoluble dietary fibers (e.g., cellulose, cereal brans) plays an important role in increasing fecal bulk and excretion of bile acids while reducing intestinal transit time due to their water insolubility and no or very limited fermentation. On the other hand, soluble fibers (e.g., gums, pectins) increase the transit time through the gastrointestinal tract, which may also delay gastric emptying (Foschia et al., 2015). Soluble fibers reduce plasma glucose, which could be related to their ability to increase the viscosity of digesta within the digestive tract (Repin et al., 2018). Dikeman et al. (2006) demonstrated that soluble fibers, such as guar gum and psyllium, promote relatively high viscosities as compared to insoluble fibers such as cellulose, rice bran, and wheat bran. Consequently, soluble dietary fibers have been reported to be able to interfere the starch digestion and absorption and reduce the rapid rise of postprandial blood glucose level, which ultimately results in lowering the GI of foods (Dikeman & Fahey, 2006; H. Zhang et al., 2021).

1.8 Psyllium

Psyllium is the common name obtained from the seed of the *Plantago* genus, which has more than 200 species (Masood & Mirafatab, 2010). Psyllium husk is the main product that includes about 80% soluble fiber and is a rich source of dietary fiber of both soluble and insoluble fractions (Franco et al., 2020).

Psyllium consumption is prevalent in India because it is a common way to avoid skin irritations, hemorrhoids, constipation, and diarrhea in the traditional Indian medicine system (Ayurveda). In recent years, its consumption has increased in Europe and the USA, fundamentally since psyllium fiber is associated with the reduced risk of coronary heart disease by the FDA (Franco et al., 2020). Psyllium has been investigated to a large extent to exert its potential benefits on health and to use in food and pharmaceutical applications (Yu et al., 2008). It is well known for the treatment of diabetes, constipation, colon cancer, diarrhea, obesity, inflammatory bowel disease (ulcerative colitis), irritable bowel syndrome, and

colon cancer. Moreover, it promotes satiety and has prebiotic effects ((Lucy) Yu et al., 2008; Franco et al., 2020; Yadav et al., 2016).

Psyllium husk is composed of a highly branched arabinoxylan (more than 60%), which is hemicellulose having xylose and arabinose. Its average composition is 65% D-xylose, 20% L-arabinose, 6% rhamnose, and 9% D-galacturonic acid. Also, higher amounts of K, Na, and P minerals are found in psyllium (Franco et al., 2020; Q. Guo et al., 2008).

Psyllium has classified as a viscous soluble fiber, which is associated with the ability to the viscous gel formation (Franco et al., 2020). It is well recognized that gums, pectins, and β -glucans can change the digesta viscosity, restricting the absorption of the nutrients such as glucose and cholesterol. Viscous soluble fibers (guar, pectin, oat gum, and psyllium) have been shown to reduce plasma cholesterol and glucose levels (Dikeman & Fahey, 2006). Studies have also shown that the psyllium fiber improves glycemic control by slowing down the digestion. Its gel forming property prevent the digestion of macronutrients (Giacco et al., 2016).

A previous study (2018) reported that the addition of 17.14% psyllium to gluten-free bread decreased glycemic response by 33% compared to the control formulation (Fratelli et al., 2018). Brennan, Derbyshire, Brennan, and Tiwari (2012) have shown that psyllium can be used to improve the glycemic response of extruded snack foods. The authors indicated that the inclusion of psyllium fiber into the snack products lowered both *in vitro* and *in vivo* glycemic response considerably against the control (Brennan et al., 2012).

Psyllium was also used because of its functional properties on different products such as bread, biscuits, and cakes in many studies (Franco et al., 2020). However, there is no study showing the behavior of different types of starches in the presence of psyllium fiber.

1.9 Objective of the Study

The objectives of the study were (1) to investigate the physical characteristics and *in vitro* digestion of different types of starch, wheat, potato, and tapioca starch, cooked with and without added psyllium fiber, (2) to understand the effect of water concentration during heating in the physical characteristics and *in vitro* digestion of different types of starch, wheat, potato, and tapioca starch.



CHAPTER 2

MATERIALS AND METHODS

2.1 MATERIALS

Wheat, potato, and tapioca starches (food grade) were obtained from Smart Chemistry (Turkey). Psyllium fiber (min. 95% purity) was obtained from Tunçkaya Chemical (Turkey). All the chemicals were of analytical grade. The chemicals used for carbohydrate digestibility analysis were as follows; glucoamylase from *Aspergillus Niger* (Cat.no: A7095, Sigma-Aldrich Chemical Co., St. Louis, MO, USA), pancreatin from porcine pancreas (8 x USP Cat.no: P-7545, Sigma-Aldrich Chemical Co., St. Louis, MO, USA,) invertase (EC.3.2.1.26, Fisher Scientific, Loughborough, UK). D-Glucose Assay Kit (GOPOD Format) was purchased from Megazyme International Ireland Ltd. (Bray Co., Wicklow, Ireland).

2.2 METHODS

2.2.1 Preparation of Samples

Moisture contents of the samples (Table 2.2) were measured with a moisture analyzer at 160°C (MX-50, AND, Japan). Starches from different botanical sources (wheat, potato, and tapioca) and mixtures, prepared by the added psyllium fiber at a starch: psyllium ratio of 1:1 (w:w), were mixed with distilled water to obtain the predefined sample: water (w:v) ratios (Table 2.1). Samples prepared without added water (WAW) were used as controls (Table 2.1). Heating was conducted at 90°C for 10 minutes in a water bath for cooking the samples. The cooked samples were frozen at -80°C overnight and then freeze-dried for 24 h in a freeze dryer (Christ, Alpha 2-4 LD plus, Germany) and passed through a 200 µm sieve (Fritsch GmbH, Idar-Oberstein, Germany). Following analyses were conducted before and after the heat treatments that were replicated three times.

Table 2.1 Experimental Design

FACTORS	LEVELS
Starch Type	A type (Wheat starch) B type (Potato starch) C type (Tapioca starch)
Sample: Water (w:v)	1:5 1:2 1:1 WAW (without added water)
Psyllium: Starch (w:w)	0:1 1:1

Table 2.2 Moisture contents of raw ingredients

Samples	Water concentrations (%)
Wheat Starch	11.9±0.35
Potato Starch	17.7±0.38
Tapioca Starch	12.1±0.42
Psyllium	8.7±0.33

2.2.2 Differential Scanning Calorimetry (DSC)

Thermal properties of samples were measured using a differential scanning calorimeter (DSC) (Perkin Elmer DSC 4000, Turkey). Different types of starch samples (~5 mg) with and without added fiber, with the predefined moisture contents (Table 2.1) were hermetically sealed in DSC pans and were allowed to equilibrate at room temperature 4h before the analysis. The scanning temperature range and the heating rates were 30-110 °C and 10 °C/min, respectively. In all measurements, the thermograms were recorded with an empty aluminum pan as a reference. The thermal transition temperatures reported were the onset (T_o), peak (T_p), conclusion (T_c) temperatures, and the enthalpy changes (ΔH) calculated through the Pyris™ Manager software.

2.2.3 X-ray Diffraction (XRD)

X-ray diffraction patterns were obtained by using X-ray diffractometer (Rigaku Ultima-IV, Japan) at Middle East Technical University Central Laboratory. X-ray diffractograms of the samples were recorded on the X-ray diffractometer operating at 40 kV and 40mA with a Cu-K α source ($\lambda=0.154$ nm). The scanning angle (2θ) was in the range of 4° to 40° at a scanning speed of 4°/min.

2.2.4 Fourier Transform Infrared Spectrometry (FTIR)

The short-range molecular order of double helices of starch samples was determined using a FTIR spectrometer (Shimadzu Corporation, Kyoto, Japan). The spectra were acquired at wavelengths between 4000–400 cm^{-1} with a resolution of 4 cm^{-1} . All spectra were obtained using 64 scans.

2.2.5 Scanning Electron Microscopy (SEM)

SEM analysis of raw and cooked samples was conducted at Middle East Technical University Central Laboratory. Pieces were coated with Au-Pd (Polaron, Range, UK) and examined using a scanning electron microscope (400F Field Emission, Quanta, Holland) at an accelerating rate of 20 kV.

2.2.6 *In Vitro* Digestion

In vitro digestibilities of raw and cooked samples were determined according to the method described by Englyst et al. (2018) with minor modifications. In this method, carbohydrate digestibility fractions were defined by enzymatic hydrolysis, and the released glucose was measured. The samples were subjected to acid-protease treatment to mimic the gastric conditions. Amylolytic enzymes were used for the hydrolysis of starch, simulating the intestinal conditions. Released glucose amounts were determined by using the glucose oxidase and peroxidase assay kits (GOPOD) (Megazyme International Ireland Ltd., Bray Co., Wicklow, Ireland).

2.2.6.1 Preparation of Solution I

0.6 g guar gum was added into a beaker and wetted with 1 ml ethanol to prevent lumps from forming. Then 120 ml 0.05 M hydrochloric acid was added, and the solution was mixed with a magnetic stirrer.

2.2.6.2 Preparation of Solution II

3.0 g of pancreatin was weighed into three 50 ml centrifuge tubes, and 20 ml 0.1 M calcium chloride was added into each. The solution was mixed using a vortex mixer, then mixed with a magnetic stirrer for 10 min. The tubes were centrifuged at 1500 g for 10 min (2-16PK, Sigma Laborzentrifugen GmbH, Germany). After centrifugation, 17 ml of supernatant was taken from each tube and combined. 4 ml glucoamylase and 2 ml distilled water were added, and the solution was mixed with a magnetic stirrer. Then, the solution was put into a water bath to equilibrate to 37 °C before use. The prepared solution should be used within 1 h.

2.2.6.3 Sample Preparation

In order to provide 500 mg available carbohydrate, samples were weighed between 0.5 and 4 g into 50 ml screw-cap polypropylene tubes. Then, 5 ml of distilled water was added to the tubes to wet the samples. Similarly, tubes for blank and control were prepared with no sample and raw starch, respectively.

2.2.6.4 Incubation at 37°C for 30 Minutes

Samples were incubated with solution I with guar gum- 0.05M hydrochloric acid solution in a shaken water bath at 37°C, 100 rpm for 30 min to mimic gastric digestion. After 30 min of incubation, sample tubes were removed from the water bath, and five glass balls were added to assist mechanical disruption. Then 5 ml of 0.5 M sodium acetate solution was added into each tube, and the pH of sample tubes kept in the 5.2 -5.3 range. The sodium acetate solution was tested and adjusted as needed with 1M HCl or 1M NaOH solution beforehand.

2.2.6.5 Enzymatic Hydrolysis of Starch

After the addition of sodium acetate solution, the tubes were shaken to disperse the content. Then, 5 ml solution II, including pancreatin and amyloglucosidase, was added. This was the time of 0 minutes. The tube was immediately capped and placed horizontally in the shaking water bath at 37 °C. The addition of enzyme solution was repeated for all the sample tubes at 1 min intervals.

Taking G20 Fraction

After 20 min incubation with solution II, each tube was removed from the water bath to allow the transfer of 0.1 ml into 4.0 ml methanol and mixed with a vortex to stop the hydrolytic enzymes. This was the G20 portion. After the samples were taken for G20, the sample tubes were immediately returned to the water bath. The rest of the sample tubes were transferred at exact 1 min intervals.

Taking G120 Fraction

After a further 100 minutes of incubation, samples were collected from each tube in the same way as in the case of G20 fractions. At 120 min of incubation, 0.1 ml of the samples were added to 15 ml centrifuge tubes containing 4.0 ml of methanol in order to stop enzymatic activities. This was the G120 fraction.

2.2.6.6 Determination of Glucose

The glucose amounts released in the digestion solutions for each fraction (0, G20, and G120) were determined using the glucose oxidase and peroxidase assay kits (GOPOD). Samples obtained in each fraction were centrifuged at 500g for 5 min. 3 ml of GOPOD reagent was added to each centrifuge tube containing 0.1ml of the sample. Similarly, the tubes for reagent blank and standard were prepared. Then,

the tubes were incubated at 40°C-50°C for 20 min. The absorbance of glucose standard and samples were measured in the spectrophotometer (Shimadzu, UV-Visible Spectrophotometer, UV-1700, Japan) at 510 nm against the reagent blank.

The glucose contents of the samples were calculated as follows;

$$D - \text{Glucose } (\mu\text{g}/0.1 \text{ mL}) = \frac{\Delta A_{\text{Sample}}}{\Delta A_{D-\text{Glucose standard}(100\mu\text{g})}} \times 100$$

2.2.6.7 Measurement of Free Glucose

Samples were weighted, providing 500 mg available carbohydrate, into 50 ml tubes. Then, five glass balls were added to each tube. 25 ml water and 0.25 ml 1 M sodium acetate at pH 4.5 were added to each tube. The sample tubes were capped and vortex mixed before putting them into the water bath at 100 °C for 30 min. Then, the samples were vortex mixed and cooled to 37°C. 0.2 ml of invertase was added to each tube. The tubes were mixed and immersed horizontally in a shaken water-bath (37 °C) for 30 min. Each sample was vortex mixed before transferring 1ml of the sample into 15 ml centrifuge tubes containing 2 ml of methanol; this was the FG portion to be measured by GOPOD kit as in 2.2.6.6.

2.2.6.8 Measurement of Total Glucose

All the sample tubes were removed from the water bath after taking G120 fraction, and each tube was vortex mixed to disperse the sample. The samples were put into a water bath at 100°C for 30 min. Afterward, the tubes were removed from the water bath and placed in ice-water. 10 ml of 7 M KOH was added to tubes and the contents were mixed by shaking. The tubes were then immersed horizontally in a

shaken water bath comprising ice-water with constant shaking speed for 30 min. 1 ml of samples were immediately transferred into 50 ml tubes, including 10 ml of 0.5 M acetic acid. 0.2 mL of amyloglucosidase solution was added just before immersing the tubes in a water bath at 70°C for 30 min. Then, the tubes were removed and put into a water bath at 100 °C for 10 min. After the sample tubes were cooled down to room temperature, 40 ml of water was added, and the tubes were capped; this was the TG portion to be measured by the GOPOD kit as in 2.2.6.



CHAPTER 3

RESULTS AND DISCUSSION

3.1 Differential Scanning Calorimetry (DSC)

3.1.1 Thermal Properties of Starches

Thermal properties of wheat, potato, and tapioca starches were shown in Tables 3.1, 3.2, and 3.3, respectively. All the starch samples showed the typical endothermic transition, representing the gelatinization of starch, between 50 and 85 °C, with a well-defined start, peak, and conclusion transition points. The enthalpy changes were depicted both per gram “sample” and per gram “starch” in the sample (dry base) (Tables 3.1, 3.2, and 3.3).

Differences in the thermal properties among the starches can be attributed to the interplay of the following factors: the botanical source of the starch, the moisture content, the ratio of amylose to amylopectin, and the ratio of crystalline to amorphous content (Gunaratne & Hoover, 2002; H. Liu et al., 2006). Gelatinization temperatures are related to crystalline stability. On the other hand, gelatinization enthalpy is related to the melting of the amylopectin crystals, where packing organization and melting enthalpies of helices can contribute. Packing of A-type crystallites are more compact and melt at a higher temperature than B-type crystallites.

Generally, A-type starches have larger proportions of short chains (15.6–27.4%) (dp 6–12), and smaller proportions of long chains (6.6–26.7%) (dp > 37) than B-type starches, which have 8.5-12.3% and 26.1-29.5% fractions for the short and long chains, respectively. The chain length fractions of amylopectin of C-type starches could favor either short and long branch-chains (Jane et al., 1999).

Hizukuri et al. (1985) have also postulated values for weight average chain length (CL) of amylopectin of A, B, and C-type starches were in the ranges 23-29, 30-44, and 26-29, (CL) respectively.

The measured gelatinization enthalpies (ΔH) of the starches followed the order of potato starch > tapioca starch > wheat starch (Table 3.1, 3.2, and 3.3). The lower ΔH value for wheat starch reflected its higher proportion of short chains with a degree of polymerization (dp) of 6-12. As stated in Chung et al. (2009), short chains can not create stable double helices. Therefore, less energy was needed to open those double helices during gelatinization, as indicated by the lower gelatinization enthalpy value for wheat starch compared to tapioca and potato starches.

Compared to the wheat and tapioca starch, the potato starch had lower T_o , T_p , and T_c but higher ΔH values. The higher fraction of long chains in amylopectin results in more ordered structures, thereby need more thermal energy to break the crystalline order of starch (Jane et al., 1999). The higher ΔH values for potato starch were due a higher ratio of long chains resulting in a higher number of double helices. On the other hand, the lowest onset, peak, and conclusion gelatinization temperatures for potato starch could be due to its higher phosphate monoester content. At the glucose unit of potato starch, phosphate groups mainly occur at C₂, C₃, and C₆ positions (Hizukuri et al., 1981). Negatively charged phosphate groups on neighboring amylopectin chains create electrostatic repulsion, which led to weaker interaction between double helices (Gunaratne & Hoover, 2002). These characteristic properties ascribed to the packing of helices in the B-type starch is less compact than in A-type starches (Gidley, 1987). Also, there are 36 water molecules in a B-type starch unit, whereas A-type starch is more compactly packed with eight water molecules per unit cell (Hsien-Chih & Sarko, 1978). Consequently, B-type starches would be more mobile and more open to disruption than A-type starches because of their packing configuration and phosphate monoester concentration. Tapioca starch with C-type polymorphism possessed an

intermediate value of ΔH lower than that of B-type starch and higher than that of A-type starch.



Table 3.1 Thermal properties of wheat starch with and without psyllium fiber

Solid: Water (g:ml)	Psyllium % in dry matter	T _o (°C)	T _p (°C)	T _c (°C)	ΔH (J/g)	ΔH (J/gstarch)
1:5	0	64.57±0.15 ^{bA}	69.38±0.02 ^{bA}	74.98±0.07 ^{bA}	11.71±0.20	11.71±0.20 ^{aA}
	50	66.05±0.27 ^{aB}	71.06±0.17 ^{aB}	76.45±0.27 ^{aB}	4.77±0.06	9.54±0.12 ^{bA}
1:2	0	63.06±0.97 ^{bB}	68.34±0.32 ^{bB}	75.68±0.43 ^{bA}	10.07±0.48	10.07±0.48 ^{aB}
	50	67.54±0.50 ^{aA}	74.47±0.59 ^{aA}	81.75±1.05 ^{aA}	4.61±0.14	9.22±0.18 ^{bA}
1:1	0	62.55±0.14 ^B	67.18±0.15 ^C	72.02±0.32 ^B	2.32±0.40	2.32±0.40 ^C
	50	N.d.	N.d.	N.d.	N.d.	N.d.
WAW	0	N.d.	N.d.	N.d.	N.d.	N.d.
	50	N.m.	N.m.	N.m.	N.m.	N.m.

The data are averages of three replicate measurements with the standard deviation. Different small letters (a,b) indicate significant differences in each box (WS and WS+P) (p<0.05). Different capital letters (A, B, C) indicate significant differences in each group (WS or WS +P) in each column (p<0.05). WS: Wheat Starch, P: psyllium, WAW: Without Added Water, N.d.: Non-detectable, N.m.: Not measured.

Table 3.2 Thermal properties of potato starch with and without psyllium fiber

Solid: Water (g:ml)	Psyllium % in dry matter	T_o(°C)	T_p(°C)	T_c(°C)	ΔH (J/g)	ΔH (J/gstarch)
1:5	0	59.33±0.12 ^{bA}	64.09±0.17 ^{bA}	70.94±0.36 ^{aA}	23.17±2.67	23.17±2.67 ^{aA}
	50	60.69±0.12 ^{aB}	65.55±0.16 ^{aB}	71.38±0.35 ^{aB}	7.41±0.21	14.83±0.42 ^{bA}
1:2	0	57.79±0.12 ^{bB}	62.07±0.10 ^{bB}	70.11±0.43 ^{cA}	15.84±0.38	15.84±0.38 ^{aB}
	50	61.51±0.37 ^{aA}	67.14±0.43 ^{aA}	73.91±0.30 ^{bA}	6.44±0.10	12.88±0.20 ^{bB}
1:1	0	57.56±0.66 ^B	60.21±0.42 ^C	63.91±0.48 ^{dB}	2.36±0.48	2.36±0.48 ^C
	50	N.d.	N.d.	N.d.	N.d.	N.d.
WAW	0	N.d.	N.d.	N.d.	N.d.	N.d.
	50	N.m.	N.m.	N.m.	N.m.	N.m.

The data are averages of three replicate measurements with the standard deviation. Different small letters (a,b) indicate significant differences in each box (PS and PS+P) (p<0.05). Different capital letters (A, B, C) indicate significant differences in each group (PS or PS +P) in each column (p<0.05). PS: Potato Starch, P: psyllium, WAW: Without Added Water, N.d.: Non-detectable, N.m.: Not measured.

Table 3.3 Thermal properties of tapioca starch with and without psyllium fiber.

Solid: Water (g:ml)	Psyllium % in dry matter	T_o(°C)	T_p(°C)	T_c(°C)	ΔH (J/g)	ΔH (J/gstarch)
1:5	0	64.08±0.08 ^{ba}	69.93±0.10 ^{ba}	79.55±0.39 ^{aA}	15.49±1.46	15.49±1.46 ^{aA}
	50	66.82±0.09 ^{aB}	72.36±0.42 ^{aB}	80.30±0.41 ^{aB}	5.91±0.65	11.83±1.30 ^{ba}
1:2	0	63.18±0.61 ^{bb}	67.70±0.47 ^{bb}	79.93±0.81 ^{ba}	13.59±1.68	13.59±1.28 ^{aA}
	50	68.88±0.72 ^{aA}	75.24±0.76 ^{aB}	83.93±0.45 ^{aA}	5.64±0.12	11.27±0.25 ^{ba}
1:1	0	63.04±0.01 ^B	66.75±0.39 ^C	70.81±0.73 ^B	2.44±0.20	2.44±0.20 ^B
	50	N.d.	N.d.	N.d.	N.d.	N.d.
WAW	0	N.d.	N.d.	N.d.	N.d.	N.d.
	50	N.m.	N.m.	N.m.	N.m.	N.m.

* The data are averages of three replicate measurements with the standard deviation. Different small letters (a,b) indicate significant differences in each box (TS and TS+P) (p<0.05). Different capital letters (A, B, C) indicate significant differences in each group (TS or TS +P) in each column (p<0.05). TS: Tapioca Starch, P: psyllium, WAW: Without Added Water, N.d.: Non-detectable, N.m.: Not measured.

Decreasing the water content during the cooking of native starches reduced the measured enthalpies, indicating limited gelatinization defined by restricted melting of crystallites and double helices (Tables 3.1, 3.2, and 3.3).

Similarly, results (Tables 3.1, 3.2, and 3.3) showed that with the addition of psyllium fiber, the gelatinization enthalpies (ΔH) of all the starch types were decreased significantly for all starch: water ratios ($p < 0.05$)

- ✓ The ΔH of the wheat starch decreased from 11.71 ± 0.20 to 9.54 ± 0.12 (J/g starch) at starch: water ratio of 1:5, and from 10.07 ± 0.48 to 9.22 ± 0.18 (J/g starch) at starch: water ratio of 1:2 whereas for the starch: water ratio of 1:1 no endothermic transition was observed for the starch samples with added psyllium fiber.
- ✓ The ΔH of the potato starch decreased from 23.17 ± 2.67 to 14.83 ± 0.42 (J/g starch) at starch: water ratio of 1:5, and from 15.84 ± 0.38 to 12.88 ± 0.20 (J/g starch) at starch: water ratio of 1:2 whereas for the starch: water ratio of 1:1 no endothermic transition was observed for the starch samples with added psyllium fiber.
- ✓ The ΔH of the tapioca starch decreased from 15.49 ± 1.46 to 11.83 ± 1.30 (J/g starch) at starch: water ratio of 1:5, and from 13.59 ± 1.68 to 11.27 ± 0.25 (J/g starch) at starch: water ratio of 1:2 whereas for the starch: water ratio of 1:1 no endothermic transition was observed for the starch samples with added psyllium fiber.

The decreased gelatinization enthalpies and higher T_o , T_p , and T_c values in the psyllium added starches could be explained by the competition for water between psyllium and starch. Psyllium is a highly hydrophilic fiber that can compete with the starch granules for the available water, thereby can inhibit the water uptake and swelling of starch granules. The limited or non-existent entrance of water into the

amorphous and crystalline regions inhibited the melting of crystallites and double helices inside the granules. Limitation of water in surrounding starch granules due to psyllium delayed the gelatinization of starches and thus caused higher T_o , T_p , and T_c values (Table 3.1, 3.2, and 3.3).

3.2 X-ray Diffraction Patterns

The X-ray diffraction patterns of the native starches (wheat, potato, tapioca) starches and psyllium fiber were shown in Figure 3.1. Wheat starch displayed the typical A-type polymorphs in the XRD diffractogram (Figure 3.1), which showed four main peaks at 15° , 23° , and an unresolved doublet at about 17° and 18° (2θ). Potato starch showed a B-type diffractogram, with a strong diffraction peak at around 17° , a few small peaks at around 15° , 22° , and 24° , and a characteristic peak at about 5.6° . C-type starch has both A- and B-type crystallinity. Tapioca starch had peaks at 15° , 23° , and the doublet at 17° and 18° , which were indicative of the A pattern, while the peak at 5.6° is characteristic of the B pattern. Thus tapioca starch was classed as C-type. Psyllium showed a broad and diffused peak at 20.36 , indicating its amorphous nature.

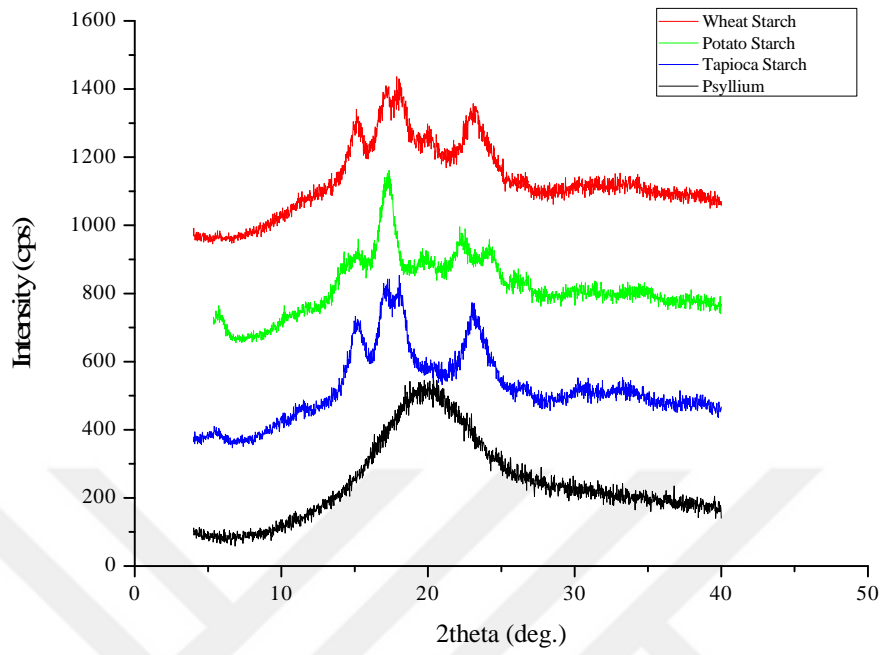


Figure 3.1 XRD profiles of native starches (wheat, potato, tapioca) and psyllium fiber.

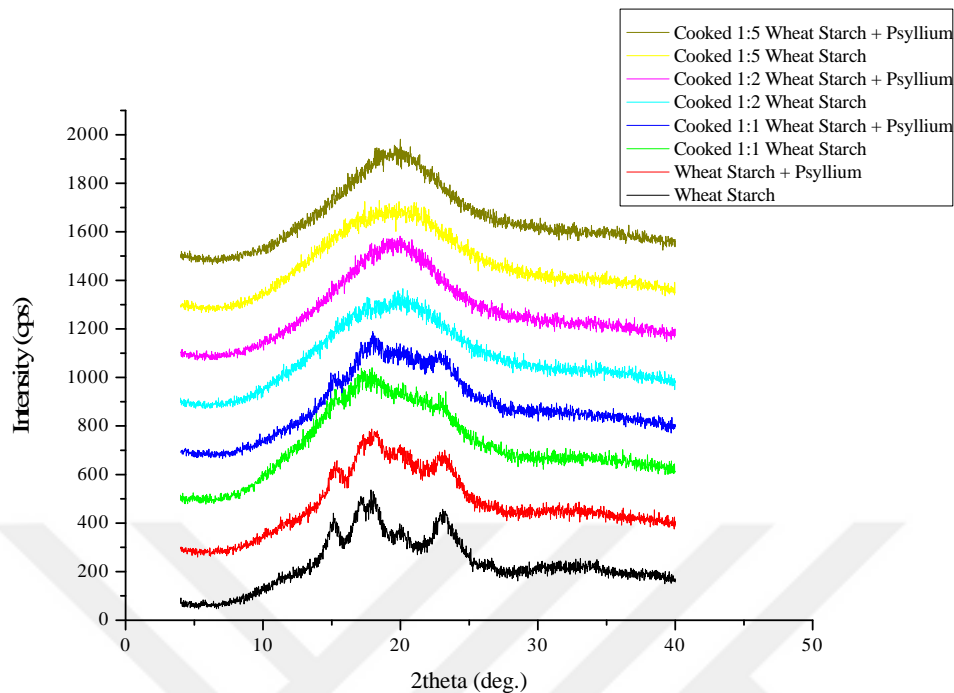


Figure 3.2 XRD profiles of raw and cooked wheat starch (A-type) with or without psyllium.

XRD diffractograms showed that the crystallinity of wheat starch without the fiber was lost during the heating process, especially at high water concentrations (1:2 and 1:5), exhibiting broad, amorphous peaks (Figure 3.2). As can be seen from the diffractogram of the raw starch-fiber mixture (Figure 3.2), the broad, amorphous peak of psyllium fiber (Figure 3.1) hid some of the peaks of raw wheat starch. Therefore, for the starches cooked especially at the higher water concentrations, it was impossible to see the remaining peaks if there were any residual peaks indicative of crystallinity. The residual A-type crystal peaks that could be seen for the starch cooked at low water concentration (1:1) could also be seen for the starch-fiber mixture with higher intensities, indicating the enhanced effect of fiber addition on the loss of crystallinity. These results showed the effect of fiber addition and decreasing the water content on the loss of crystallinity.

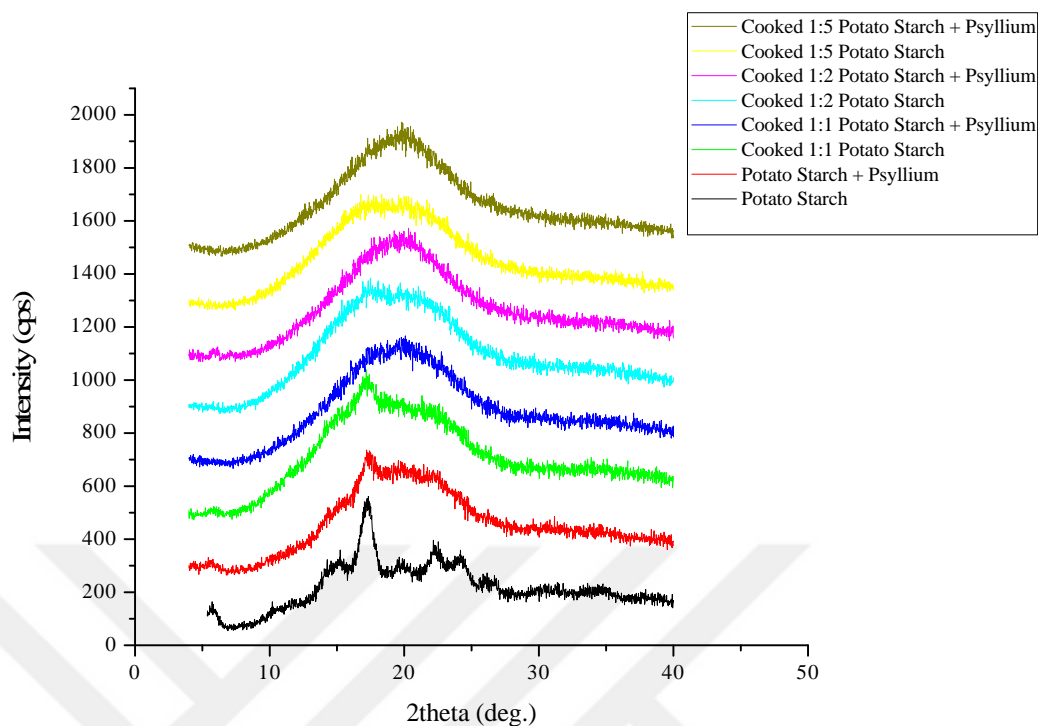


Figure 3.3 XRD profiles of raw and cooked potato starch (B-type) with or without psyllium

The crystallinity of potato starch without the fiber was lost during the heating process, especially at high water concentrations, exhibiting broad, amorphous peaks (Figure 3.3). Similar to wheat starch samples, diffractograms of the raw potato-psyllium mixtures showed that the signals coming from the fiber hid some of the signals representative of the peaks of the raw potato starch (Figure 3.3). Thus, the residual peaks belonging to potato starch, if there were any after the heating process, could not be seen accurately, hiding behind the diffractogram of the fiber. Only the tip of the peak (17°) was visible clearly in the raw starch fiber mixture. The intensity of the peak (17°) decreased for the lowest water ratio (1:1) for the potato starch without the fiber and disappeared behind the signals of the fiber for the starch-fiber mixture after cooking (Figure 3.3).

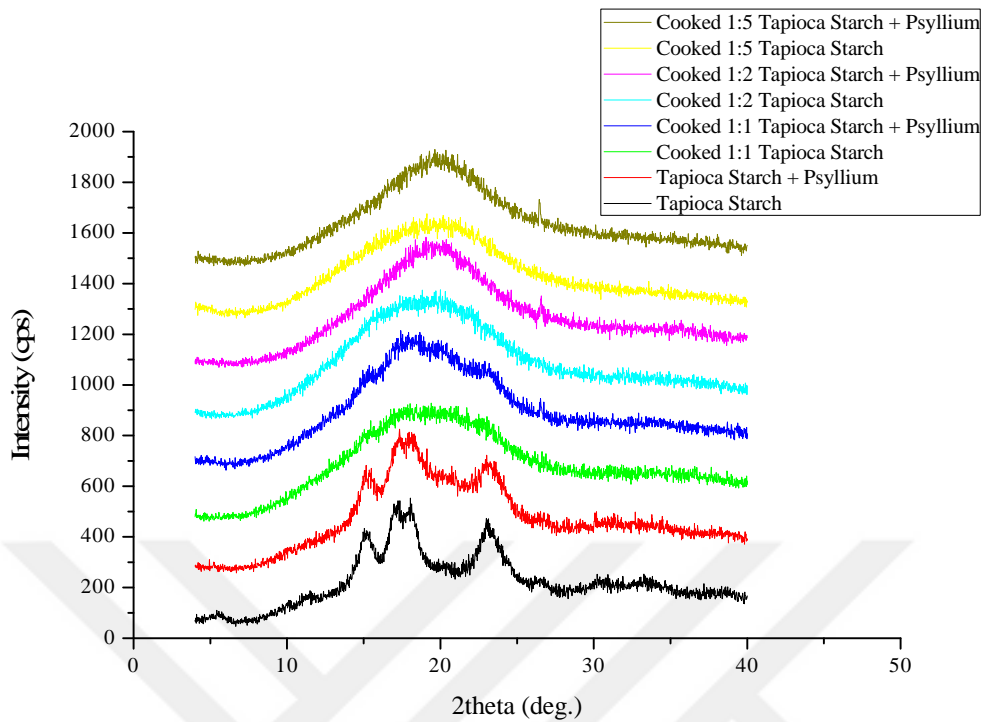


Figure 3.4 XRD profiles of raw and cooked tapioca starch (C-type) with or without psyllium

The typical peaks of native tapioca starch were lost after the heating process at all water concentrations (Figure 3.4), exhibiting broad, amorphous peaks. Some remaining residual peaks were visible for the starch-fiber mixtures, which were cooked at 1:1 water concentration. This result indicated psyllium fiber addition, especially at low water concentration, limited the loss of crystallinity (Figure 3.4). For high water concentrations, there were no visible peaks. These results showed that increasing the water concentration during heating reduced the crystallinity of starch. During heating, starch absorbs water and expands; this causes enlargement of the amorphous region and reduces crystallinity. The decreased crystallinity indicated dissociated double helix and disintegrated crystallite structures. Water promotes the effects of heat treatment on starch crystallite disruptions by inducing the breakage of hydrogen bonds; therefore, the three starch types were expectedly degraded as the water content rose.

3.3 FTIR Spectroscopy

The FTIR spectrum is responsive to changes in the structure on a short-range order (molecular level), described as the double-helical order, while X-ray diffraction is responsive to the packing of double helices related to the long-range order of crystallites (Martínez et al., 2019). FTIR spectra of starch indicate a short-range order near the granule surface. The absorption bands at 1047 and 1022 cm^{-1} are characteristics of crystalline and amorphous starch structures, respectively. Thus, the ratio of 1047 cm^{-1} /1022 cm^{-1} corresponds to the short-range order of double helices in starches (B. Zhang et al., 2013).

The corresponding peaks for 1047 cm^{-1} and 1022 cm^{-1} were observed 1043 cm^{-1} and 1016 cm^{-1} respectively for all three starch samples. The low value for the ratio of 1043 cm^{-1} /1016 cm^{-1} for the native potato (0.684 ± 0.004) starch compared to native wheat (0.701 ± 0.008) starch indicated loosely packed double helices near the surface (Table 3.4). The IR ratio for tapioca starch, a C-type, was not significantly different from either starch type. Results show that there was not any significant change in the short-range order for the native starch samples after cooking at low water concentration (1:1) (Tables 3.5, 3.6, and 3.7). Thus, the short-range order of starch granules was preserved at low water concentration. Increasing the water content during cooking decreased ($p < 0.05$) the ratio of ordered crystalline to amorphous structure ($1043/1016 \text{ cm}^{-1}$) for all the starch types (Tables 3.5, 3.6, and 3.7). The results indicated that increasing the water content led to the loss of regularity in the short-range molecular order of starches. During starch gelatinization, crystalline starch structures have disrupted, leading to a decreased intensity of the band at 1043 cm^{-1} . The band at 1016 cm^{-1} significantly rises with the increased amorphous region in starch (Wang et al., 2017).

Psyllium added cooked starch mixtures had higher values for the ratio of 1043 cm^{-1} /1016 cm^{-1} compared to cooked starch samples due to relatively higher value for

the ratio of absorbances obtained for psyllium fiber compared to native starches (Tables 3.5, 3.6, and 3.7). Similarly, increasing the water content decreased ($p < 0.05$) the ratio of absorbances at $1043/1016 \text{ cm}^{-1}$ for all the starch types cooked with added psyllium fiber (Tables 3.5, 3.6, and 3.7). Consequently, water molecules have played a vital role in the stability of the structure of starch granules. During heating, the presence of water facilitated the destruction of the hydrogen bonds. As a result, a higher portion of double helices of starch remained after cooking in the samples with little water (Tables 3.5, 3.6, and 3.7).

Table 3.4 IR ratios of $1043 \text{ cm}^{-1}/1016 \text{ cm}^{-1}$ of raw starches & psyllium determined by FTIR

Sample	IR Ratio $1043 \text{ cm}^{-1}/1016 \text{ cm}^{-1}$
Raw wheat starch	0.701 ± 0.008^a
Raw potato starch	0.684 ± 0.004^b
Raw tapioca starch	0.694 ± 0.006^{ab}
Raw psyllium	0.923 ± 0.01

The data are averages of three measurements with the standard deviation. Different small letters indicate significant differences in the column ($p < 0.05$).

Table 3.5 IR ratios of 1043 cm⁻¹/ 1016 cm⁻¹ of wheat starch with and without added psyllium fiber determined by FTIR

Samples	Psyllium Content (%)	IR Ratio 1043 cm⁻¹/ 1016 cm⁻¹
Cooked WS-1:5	0	0.613 ± 0.005 ^c
	50	0.741 ± 0.014 ^c
Cooked-WS-1:2	0	0.632 ± 0.004 ^b
	50	0.764 ± 0.005 ^b
Cooked-WS-1:1	0	0.685 ± 0.010 ^a
	50	0.791 ± 0.004 ^a
Raw-WS-WAW	0	0.701 ± 0.008 ^a
Raw-P-WAW	100	0.923 ± 0.01

The data are averages of three measurements with the standard deviation. Different small letters indicate significant differences in the column (p<0.05). WS: Wheat starch; P; Psyllium; WAW: without added water.

Table 3.6 IR ratios of 1043 cm⁻¹/ 1016 cm⁻¹ of potato starch with and without added psyllium fiber determined by FTIR

	Psyllium Content (%)	IR Ratio 1043 cm ⁻¹ / 1016 cm ⁻¹
Cooked-PS-1:5	0	0.637± 0.013 ^c
	50	0.792± 0.007 ^c
Cooked-PS-1:2	0	0.660 ± 0.004 ^b
	50	0.811 ± 0.006 ^b
Cooked-PS-1:1	0	0.678 ± 0.008 ^a
	50	0.839 ± 0.009 ^a
Raw-PS-WAW	0	0.684 ± 0.004 ^a
Raw P-WAW	100	0.923 ± 0.01

The data are averages of three measurements with the standard deviation. Different small letters indicate significant differences in the column (p<0.05). PS: Potato starch; P; Psyllium; WAW: without added water.

Table 3.7 IR ratios of 1043 cm⁻¹/ 1016 cm⁻¹ of tapioca starch with and without added psyllium fiber determined by FTIR

	Psyllium Content (%)	IR Ratio 1043 cm ⁻¹ / 1016 cm ⁻¹
Cooked-TS-1:5	0	0.641 ± 0.007 ^c
	50	0.787 ± 0.005 ^c
Cooked-TS-1:2	0	0.659 ± 0.004 ^b
	50	0.803 ± 0.008 ^b
Cooked-TS-1:1	0	0.680 ± 0.006 ^a
	50	0.822 ± 0.005 ^a
Raw-TS-WAW	0	0.694 ± 0.006 ^a
Raw P-WAW	100	0.923 ± 0.01

The data are averages of three measurements with the standard deviation. Different small letters indicate significant differences in the column (p<0.05). TS: Tapioca starch; P; Psyllium; WAW: without added water.

3.4 Scanning Electron Microscopy (SEM)

Morphologies of starch granules of wheat, potato, and tapioca starches before and after cooking were analyzed using scanning electron microscopy (SEM). The SEM images of native starches and psyllium fiber were depicted in Fig.3.5. The images showed that starch granules of wheat, potato, and tapioca starches had different morphological characteristics. Wheat starch had starch granules of two different sizes. The large granules displayed spherical and disk-like shapes with shallow grooves, whereas the small granules showed spherical and ellipsoidal shapes (Figure 3.5a) (Jackson, 2003). For potato starch, larger granules were flattened ellipsoidal shaped, and the smaller granules were mainly spherical shaped (Figure 3.5b) (Jackson, 2003; Singh et al., 2016). The granules of tapioca starch were round in shape with some truncated structure (Figure 3.5c) (Mishra & Rai, 2006). Psyllium fiber with an elongated shape was displayed in Figure 3.5d.

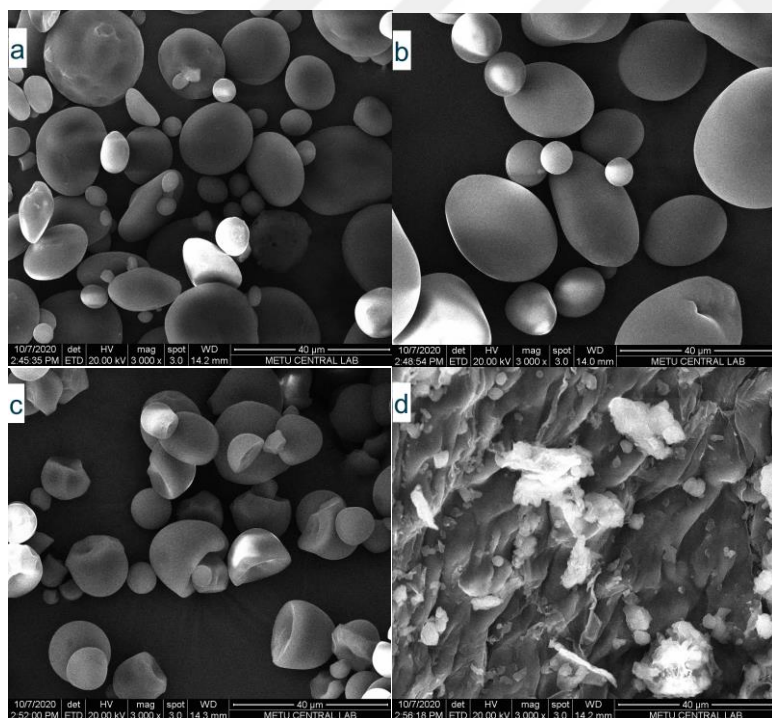


Figure 3.5 SEM images of a) wheat starch, b) potato starch, c) tapioca starch, d) psyllium

The morphological changes of wheat, potato, and tapioca starches with or without psyllium fiber cooked at different water contents were depicted in Fig.3.6, Fig.3.7, and Fig.3.8, respectively. After cooking, granules of the three starches showed distinct swelling and disintegration behavior due to their botanical origin. When they cooked at low water concentrations (1:1), tapioca starch granules were agglomerated with porous granules on the surface (Fig3.8e). On the other hand, cooking caused the rough surface and eroded granules for wheat and potato starches (Fig3.6-7e). It was possible to see deformed granules in the starch samples cooked at low water concentrations (1:1), even with psyllium fiber.

Starch granules cooked at high water concentrations were almost completely disrupted; they had swollen and coalesced substantially (Fig3.6a-b). Since water promotes the disruption of the crystalline structure of starch, the three starches were expectedly gelatinized as the water content increased. However, the addition of psyllium fiber limited the degree of gelatinization and led to the incomplete disruption of starch, especially at low water concentration.

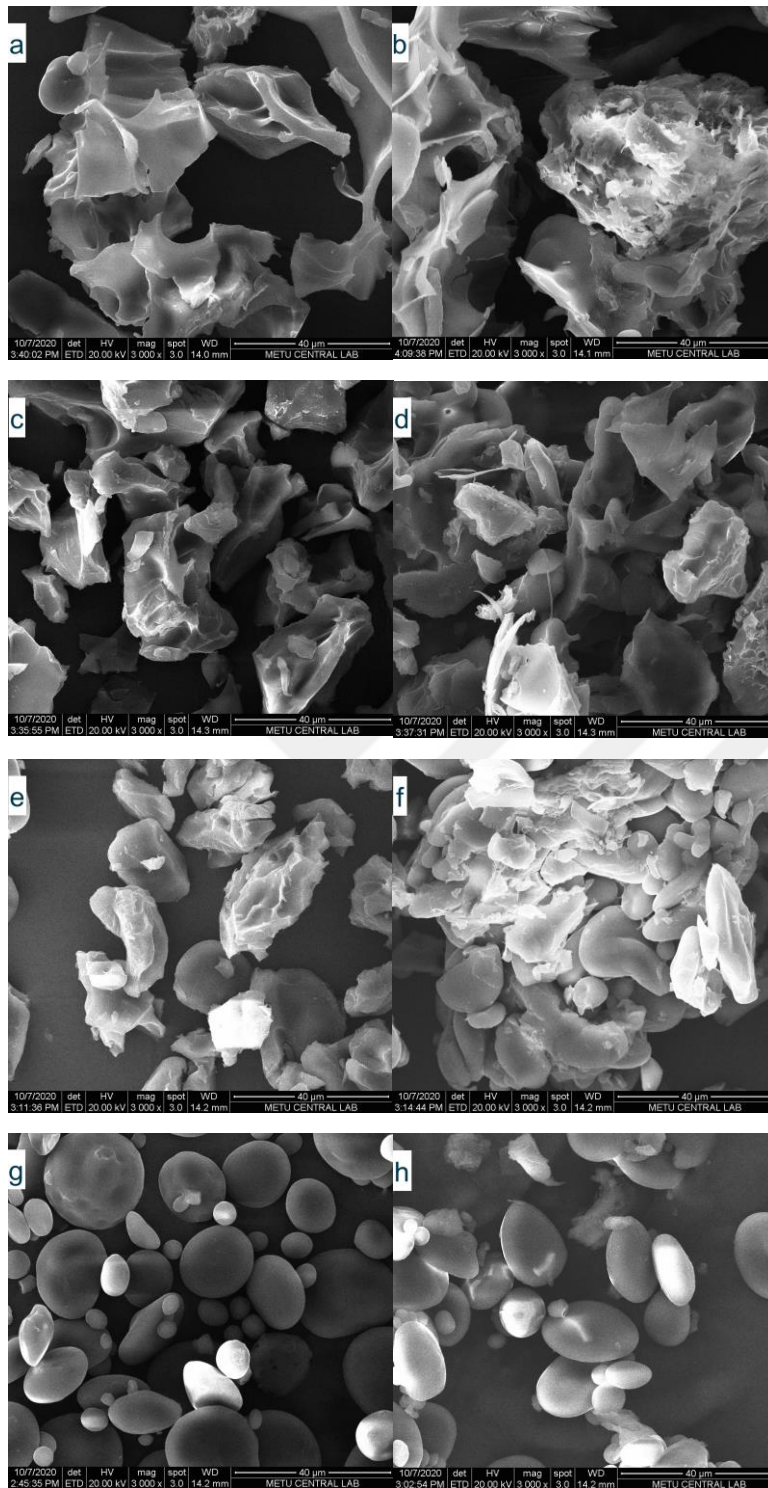


Figure 3.6 SEM images of wheat starches: a) Cooked 1:5 WS; b) Cooked 1:5 WS+P; c) Cooked 1:2 WS; d) Cooked 1:2 WS+P; e) Cooked 1:1 WS; f) Cooked 1:1 WS+P; g) Raw WS; h) Raw WS+P (WS: Wheat Starch; P: Psyllium) .

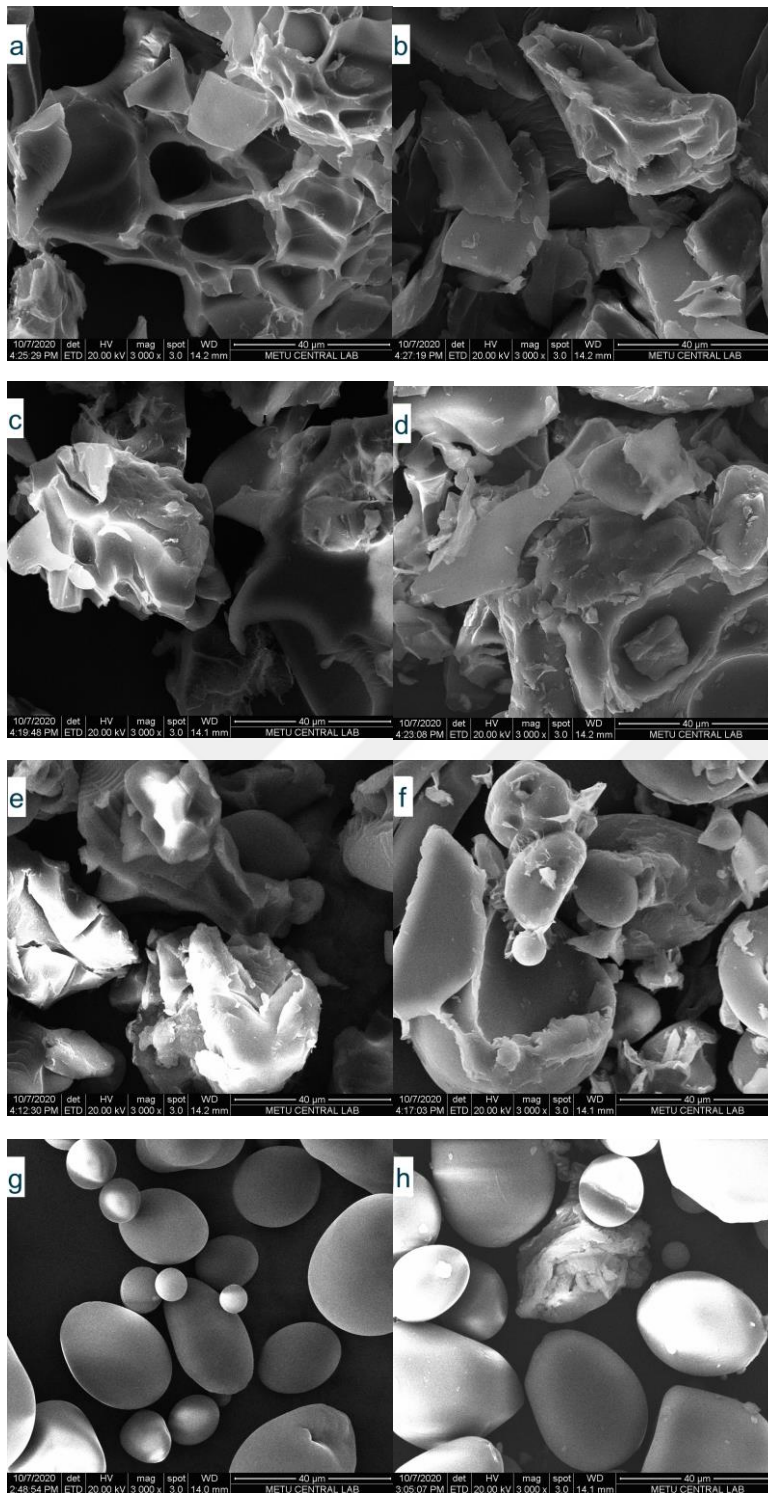


Figure 3.7 SEM images of potato starches: a) Cooked 1:5 PS; b) Cooked 1:5 WP+P; c) Cooked 1:2 PS; d) Cooked 1:2 PS+P; e) Cooked 1:1 PS; f) Cooked 1:1 PS+P; g) Raw PS; h) Raw PS+P (PS: Potato Starch; P: Psyllium).

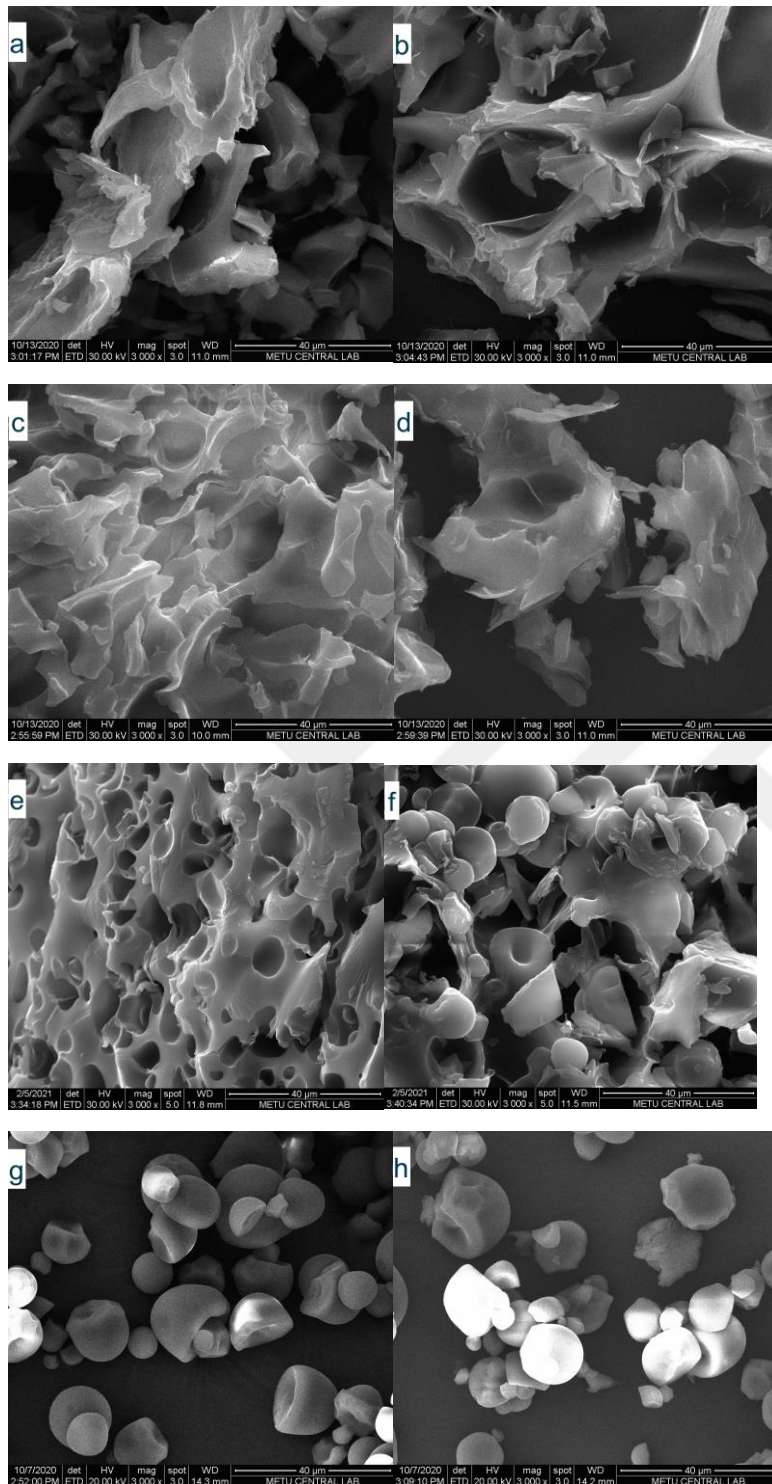


Figure 3.8 SEM images of tapioca starches: a) Cooked 1:5 TS; b) Cooked 1:5 TP+P; c) Cooked 1:2 TS; d) Cooked 1:2 TS+P; e) Cooked 1:1 TS; f) Cooked 1:1 TS+P; g) Raw TS; h) Raw TS+P (TS: Tapioca Starch; P: Psyllium).

3.5 *In vitro* Starch Digestibility

Rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS) fractions, which were determined as digested starch fractions “per total starch” in the samples for all the starch types, were presented in Figure 3.9 for visual observation. Tables 3.8, 3.9, and 3.10 depict RDS, SDS, and RS fractions “per total starch” and “per sample weight” to show the effect of starch dilution with psyllium. As seen from the tables, psyllium addition could cause a reduction in all the obtained RDS, SDS, and RS fractions calculated “per sample weight” for the all starch types, raw or cooked, due to dilution, which could be significant, especially at high fiber concentrations.

Among the native starches, wheat starch had the highest RDS and SDS level, where the order was WS>TS>PS for both RDS and SDS levels (Figure 3.9 and Tables 3.8-3.10). Native potato starch had the highest level of RS where the order was PS>TS>WS (Figure 3.9 and Tables 3.8-3.10). A similar trend was also observed for cooked starches except for the SDS fractions. The RDS and RS fractions of cooked starches were in the following order: WS>TS>PS, PS>TS>WS, respectively. Native and cooked potato starches were more resistant to enzymatic digestion than wheat and tapioca starches. This could be attributed to the crystalline packing arrangement was not the main factor predicting enzymatic susceptibility. The larger amount of short chains (DP 6–12) could result in weak points in the structure of wheat starch (A-type) and leads to a higher susceptibility to enzymatic hydrolysis (Honda et al., 2020). The lower ΔH value obtained for wheat starch confirmed the higher proportion of short-chain fractions needing less energy to open the bonds (Table 3.8). On the other hand, B-type starches have branch points in the amorphous regions and have many long chains in amylopectin, causing a higher amount of ordered structure. Therefore, being a B-type starch, potato starch was more resistant to hydrolysis and had a higher RS level. Tapioca starch, a C-type, had shown starch fraction levels between the wheat and potato starches.

After cooking RDS/TS levels were increased, and SDS/TS and RS/TS levels decreased for all the starch types (Figure 3.9). The changes in RDS/TS and RS/TS levels after cooking were immense, whereas the differences in SDS/TS levels were relatively small for all starch types (Figure 3.9 and Tables 3.8-3.10). RDS/TS levels increased, and RS/TS levels decreased for all the starch types as the water content increased during cooking (Figure 3.9 and Tables 3.8-3.10). However, the decrease in the SDS/TS levels after cooking was not proportional to the increase in water content for all starch types (Figure 3.9 and Tables 3.8-3.10).

The results indicated that most of the SDS/TS fractions in the native starches converted to RDS/TS fractions after cooking, and some of the RS/TS fractions converted to SDS/TS fractions (Figure 3.9 and Tables 3.8-3.10). In other words, cooking diminished the crystalline and ordered molecular structure of the native starches and facilitated the access of amyolytic enzymes to starch chains for hydrolysis. During cooking, starch granules expanded and gelatinized. The high temperature and water caused the hydrogen bonds between the chains to break, diminish the crystal structure, and transform them into a continuous amorphous form. Therefore, allowing the enzyme to break down the starch. The decrease in RS/TS levels could be due to the reduced forces between amylose molecules during cooking. Moreover, increasing RDS/TS levels with increasing water content for all the starch types ($p < 0.05$) could be attributed to the increased gelatinization degree hence, the opening of more starch chains (Table 3.8, 3.9, and 3.10).

When native starches with and without added psyllium fiber were compared, samples with the psyllium fiber had significantly lower RDS/TS and SDS/TS levels and higher RS/TS levels for all the starch types ($p < 0.05$) (Figure 3.9 and Tables 3.8-3.10). On the other hand, when cooked samples with and without added psyllium fiber were compared, it was observed that the samples cooked with psyllium had lower RDS/TS and higher SDS/TS and RS/TS levels (Figure 3.9).

The RDS fraction of the wheat starch decreased from 72.70 ± 0.87 to 47.70 ± 0.69 (g starch/g total starch) at starch: water ratio of 1:5, from 68.04 ± 0.86 to 36.89 ± 0.39 (g starch/g total starch) at starch: water ratio of 1:2, and from 61.66 ± 0.68 to 28.22 ± 0.40 (g starch/g total starch) at starch: water ratio of 1:1 with the addition of psyllium fiber.

The RDS fraction of the potato starch decreased from 64.17 ± 0.94 to 39.12 ± 0.65 (g starch/g total starch) at starch: water ratio of 1:5, from 58.52 ± 0.72 to 27.10 ± 0.49 (g starch/g total starch) at starch: water ratio of 1:2, and from 50.60 ± 0.59 to 18.81 ± 0.21 (g starch/g total starch) at starch: water ratio of 1:1 with the addition of psyllium fiber.

The RDS fraction of the tapioca starch decreased from 70.54 ± 1.04 to 43.56 ± 0.58 (g starch/g total starch) at starch: water ratio of 1:5, from 65.90 ± 0.86 to 32.17 ± 0.65 (g starch/g total starch) at starch: water ratio of 1:2, and from 58.04 ± 0.50 to 20.51 ± 0.39 (g starch/g total starch) at starch: water ratio of 1:1 with the addition of psyllium fiber.

The differences in RDS/TS and RS/TS levels due to added fiber were immense for the cooked samples, whereas the differences in SDS/TS levels were relatively small or non-significant ($p < 0.05$) (Figure 3.9 and Tables 3.8 - 3.10). The lower RDS/TS and higher RS/TS levels in the psyllium added cooked starches could be attributed to reduced gelatinization observed by the DSC data (Tables 3.1, 3.2, and 3.3). The limited gelatinization caused by the high water absorption capacity of psyllium fiber resulted in a more ordered structure in the end product, leading to a reduced starch hydrolysis rate during digestion. Besides, during digestion, the high viscosity of psyllium could also interfere with the mobility of the enzymes limiting the starch hydrolysis. The limitation associated with the higher viscosity may provide a protective barrier to starch granules, leading to an inhibited access of enzymes to starch substrates. Increased thickness could reduce the diffusion rate of

the enzymes. The effect of limited enzyme mobility was better observed with the native starch samples with and without fiber. In addition to large differences in RDS and RS levels, the differences in SDS levels were also immense for the raw samples (Figure 3.9 and Tables 3.8 - 3.10).

When raw starch-fiber mixtures were compared with the cooked starch-fiber mixtures, it was seen that after cooking RDS/TS levels were increased, and SDS/TS and RS/TS levels were decreased even for the samples cooked at low water concentrations (1:1) except for potato starch mix (Figure 3.9 and Tables 3.8 - 3.10). The potato starch-fiber mixture did not show significantly different SDS/TS level from the raw mix, only at 1:1 water concentration. At this water concentration, loss of some crystallinity or enlargement of amorphous regions due to heat treatment was observed in the XRD diffractograms. Also, slightly damaged/deformed starch granules were observed in the SEM images (Figures 3.6, 3.7, and 3.8), where FTIR data showed that some of the short-range order of starch granules was preserved after cooking at this low water concentration. All these data suggested that the long-range order crystalline structure was disrupted to some degree, allowing enzymatic hydrolysis at this water concentration (1:1).

**DIGESTIBILITY FRACTIONS OF WHEAT, POTATO, AND TAPIOCA STARCHES
(RDS/TS, SDS/TS, RS/TS, RS/TS)**

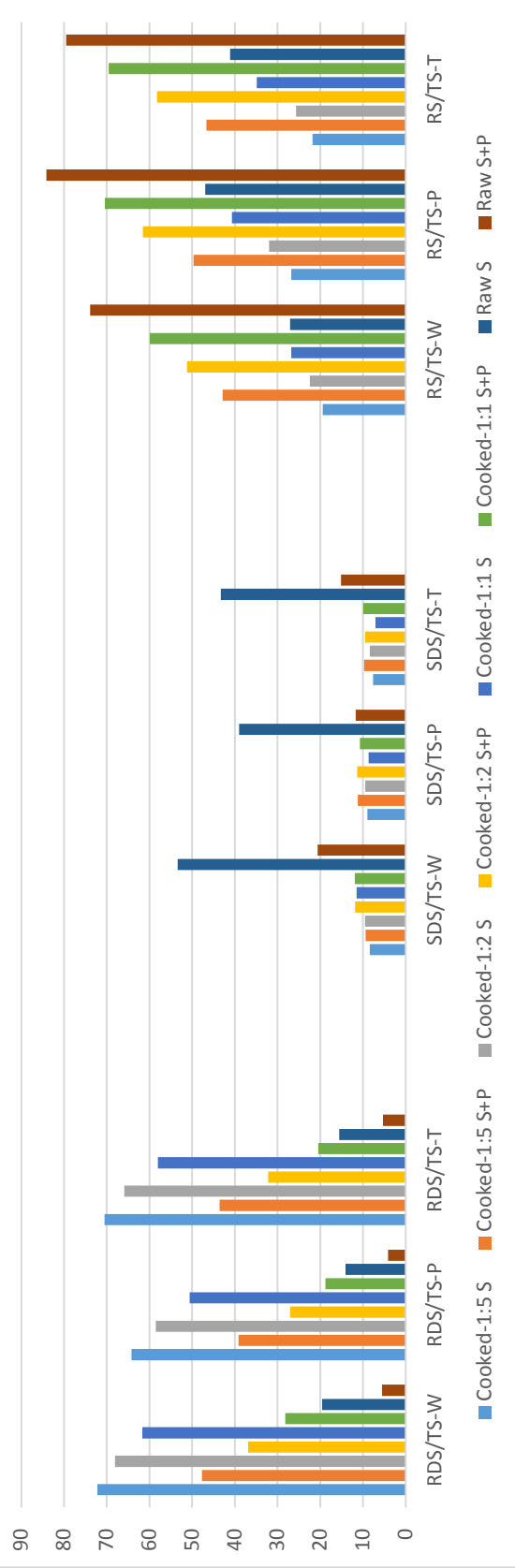


Figure 3.9 Digestibility Fractions of Wheat, Potato and Tapioca Starches (RDS/TS, SDS/TS, and RS/TS)

Table 3.8 The amount of wheat starch nutritional fractions with and without added psyllium fiber (RDS/TS, SDS/TS, SDS/SW, and RS/TS).

Sample	RDS/TS (%)	RDS/SW (%)	SDS/TS (%)	SDS/SW (%)	RS/TS (%)	RS/SW (%)
Cooked-1:5 WS	72.20±0.87 ^{aA}	74.82±0.87	8.38±0.50 ^{bC}	8.69±0.50	19.42±1.01 ^{bC}	20.12±1.01
Cooked-1:5 WS+P	47.70±0.69 ^{bA}	24.24±0.34	9.40±0.31 ^{aC}	4.78±0.16	42.90±0.63 ^{aD}	21.80±0.31
Cooked-1:2 WS	68.04±0.86 ^{aB}	70.33±0.86	9.53±0.51 ^{bB}	9.85±0.51	22.42±0.82 ^{bB}	23.17±0.82
Cooked-1:2 WS+P	36.89±0.39 ^{bB}	18.83±0.19	11.88±0.34 ^{aB}	6.06±0.17	51.23±0.58 ^{aC}	26.15±0.29
Cooked-1:1 WS	61.66±0.68 ^{aC}	63.91±0.68	10.49±0.26 ^{bB}	11.93±0.26	25.85±0.63 ^{bA}	26.43±0.63
Cooked-1:1 WS+P	28.22±0.40 ^{bC}	14.21±0.20	11.89±0.39 ^{aB}	5.98±0.20	59.89±0.68 ^{aB}	30.15±0.33
WS-WAW	19.56±0.31 ^{aD}	19.89±0.31	53.37±0.44 ^{aA}	54.28±0.44	27.07±0.57 ^{bA}	27.53±0.57
WS+P-WAW	5.51±0.07 ^{bD}	2.86±0.04	20.59±0.22 ^{bA}	10.69±0.11	73.90±0.20 ^{aA}	38.37±0.09

The data are averages of three replicate measurements with the standard deviation. Different small letters (a,b) indicate significant differences between the samples with and without fiber at the same water concentration ($p < 0.05$). Different capital letters indicate significant differences in each group (WS or WS + P) in each column ($p < 0.05$). TS: the measured amount of total starch (dry weight), SW: Total weight of the sample (dry base), WS: Wheat Starch, P: Psyllium, WAW: Without Added Water.

Table 3.9 The amount of potato starch nutritional fractions with and without added psyllium fiber (RDS/TS, SDS/TS, and RS/TS).

Sample	RDS/TS (%)	RDS/SW (%)	SDS/TS (%)	SDS/SW (%)	RS/TS (%)	RS/SW (%)
Cooked-1:5 PS	64.17±0.94 ^{3aA}	64.57±0.94	9.00±0.36 ^{bb}	9.06±0.36	26.82±0.88 ^{bd}	26.99±0.88
Cooked-1:5 PS+P	39.12±0.65 ^{bA}	20.61±0.32	11.21±0.47 ^{aA}	5.91±0.23	49.67±0.64 ^{ab}	26.18±0.32
Cooked-1:2 PS	58.52±0.72 ^{ab}	59.27±0.72	9.48±0.56 ^{bb}	9.59±0.56	32.01±0.90 ^{bc}	32.42±0.90
Cooked-1:2 PS+P	27.10±0.49 ^{bb}	14.32±0.24	11.38±0.26 ^{aA}	6.01±0.13	61.52±0.69 ^{aC}	32.50±0.34
Cooked-1:1 PS	50.60±0.59 ^{aC}	51.98±0.59	8.72±0.37 ^{bb}	8.96±0.37	40.68±0.60 ^{bb}	41.79±0.60
Cooked-1:1 PS+P	18.81±0.21 ^{bc}	9.32±0.10	10.74±0.42 ^{aA}	5.32±0.21	70.43±0.43 ^{ab}	34.86±0.21
PS-WAW	14.11±0.19 ^{ad}	14.07±0.19	38.98±0.32 ^{aA}	38.85±0.32	46.91±0.66 ^{bA}	46.76±0.66
PS+P-WAW	4.15±0.13 ^{bd}	2.12±0.06	11.71±0.17 ^{bA}	5.99±0.08	84.13±0.38 ^{aA}	43.04±0.19

The data are averages of three replicate measurements with the standard deviation. Different small letters (a,b) indicate significant differences between the samples with and without fiber at the same water concentration ($p<0.05$). Different capital letters indicate significant differences in each group (WS or WS + P) in each column ($p<0.05$). TS: the measured amount of total starch (dry weight), SW: Total weight of the sample (dry base), PS: Potato Starch, P: Psyllium, WAW: Without Added Water.

Table 3.10 The amount of tapioca starch nutritional fractions with and without added psyllium fiber (RDS/TS, SDS/TS, and RS/TS).

Sample	RDS/TS (%)	RDS/SW (%)	SDS/TS (%)	SDS/SW (%)	RS/TS (%)	RS/SW (%)
Cooked-1:5 TS	70.54±1.04 ^{aA}	71.60±1.04	7.66±0.42 ^{bC}	7.78±0.42	21.80±1.13 ^{bD}	22.12±1.13
Cooked-1:5 TS+P	43.56±0.58 ^{bA}	22.70±0.29	9.74±0.59 ^{aB}	5.08±0.29	46.69±0.76 ^{aD}	2.33±0.38
Cooked-1:2 TS	65.90±0.86 ^{aB}	65.51±0.86	8.40±0.52 ^{bB}	8.35±0.52	25.71±0.78 ^{bC}	25.55±0.78
Cooked-1:2 TS+P	32.17±0.65 ^{bB}	17.00±0.32	9.56±0.32 ^{aB}	5.05±0.16	58.26±0.74 ^{aC}	30.80±0.37
Cooked-1:1 TS	58.04±0.50 ^{aC}	60.63±0.50	7.06±0.29 ^{bC}	7.38±0.29	34.89±0.69 ^{bB}	36.45±0.69
Cooked-1:1 TS+P	20.51±0.39 ^{bC}	10.35±0.19	9.98±0.47 ^{aB}	5.04±0.23	69.51±0.41 ^{aB}	35.09±0.20
TS-WAW	15.55±0.42 ^{aD}	16.29±0.42	43.32±0.58 ^{aA}	45.39±0.58	41.13±0.68 ^{aA}	43.09±0.68
TS+P-WAW	5.34±0.28 ^{bD}	2.78±0.14	15.16±0.26 ^{bA}	7.90±0.13	79.50±0.43 ^{aA}	41.42±0.21

The data are averages of three replicate measurements with the standard deviation. Different small letters (a,b) indicate significant differences between the samples with and without fiber at the same water concentration ($p<0.05$). Different capital letters indicate significant differences in each group (WS or WS + P) in each column ($p<0.05$). TS: the measured amount of total starch (dry weight), SW: Total weight of the sample (dry base), TS: Tapioca Starch, P: Psyllium, WAW: Without Added Water.

CHAPTER 4

CONCLUSION AND RECOMMENDATIONS

This study showed that wheat, potato, and tapioca starches had different structural, morphological, and starch digestibility properties. Besides, water content and psyllium fiber addition during cooking affected the structural, morphological, and digestion properties of wheat, potato, and tapioca starches. Psyllium addition during cooking decreased the rapidly digestible starch (RDS) fractions while increased the slowly digestible starch (SDS), and resistant starch (RS) fractions. The effect of psyllium fiber addition was not limited to restricting the swelling and gelatinization of a starch granule during cooking. Psyllium fiber also constrained the mobility of digestive enzymes during digestion.

Understanding the relationship between psyllium and starch digestibility could assist in designing food formulations with lower starch digestibility. These *in vitro* data, however, should be confirmed by *in vivo* studies



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APPENDICES

A. STATISTICAL ANALYSIS

Table A. 1 One way ANOVA and Tukey's Comparison Test with 95% confidence level for To at starch: water ratio of 1:5 of wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: To versus WS-1:5

Factor	Type	Levels	Values
WS-1:5	fixed	2	0; 50

Analysis of Variance for To, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-1:5	1	3,2856	3,2856	3,2856	68,88	0,001
Error	4	0,1908	0,1908	0,0477		
Total	5	3,4764				

S = 0,218403 R-Sq = 94,51% R-Sq(adj) = 93,14%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-1:5	N	Mean	Grouping
50	3	66,0	A
0	3	64,6	B

Means that do not share a letter are significantly different.

Table A. 2 One way ANOVA and Tukey's Comparison Test with 95% confidence level for To at starch: water ratio of 1:2 of wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: To versus WS-1:2

Factor	Type	Levels	Values
WS-1:2	fixed	2	0; 50

Analysis of Variance for To, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-1:2	1	30,106	30,106	30,106	50,56	0,002
Error	4	2,382	2,382	0,595		
Total	5	32,487				

S = 0,771654 R-Sq = 92,67% R-Sq(adj) = 90,84%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-1:2	N	Mean	Grouping
50	3	67,5	A
0	3	63,1	B

Means that do not share a letter are significantly different.

Table A. 3 One way ANOVA and Tukey's Comparison Test with 95% confidence level for To depending on water concentration for wheat starch without psyllium fiber

General Linear Model: To versus WS-water conc

Factor	Type	Levels	Values
WS-water conc	fixed	3	1; 2; 5

Analysis of Variance for To, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-water conc	2	6,6206	6,6206	3,3103	10,10	0,012
Error	6	1,9660	1,9660	0,3277		
Total	8	8,5866				

S = 0,572422 R-Sq = 77,10% R-Sq(adj) = 69,47%

Unusual Observations for To

Obs	T0	Fit	SE Fit	Residual	St Resid
5	64,0300	63,0600	0,3305	0,9700	2,08 R
6	62,0900	63,0600	0,3305	-0,9700	-2,08 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95,0% Confidence

WS-water conc	N	Mean	Grouping
5	3	64,6	A
2	3	63,1	B
1	3	62,5	B

Means that do not share a letter are significantly different.

Table A. 4 One way ANOVA and Tukey's Comparison Test with 95% confidence level for To depending on water concentration for wheat starch with psyllium fiber

General Linear Model: To versus WS-W/PSYLLIUM

Factor	Type	Levels	Values
WS-W/PSYLLIUM	fixed	2	2; 5

Analysis of Variance for To, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-W/PSYLLIUM	1	3,3302	3,3302	3,3302	20,63	0,010
Error	4	0,6458	0,6458	0,1614		
Total	5	3,9760				

S = 0,401808 R-Sq = 83,76% R-Sq(adj) = 79,70%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-W/PSYLLIUM	N	Mean	Grouping
2	3	67,5	A
5	3	66,0	B

Means that do not share a letter are significantly different.

Table A. 5 One way ANOVA and Tukey's Comparison Test with 95% confidence level for Tp at starch: water ratio of 1:5 of wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: Tp versus WS-1:5

Factor	Type	Levels	Values
WS-water conc	fixed	2	0; 50

Analysis of Variance for Tp, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-1:5	1	4,2336	4,2336	4,2336	288,98	0,000
Error	4	0,0586	0,0586	0,0147		
Total	5	4,2922				

S = 0,121037 R-Sq = 98,63% R-Sq(adj) = 98,29%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-1:5	N	Mean	Grouping
50	3	71,1	A
0	3	69,4	B

Means that do not share a letter are significantly different.

Table A. 6 One way ANOVA and Tukey's Comparison Test with 95% confidence level for Tp at starch: water ratio of 1:2 of wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: Tp versus WS-1:2

Factor	Type	Levels	Values
WS-1:2	fixed	2	0; 50

Analysis of Variance for Tp, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-1:2	1	56,365	56,365	56,365	250,23	0,000
Error	4	0,901	0,901	0,225		
Total	5	57,266				

S = 0,474605 R-Sq = 98,43% R-Sq(adj) = 98,03%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-1:2	N	Mean	Grouping
50	3	74,5	A
0	3	68,3	B

Means that do not share a letter are significantly different.

Table A. 7 One way ANOVA and Tukey's Comparison Test with 95% confidence level for Tp depending on water concentration for wheat starch without psyllium fiber

General Linear Model: Tp versus WS-water conc

Factor	Type	Levels	Values
WS-water conc	fixed	3	1; 2; 5

Analysis of Variance for Tp, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-water conc	2	7,2672	7,2672	3,6336	87,00	0,000
Error	6	0,2506	0,2506	0,0418		
Total	8	7,5178				

S = 0,204369 R-Sq = 96,67% R-Sq(adj) = 95,56%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-water conc	N	Mean	Grouping
5	3	69,4	A
2	3	68,3	B
1	3	67,2	C

Means that do not share a letter are significantly different.

Table A. 8 One way ANOVA and Tukey's Comparison Test with 95% confidence level for Tp depending on water concentration for wheat starch with psyllium fiber

General Linear Model: Tp versus WS-/W PSYLLIUM

Factor	Type	Levels	Values
WS-/W PSYLLIUM	fixed	2	2; 5

Analysis of Variance for Tp, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-/W PSYLLIUM	1	17,442	17,442	17,442	92,53	0,001
Error	4	0,754	0,754	0,189		
Total	5	18,196				

S = 0,434166 R-Sq = 95,86% R-Sq(adj) = 94,82%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-/W PSYLLIUM	N	Mean	Grouping
2	3	74,5	A
5	3	71,1	B

Means that do not share a letter are significantly different.

Table A. 9 One way ANOVA and Tukey's Comparison Test with 95% confidence level for Tc at starch: water ratio of 1:5 of wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: Tc versus WS-1:5

Factor	Type	Levels	Values
WS-1:5	fixed	2	0; 50

Analysis of Variance for Tc, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-1:5	1	3,2413	3,2413	3,2413	83,33	0,001
Error	4	0,1556	0,1556	0,0389		
Total	5	3,3969				

S = 0,197231 R-Sq = 95,42% R-Sq(adj) = 94,27%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-1:5	N	Mean	Grouping
50	3	76,5	A
0	3	75,0	B

Means that do not share a letter are significantly different.

Table A. 10 One way ANOVA and Tukey's Comparison Test with 95% confidence level for at starch: water ratio of 1:2 of wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: Tc versus WS-1:2

Factor	Type	Levels	Values
WS-1:2	fixed	2	0; 50

Analysis of Variance for Tc, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-1:2	1	55,267	55,267	55,267	85,86	0,001
Error	4	2,575	2,575	0,644		
Total	5	57,842				

S = 0,802309 R-Sq = 95,55% R-Sq(adj) = 94,44%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-1:2	N	Mean	Grouping
50	3	81,8	A
0	3	75,7	B

Means that do not share a letter are significantly different.

Table A. 11 One way ANOVA and Tukey's Comparison Test with 95% confidence level for Tc depending on water concentration for wheat starch without psyllium fiber

General Linear Model: Tc versus WS-water conc

Factor	Type	Levels	Values
WS-water conc	fixed	3	1; 2; 5

Analysis of Variance for Tc, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-water conc	2	22,647	22,647	11,324	116,26	0,000
Error	6	0,584	0,584	0,097		
Total	8	23,232				

S = 0,312090 R-Sq = 97,48% R-Sq(adj) = 96,65%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-water conc	N	Mean	Grouping
2	3	75,7	A
5	3	75,0	A
1	3	72,0	B

Means that do not share a letter are significantly different.

Table A. 12 One way ANOVA and Tukey's Comparison Test with 95% confidence level for Tc depending on water concentration for wheat starch with psyllium fiber

General Linear Model: Tc versus WS-/W PSYLLIUM

Factor	Type	Levels	Values
WS-/W PSYLLIUM	fixed	2	2; 5

Analysis of Variance for Tc, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-/W PSYLLIUM	1	42,135	42,135	42,135	71,69	0,001
Error	4	2,351	2,351	0,588		
Total	5	44,486				

S = 0,766616 R-Sq = 94,72% R-Sq(adj) = 93,39%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-/W PSYLLIUM	N	Mean	Grouping
2	3	81,8	A
5	3	76,5	B

Means that do not share a letter are significantly different.

Table A. 13 One way ANOVA and Tukey's Comparison Test with 95% confidence level for DH at starch: water ratio of 1:5 of wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: DH versus WS-1:5

Factor	Type	Levels	Values
WS-1:5	fixed	2	0; 50

Analysis of Variance for DH, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-1:5	1	7,0634	7,0634	7,0634	259,68	0,000
Error	4	0,1088	0,1088	0,0272		
Total	5	7,1722				

S = 0,164924 R-Sq = 98,48% R-Sq(adj) = 98,10%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-1:5	N	Mean	Grouping
0	3	11,7	A
50	3	9,5	B

Means that do not share a letter are significantly different.

Table A. 14 One way ANOVA and Tukey's Comparison Test with 95% confidence level for DH at starch: water ratio of 1:2 of wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: DH versus WS-1:2

Factor	Type	Levels	Values
WS-1:2	fixed	2	0; 50

Analysis of Variance for DH, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-1:2	1	1,0837	1,0837	1,0837	8,25	0,045
Error	4	0,5256	0,5256	0,1314		
Total	5	1,6093				

S = 0,362491 R-Sq = 67,34% R-Sq(adj) = 59,18%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-1:2	N	Mean	Grouping
0	3	10,1	A
50	3	9,2	B

Means that do not share a letter are significantly different.

Table A. 15 One way ANOVA and Tukey's Comparison Test with 95% confidence level for DH depending on water concentration for wheat starch without psyllium fiber

General Linear Model: DH versus WS-water conc

Factor	Type	Levels	Values
WS-water conc	fixed	3	1; 2; 5

Analysis of Variance for DH, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-water conc	2	150,924	150,924	75,462	525,99	0,000
Error	6	0,861	0,861	0,143		
Total	8	151,785				

S = 0,378770 R-Sq = 99,43% R-Sq(adj) = 99,24%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-water conc	N	Mean	Grouping
5	3	11,7	A
2	3	10,1	B
1	3	2,3	C

Means that do not share a letter are significantly different.

Table A. 16 One way ANOVA and Tukey's Comparison Test with 95% confidence level for DH depending on water concentration for wheat starch with psyllium fiber

General Linear Model: DH versus WS-W/PSYLLIUM

Factor	Type	Levels	Values
WS-W/PSYLLIUM	fixed	2	2; 5

Analysis of Variance for DH, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-W/PSYLLIUM	1	0,15360	0,15360	0,15360	6,56	0,063
Error	4	0,09360	0,09360	0,02340		
Total	5	0,24720				

S = 0,152971 R-Sq = 62,14% R-Sq(adj) = 52,67%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-W/PSYLLIUM	N	Mean	Grouping
5	3	9,5	A
2	3	9,2	A

Means that do not share a letter are significantly different.

Table A. 17 One way ANOVA and Tukey's Comparison Test with 95% confidence level for To at starch: water ratio of 1:5 of potato starch with (50%) and without (0%) psyllium fiber

General Linear Model: To versus PS-1:5

Factor Type Levels Values
 PS-1:5 fixed 2 0; 50

Analysis of Variance for To, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PS-1:5	1	2,7744	2,7744	2,7744	192,67	0,000
Error	4	0,0576	0,0576	0,0144		
Total	5	2,8320				

S = 0,12 R-Sq = 97,97% R-Sq(adj) = 97,46%

Grouping Information Using Tukey Method and 95,0% Confidence

PS-1:5	N	Mean	Grouping
50	3	60,7	A
0	3	59,3	B

Means that do not share a letter are significantly different.

Table A. 18 One way ANOVA and Tukey's Comparison Test with 95% confidence level for To at starch: water ratio of 1:2 of potato starch with (50%) and without (0%) psyllium fiber

General Linear Model: To versus PS-1:2

Factor Type Levels Values
 PS-1:2 fixed 2 0; 50

Analysis of Variance for To, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PS-1:2	1	20,758	20,758	20,758	274,39	0,000
Error	4	0,303	0,303	0,076		
Total	5	21,060				

S = 0,275045 R-Sq = 98,56% R-Sq(adj) = 98,20%

Grouping Information Using Tukey Method and 95,0% Confidence

PS-1:2	N	Mean	Grouping
50	3	61,5	A
0	3	57,8	B

Means that do not share a letter are significantly different.

Table A. 19 One way ANOVA and Tukey's Comparison Test with 95% confidence level for To depending on water concentration for potato starch without psyllium fiber

General Linear Model: To versus PS-water conc

Factor	Type	Levels	Values
PS-water conc	fixed	3	1; 2; 5

Analysis of Variance for To, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PS-water conc	2	5,5574	5,5574	2,7787	17,95	0,003
Error	6	0,9288	0,9288	0,1548		
Total	8	6,4862				

S = 0,393446 R-Sq = 85,68% R-Sq(adj) = 80,91%

Unusual Observations for To

Obs	To	Fit	SE Fit	Residual	St Resid
8	58,2200	57,5600	0,2272	0,6600	2,05 R
9	56,9000	57,5600	0,2272	-0,6600	-2,05 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95,0% Confidence

PS-water conc	N	Mean	Grouping
5	3	59,3	A
2	3	57,8	B
1	3	57,6	B

Means that do not share a letter are significantly different.

Table A. 20 One way ANOVA and Tukey's Comparison Test with 95% confidence level for To depending on water concentration for potato starch with psyllium fiber

General Linear Model: To versus PS-/W PSYLLIUM

Factor	Type	Levels	Values
PS-/W PSYLLIUM	fixed	2	2; 5

Analysis of Variance for To, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PS-/W PSYLLIUM	1	1,0086	1,0086	1,0086	13,33	0,022
Error	4	0,3026	0,3026	0,0756		
Total	5	1,3112				

S = 0,275045 R-Sq = 76,92% R-Sq(adj) = 71,15%

Grouping Information Using Tukey Method and 95,0% Confidence

PS-/W PSYLLIUM	N	Mean	Grouping
2	3	61,5	A
5	3	60,7	B

Means that do not share a letter are significantly different.

Table A. 21 One way ANOVA and Tukey's Comparison Test with 95% confidence level for Tp at starch: water ratio of 1:5 of potato starch with (50%) and without (0%) psyllium fiber

General Linear Model: Tp versus PS-1:5

Factor	Type	Levels	Values
PS-1:5	fixed	2	0; 50

Analysis of Variance for Tp, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PS-1:5	1	3,1974	3,1974	3,1974	117,34	0,000
Error	4	0,1090	0,1090	0,0272		
Total	5	3,3064				

S = 0,165076 R-Sq = 96,70% R-Sq(adj) = 95,88%

Grouping Information Using Tukey Method and 95,0% Confidence

PS-1:5	N	Mean	Grouping
50	3	65,5	A
0	3	64,1	B

Means that do not share a letter are significantly different.

Table A. 22 One way ANOVA and Tukey's Comparison Test with 95% confidence level for Tp at starch: water ratio of 1:2 of potato starch with (50%) and without (0%) psyllium fiber

General Linear Model: Tp versus PS-1:2

Factor	Type	Levels	Values
PS-1:2	fixed	2	0; 50

Analysis of Variance for Tp, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PS-1:2	1	38,557	38,557	38,557	395,66	0,000
Error	4	0,390	0,390	0,097		
Total	5	38,947				

S = 0,312170 R-Sq = 99,00% R-Sq(adj) = 98,75%

Grouping Information Using Tukey Method and 95,0% Confidence

PS-1:2	N	Mean	Grouping
50	3	67,1	A
0	3	62,1	B

Means that do not share a letter are significantly different.

Table A. 23 One way ANOVA and Tukey's Comparison Test with 95% confidence level for Tp depending on water concentration for potato starch without psyllium fiber

General Linear Model: Tp versus PS-water conc

Factor	Type	Levels	Values
PS-water conc	fixed	3	1; 2; 5

Analysis of Variance for Tp, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PS-water conc	2	22,594	22,594	11,297	157,42	0,000
Error	6	0,431	0,431	0,072		
Total	8	23,025				

S = 0,267893 R-Sq = 98,13% R-Sq(adj) = 97,51%

Grouping Information Using Tukey Method and 95,0% Confidence

PS-water conc	N	Mean	Grouping
5	3	64,1	A
2	3	62,1	B
1	3	60,2	C

Means that do not share a letter are significantly different.

Table A. 24 One way ANOVA and Tukey's Comparison Test with 95% confidence level for Tp depending on water concentration for potato starch with psyllium fiber

General Linear Model: Tp versus PS-/W PSYLLIUM

Factor Type Levels Values
 PS-/W PSYLLIUM fixed 2 2; 5

Analysis of Variance for Tp, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PS-/W PSYLLIUM	1	3,7922	3,7922	3,7922	36,03	0,004
Error	4	0,4210	0,4210	0,1053		
Total	5	4,2132				

S = 0,324423 R-Sq = 90,01% R-Sq(adj) = 87,51%

Grouping Information Using Tukey Method and 95,0% Confidence

PS-/W PSYLLIUM	N	Mean	Grouping
2	3	67,1	A
5	3	65,5	B

Means that do not share a letter are significantly different.

Table A. 25 One way ANOVA and Tukey's Comparison Test with 95% confidence level for DH at starch: water ratio of 1:5 of potato starch with (50%) and without (0%) psyllium fiber

General Linear Model: DH versus PS-1:5

Factor Type Levels Values
 PS-1:5 fixed 2 0; 50

Analysis of Variance for DH, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PS-1:5	1	104,33	104,33	104,33	28,56	0,006
Error	4	14,61	14,61	3,65		
Total	5	118,94				

S = 1,91119 R-Sq = 87,72% R-Sq(adj) = 84,65%

Grouping Information Using Tukey Method and 95,0% Confidence

PS-1:5	N	Mean	Grouping
0	3	23,2	A
50	3	14,8	B

Means that do not share a letter are significantly different.

Table A. 26 One way ANOVA and Tukey's Comparison Test with 95% confidence level for DH at starch: water ratio of 1:2 of potato starch with (50%) and without (0%) psyllium fiber

General Linear Model: DH versus PS-1:2

Factor	Type	Levels	Values
PS-1:2	fixed	2	0; 50

Analysis of Variance for DH, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PS-1:2	1	13,142	13,142	13,142	142,54	0,000
Error	4	0,369	0,369	0,092		
Total	5	13,511				

S = 0,303645 R-Sq = 97,27% R-Sq(adj) = 96,59%

Grouping Information Using Tukey Method and 95,0% Confidence

PS-1:2	N	Mean	Grouping
0	3	15,8	A
50	3	12,9	B

Means that do not share a letter are significantly different.

Table A. 27 One way ANOVA and Tukey's Comparison Test with 95% confidence level for DH depending on water concentration for potato starch without psyllium fiber

General Linear Model: DH versus PS-water conc

Factor	Type	Levels	Values
PS-water conc	fixed	3	1; 2; 5

Analysis of Variance for DH, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PS-water conc	2	668,50	668,50	334,25	133,63	0,000
Error	6	15,01	15,01	2,50		
Total	8	683,50				

S = 1,58153 R-Sq = 97,80% R-Sq(adj) = 97,07%

Unusual Observations for DH

Obs	DH	Fit	SE Fit	Residual	St Resid
2	25,8400	23,1700	0,9131	2,6700	2,07 R
3	20,5000	23,1700	0,9131	-2,6700	-2,07 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95,0% Confidence

PS-water conc	N	Mean	Grouping
5	3	23,2	A
2	3	15,8	B
1	3	2,4	C

Table A. 28 One way ANOVA and Tukey's Comparison Test with 95% confidence level for DH depending on water concentration for potato starch with psyllium fiber

General Linear Model: DH versus PS-/W PSYLLIUM

Factor	Type	Levels	Values
PS-/W PSYLLIUM	fixed	2	2; 5

Analysis of Variance for DH, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PS-/W PSYLLIUM	1	5,7037	5,7037	5,7037	52,71	0,002
Error	4	0,4328	0,4328	0,1082		
Total	5	6,1365				

S = 0,328938 R-Sq = 92,95% R-Sq(adj) = 91,18%

Grouping Information Using Tukey Method and 95,0% Confidence

PS-/W PSYLLIUM	N	Mean	Grouping
5	3	14,8	A
2	3	12,9	B

Means that do not share a letter are significantly different.

Means that do not share a letter are significantly different.

Table A. 29 One way ANOVA and Tukey's Comparison Test with 95% confidence level for To at starch: water ratio of 1:5 of tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: To versus TS-1:5

Factor	Type	Levels	Values
TS-1:5	fixed	2	0; 50

Analysis of Variance for To, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-1:5	1	11,426	11,426	11,426	2218,72	0,000
Error	4	0,021	0,021	0,005		
Total	5	11,447				

S = 0,0717635 R-Sq = 99,82% R-Sq(adj) = 99,78%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-1:5	N	Mean	Grouping
50	3	66,8	A
0	3	64,1	B

Means that do not share a letter are significantly different.

Table A. 30 One way ANOVA and Tukey's Comparison Test with 95% confidence level for To at starch: water ratio of 1:2 of tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: To versus TS-1:2

Factor Type Levels Values
 TS-1:2 fixed 2 0; 50

Analysis of Variance for To, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-1:2	1	48,735	48,735	48,735	109,46	0,000
Error	4	1,781	1,781	0,445		
Total	5	50,516				

S = 0,667271 R-Sq = 96,47% R-Sq(adj) = 95,59%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-1:2	N	Mean	Grouping
50	3	68,9	A
0	3	63,2	B

Means that do not share a letter are significantly different.

Table A. 31 One way ANOVA and Tukey's Comparison Test with 95% confidence level for To depending on water concentration for tapioca starch without psyllium fiber

General Linear Model: To versus TS- water conc

Factor	Type	Levels	Values
TS- water conc	fixed	3	1; 2; 5

Analysis of Variance for To, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS- water conc	2	1,9112	1,9112	0,9556	7,57	0,023
Error	6	0,7572	0,7572	0,1262		
Total	8	2,6684				

S = 0,355246 R-Sq = 71,62% R-Sq(adj) = 62,16%

Unusual Observations for To

Obs	To	Fit	SE Fit	Residual	St Resid
5	63,7900	63,1800	0,2051	0,6100	2,10 R
6	62,5700	63,1800	0,2051	-0,6100	-2,10 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95,0% Confidence

TS- water conc	N	Mean	Grouping
5	3	64,1	A
2	3	63,2	B
1	3	63,0	B

Means that do not share a letter are significantly different.

Table A. 32 One way ANOVA and Tukey's Comparison Test with 95% confidence level for To depending on water concentration for tapioca starch with psyllium fiber

General Linear Model: To versus TS-/W PSYLLIUM

Factor	Type	Levels	Values
TS-/W PSYLLIUM	fixed	2	2; 5

Analysis of Variance for To, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-/W PSYLLIUM	1	6,2424	6,2424	6,2424	23,90	0,008
Error	4	1,0446	1,0446	0,2611		
Total	5	7,2870				

S = 0,511028 R-Sq = 85,66% R-Sq(adj) = 82,08%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-/W PSYLLIUM	N	Mean	Grouping
2	3	68,9	A
5	3	66,8	B

Means that do not share a letter are significantly different.

Table A. 33 One way ANOVA and Tukey's Comparison Test with 95% confidence level for Tp at starch: water ratio of 1:5 of tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: Tp versus TS-1:5

Factor	Type	Levels	Values
TS-1:5	fixed	2	0; 50

Analysis of Variance for Tp, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-1:5	1	8,8573	8,8573	8,8573	104,20	0,001
Error	4	0,3400	0,3400	0,0850		
Total	5	9,1973				

S = 0,291548 R-Sq = 96,30% R-Sq(adj) = 95,38%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-1:5	N	Mean	Grouping
50	3	72,4	A
0	3	69,9	B

Means that do not share a letter are significantly different.

Table A. 34 One way ANOVA and Tukey's Comparison Test with 95% confidence level for Tp at starch: water ratio of 1:2 of tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: Tp versus TS-1:2

Factor	Type	Levels	Values
TS-1:2	fixed	2	0; 50

Analysis of Variance for Tp, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-1:2	1	84,225	84,225	84,225	253,94	0,000
Error	4	1,327	1,327	0,332		
Total	5	85,552				

S = 0,575905 R-Sq = 98,45% R-Sq(adj) = 98,06%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-1:2	N	Mean	Grouping
50	3	75,2	A
0	3	67,7	B

Means that do not share a letter are significantly different.

Table A. 35 One way ANOVA and Tukey's Comparison Test with 95% confidence level for To depending on water concentration for tapioca starch without psyllium fiber

General Linear Model: Tp versus TS-water conc

Factor	Type	Levels	Values
TS-water conc	fixed	3	1; 2; 5

Analysis of Variance for Tp, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-water conc	2	15,9878	15,9878	7,9939	92,24	0,000
Error	6	0,5200	0,5200	0,0867		
Total	8	16,5078				

S = 0,294392 R-Sq = 96,85% R-Sq(adj) = 95,80%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-water conc	N	Mean	Grouping
5	3	69,9	A
2	3	67,7	B
1	3	66,8	C

Means that do not share a letter are significantly different.

Table A. 36 One way ANOVA and Tukey's Comparison Test with 95% confidence level for To depending on water concentration for tapioca starch with psyllium fiber

General Linear Model: Tp versus TS-/W PSYLLIUM

Factor	Type	Levels	Values
TS-/W PSYLLIUM	fixed	2	2; 5

Analysis of Variance for Tp, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-/W PSYLLIUM	1	12,042	12,042	12,042	36,31	0,004
Error	4	1,327	1,327	0,332		
Total	5	13,368				

S = 0,575905 R-Sq = 90,08% R-Sq(adj) = 87,60%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-/W PSYLLIUM	N	Mean	Grouping
2	3	75,2	A
5	3	72,4	B

Means that do not share a letter are significantly different.

Table A. 37 One way ANOVA and Tukey's Comparison Test with 95% confidence level for Tc at starch: water ratio of 1:5 of tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: Tc versus TS-1:5

Factor	Type	Levels	Values
TS-1:5	fixed	2	0; 50

Analysis of Variance for Tc, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-1:5	1	0,8438	0,8438	0,8438	5,41	0,081
Error	4	0,6242	0,6242	0,1560		
Total	5	1,4680				

S = 0,395032 R-Sq = 57,48% R-Sq(adj) = 46,85%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-1:5	N	Mean	Grouping
50	3	80,3	A
0	3	79,5	A

Means that do not share a letter are significantly different.

Table A. 38 One way ANOVA and Tukey's Comparison Test with 95% confidence level for Tc at starch: water ratio of 1:2 of tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: Tc versus TS-1:2

Factor	Type	Levels	Values
TS-1:2	fixed	2	0; 50

Analysis of Variance for Tc, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-1:2	1	24,000	24,000	24,000	56,97	0,002
Error	4	1,685	1,685	0,421		
Total	5	25,685				

S = 0,649038 R-Sq = 93,44% R-Sq(adj) = 91,80%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-1:2	N	Mean	Grouping
50	3	83,9	A
0	3	79,9	B

Means that do not share a letter are significantly different.

Table A. 39 One way ANOVA and Tukey's Comparison Test with 95% confidence level for Tc depending on water concentration for tapioca starch without psyllium fiber

General Linear Model: Tc versus TS-water conc

Factor	Type	Levels	Values
TS-water conc	fixed	3	1; 2; 5

Analysis of Variance for Tc, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-water conc	2	159,706	159,706	79,853	180,80	0,000
Error	6	2,650	2,650	0,442		
Total	8	162,356				

S = 0,664580 R-Sq = 98,37% R-Sq(adj) = 97,82%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-water conc	N	Mean	Grouping
2	3	79,9	A
5	3	79,5	A
1	3	70,8	B

Means that do not share a letter are significantly different.

Table A. 40 One way ANOVA and Tukey's Comparison Test with 95% confidence level for Tc depending on water concentration for tapioca starch with psyllium fiber

General Linear Model: Tc versus TS-/W PSYLLIUM

Factor	Type	Levels	Values
TS-/W PSYLLIUM	fixed	2	2; 5

Analysis of Variance for Tc, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-/W PSYLLIUM	1	19,765	19,765	19,765	109,05	0,000
Error	4	0,725	0,725	0,181		
Total	5	20,490				

S = 0,425735 R-Sq = 96,46% R-Sq(adj) = 95,58%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-/W PSYLLIUM	N	Mean	Grouping
2	3	83,9	A
5	3	80,3	B

Means that do not share a letter are significantly different.

Table A. 41 One way ANOVA and Tukey's Comparison Test with 95% confidence level for DH at starch: water ratio of 1:5 of tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: DH versus TS-1:5

Factor	Type	Levels	Values
TS-1:5	fixed	2	0; 50

Analysis of Variance for DH, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-1:5	1	20,093	20,093	20,093	10,52	0,032
Error	4	7,643	7,643	1,911		
Total	5	27,737				

S = 1,38232 R-Sq = 72,44% R-Sq(adj) = 65,55%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-1:5	N	Mean	Grouping
0	3	15,5	A
50	3	11,8	B

Means that do not share a letter are significantly different.

Table A. 42 One way ANOVA and Tukey's Comparison Test with 95% confidence level for DH at starch: water ratio of 1:2 of tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: DH versus TS-1:2

Factor Type Levels Values
 TS-1:2 fixed 2 0; 50

Analysis of Variance for DH, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-1:2	1	8,0736	8,0736	8,0736	9,49	0,037
Error	4	3,4018	3,4018	0,8504		
Total	5	11,4754				

S = 0,922198 R-Sq = 70,36% R-Sq(adj) = 62,94%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-1:2	N	Mean	Grouping
0	3	13,6	A
50	3	11,3	B

Means that do not share a letter are significantly different.

Table A. 43 One way ANOVA and Tukey's Comparison Test with 95% confidence level for DH depending on water concentration for tapioca starch without psyllium fiber

General Linear Model: DH versus TS-water conc

Factor Type Levels Values
 TS-water conc fixed 3 1; 2; 5

Analysis of Variance for DH, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-water conc	2	298,23	298,23	149,12	117,42	0,000
Error	6	7,62	7,62	1,27		
Total	8	305,85				

S = 1,12694 R-Sq = 97,51% R-Sq(adj) = 96,68%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-water conc	N	Mean	Grouping
5	3	15,5	A
2	3	13,6	A
1	3	2,4	B

Means that do not share a letter are significantly different.

Table A. 44 One way ANOVA and Tukey's Comparison Test with 95% confidence level for DH depending on water concentration for tapioca starch with psyllium fiber

General Linear Model: DH versus TS-/W PSYLLIUM

Factor	Type	Levels	Values
TS-/W PSYLLIUM	fixed	2	2; 5

Analysis of Variance for DH, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-/W PSYLLIUM	1	0,4704	0,4704	0,4704	0,54	0,504
Error	4	3,5050	3,5050	0,8763		
Total	5	3,9754				

S = 0,936082 R-Sq = 11,83% R-Sq(adj) = 0,00%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-/W PSYLLIUM	N	Mean	Grouping
5	3	11,8	A
2	3	11,3	A

Means that do not share a letter are significantly different.

Table A. 45 One way ANOVA and Tukey's Comparison Test with 95% confidence level for 1043/1016 cm⁻¹ depending on the water concentration for cooked wheat starch without psyllium fiber

General Linear Model: IR Ratio 1043 cm versus WS-water concent

Factor	Type	Levels	Values
WS-water concentration w/o psyl	fixed	4	0; 1; 2; 5

Analysis of Variance for IR Ratio 1043 cm-1/ 1016 cm-1, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F
WS-water concentration w/o psyl	3	0,0158363	0,0158363	0,0052788	103,00
Error	8	0,0004100	0,0004100	0,0000513	
Total	11	0,0162463			

Source	P
WS-water concentration w/o psyl	0,000
Error	
Total	

S = 0,00715891 R-Sq = 97,48% R-Sq(adj) = 96,53%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-water concentration w/o psyl	N	Mean	Grouping
0	3	0,7	A
1	3	0,7	A
2	3	0,6	B
5	3	0,6	C

Means that do not share a letter are significantly different.

Table A. 46 One way ANOVA and Tukey's Comparison Test with 95% confidence level for 1043/1016 cm⁻¹ depending on the water concentration for cooked wheat starch with psyllium fiber

General Linear Model: IR Ratio 1043 cm versus WS-water concent

Factor	Type	Levels	Values
WS-water concentration w/psylli	fixed	3	1; 2; 5

Analysis of Variance for IR Ratio 1043 cm-1/ 1016 cm-1, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F
WS-water concentration w/psylli	2	0,0037580	0,0037580	0,0018790	23,78
Error	6	0,0004740	0,0004740	0,0000790	
Total	8	0,0042320			

Source	P
WS-water concentration w/psylli	0,001
Error	
Total	

S = 0,00888819 R-Sq = 88,80% R-Sq(adj) = 85,07%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-water concentration w/psylli	N	Mean	Grouping
1	3	0,8	A
2	3	0,8	B
5	3	0,7	C

Means that do not share a letter are significantly different.

Table A. 47 One way ANOVA and Tukey's Comparison Test with 95% confidence level for 1043/1016 cm⁻¹ depending on the water concentration for cooked potato starch without psyllium fiber

General Linear Model: IR Ratio 1043 cm versus PS-water concent

Factor	Type	Levels	Values
PS-water concentration w/o psyl	fixed	4	0; 1; 2; 5

Analysis of Variance for IR Ratio 1043 cm-1/ 1016 cm-1, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F
PS-water concentration w/o psyl	3	0,0040163	0,0040163	0,0013388	17,97
Error	8	0,0005960	0,0005960	0,0000745	
Total	11	0,0046123			

Source	P
PS-water concentration w/o psyl	0,001
Error	
Total	

S = 0,00863134 R-Sq = 87,08% R-Sq(adj) = 82,23%

Grouping Information Using Tukey Method and 95,0% Confidence

PS-water concentration w/o psyl	N	Mean	Grouping
0	3	0,7	A
1	3	0,7	A B
2	3	0,7	B
5	3	0,6	C

Means that do not share a letter are significantly different.

Table A. 48 One way ANOVA and Tukey's Comparison Test with 95% confidence level for 1043/1016 cm⁻¹ depending on the water concentration for cooked potato starch with psyllium fiber

General Linear Model: IR Ratio 1043 cm versus PS-water concent

Factor	Type	Levels	Values
PS-water concentration w/psylli	fixed	3	1; 2; 5

Analysis of Variance for IR Ratio 1043 cm-1/ 1016 cm-1, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F
PS-water concentration w/psylli	2	0,0033540	0,0033540	0,0016770	30,31
Error	6	0,0003320	0,0003320	0,0000553	
Total	8	0,0036860			

Source	P
PS-water concentration w/psylli	0,001
Error	
Total	

S = 0,00743864 R-Sq = 90,99% R-Sq(adj) = 87,99%

Grouping Information Using Tukey Method and 95,0% Confidence

PS-water concentration w/psylli	N	Mean	Grouping
1	3	0,8	A
2	3	0,8	B
5	3	0,8	C

Means that do not share a letter are significantly different.

Table A. 49 One way ANOVA and Tukey's Comparison Test with 95% confidence level for 1043/1016 cm⁻¹ depending on the water concentration for cooked tapioca starch without psyllium fiber

General Linear Model: IR Ratio 1043 cm versus TS-water concent

Factor	Type	Levels	Values
TS-water concentration w/o psyl	fixed	4	0; 1; 2; 5

Analysis of Variance for IR Ratio 1043 cm-1/ 1016 cm-1, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F
TS-water concentration w/o psyl	3	0,0048870	0,0048870	0,0016290	47,56
Error	8	0,0002740	0,0002740	0,0000343	
Total	11	0,0051610			

Source	P
TS-water concentration w/o psyl	0,000
Error	
Total	

S = 0,00585235 R-Sq = 94,69% R-Sq(adj) = 92,70%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-water concentration w/o psyl	N	Mean	Grouping
0	3	0,7	A
1	3	0,7	A
2	3	0,7	B
5	3	0,6	C

Means that do not share a letter are significantly different.

Table A. 50 One way ANOVA and Tukey's Comparison Test with 95% confidence level for 1043/1016 cm⁻¹ depending on the water concentration for cooked tapioca starch with psyllium fiber

General Linear Model: IR Ratio 1043 cm versus TS-water concent

Factor	Type	Levels	Values
TS-water concentration w/psylli	fixed	3	1; 2; 5

Analysis of Variance for IR Ratio 1043 cm-1/ 1016 cm-1, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F
TS-water concentration w/psylli	2	0,0018420	0,0018420	0,0009210	24,24
Error	6	0,0002280	0,0002280	0,0000380	
Total	8	0,0020700			

Source	P
TS-water concentration w/psylli	0,001
Error	
Total	

S = 0,00616441 R-Sq = 88,99% R-Sq(adj) = 85,31%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-water concentration w/psylli	N	Mean	Grouping
1	3	0,8	A
2	3	0,8	B
5	3	0,8	C

Means that do not share a letter are significantly different.

Table A. 51 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RDS/TS for cooked 1:5 wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: RDS/TS versus Cooked 1:5 WS

Factor	Type	Levels	Values
Cooked 1:5 WS	fixed	2	0; 50

Analysis of Variance for RDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:5 WS	1	900,37	900,37	900,37	1460,46	0,000
Error	4	2,47	2,47	0,62		
Total	5	902,84				

S = 0,785175 R-Sq = 99,73% R-Sq(adj) = 99,66%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked			
1:5 WS	N	Mean	Grouping
0	3	72,2	A
50	3	47,7	B

Means that do not share a letter are significantly different.

Table A. 52 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RDS/TS for cooked 1:2 wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: RDS/TS versus Cooked 1:2 WS

Factor	Type	Levels	Values
Cooked 1:2 WS	fixed	2	0; 50

Analysis of Variance for RDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:2 WS	1	1455,5	1455,5	1455,5	3264,51	0,000
Error	4	1,8	1,8	0,4		
Total	5	1457,3				

S = 0,667720 R-Sq = 99,88% R-Sq(adj) = 99,85%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked			
1:2 WS	N	Mean	Grouping
0	3	68,0	A
50	3	36,9	B

Means that do not share a letter are significantly different.

Table A. 53 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RDS/TS for cooked 1:1 wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: RDS/TS versus Cooked 1:1 WS

Factor	Type	Levels	Values
Cooked 1:1 WS	fixed	2	0; 50

Analysis of Variance for RDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:1 WS	1	1677,4	1677,4	1677,4	5389,94	0,000
Error	4	1,2	1,2	0,3		
Total	5	1678,6				

S = 0,557853 R-Sq = 99,93% R-Sq(adj) = 99,91%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked			
1:1 WS	N	Mean	Grouping
0	3	61,7	A
50	3	28,2	B

Means that do not share a letter are significantly different.

Table A. 54 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RDS/TS for raw wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: RDS/TS versus Cooked Raw WS

Factor	Type	Levels	Values
Cooked Raw WS	fixed	2	0; 50

Analysis of Variance for RDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked Raw WS	1	296,10	296,10	296,10	5863,44	0,000
Error	4	0,20	0,20	0,05		
Total	5	296,31				

S = 0,224722 R-Sq = 99,93% R-Sq(adj) = 99,91%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked			
Raw WS	N	Mean	Grouping
0	3	19,6	A
50	3	5,5	B

Means that do not share a letter are significantly different.

Table A. 55 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RDS/TS depending on the water concentration for wheat starch without psyllium fiber

General Linear Model: RDS/TS versus WS-water conc

Factor	Type	Levels	Values
WS-water conc	fixed	4	0; 1; 2; 5

Analysis of Variance for RDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-water conc	3	5297,1	5297,1	1765,7	3436,88	0,000
Error	8	4,1	4,1	0,5		
Total	11	5301,2				

S = 0,716764 R-Sq = 99,92% R-Sq(adj) = 99,89%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-water conc	N	Mean	Grouping
5	3	72,2	A
2	3	68,0	B
1	3	61,7	C
0	3	19,6	D

Means that do not share a letter are significantly different.

Table A. 56 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RDS/TS depending on the water concentration for wheat starch with psyllium fiber

General Linear Model: RDS/TS versus WS-/W PSYLLIUM

Factor	Type	Levels	Values
WS-/W PSYLLIUM	fixed	4	0; 1; 2; 5

Analysis of Variance for RDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-/W PSYLLIUM	3	2888,96	2888,96	962,99	4856,82	0,000
Error	8	1,59	1,59	0,20		
Total	11	2890,54				

S = 0,445281 R-Sq = 99,95% R-Sq(adj) = 99,92%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-/W PSYLLIUM	N	Mean	Grouping
5	3	47,7	A
2	3	36,9	B
1	3	28,2	C
0	3	5,5	D

Means that do not share a letter are significantly different.

Table A. 57 One way ANOVA and Tukey's Comparison Test with 95% confidence level for SDS/TS for cooked 1:5 wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: SDS/TS versus Cooked 1:5 WS

Factor	Type	Levels	Values
Cooked 1:5 WS	fixed	2	0; 50

Analysis of Variance for SDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:5 WS	1	1,5606	1,5606	1,5606	9,02	0,040
Error	4	0,6922	0,6922	0,1731		
Total	5	2,2528				

S = 0,415993 R-Sq = 69,27% R-Sq(adj) = 61,59%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked 1:5 WS	N	Mean	Grouping
50	3	9,4	A
0	3	8,4	B

Means that do not share a letter are significantly different.

Table A. 58 One way ANOVA and Tukey's Comparison Test with 95% confidence level for SDS/TS for cooked 1:2 wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: SDS/TS versus Cooked 1:2 WS

Factor	Type	Levels	Values
Cooked 1:2 WS	fixed	2	0; 50

Analysis of Variance for SDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:2 WS	1	8,2838	8,2838	8,2838	44,10	0,003
Error	4	0,7514	0,7514	0,1878		
Total	5	9,0352				

S = 0,433417 R-Sq = 91,68% R-Sq(adj) = 89,60%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked			
1:2 WS	N	Mean	Grouping
50	3	11,9	A
0	3	9,5	B

Means that do not share a letter are significantly different.

Table A. 59 One way ANOVA and Tukey's Comparison Test with 95% confidence level for SDS/TS for cooked 1:1 wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: SDS/TS versus Cooked 1:1 WS

Factor	Type	Levels	Values
Cooked 1:1 WS	fixed	2	0; 50

Analysis of Variance for SDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:1 WS	1	2,9400	2,9400	2,9400	26,76	0,007
Error	4	0,4394	0,4394	0,1099		
Total	5	3,3794				

S = 0,331436 R-Sq = 87,00% R-Sq(adj) = 83,75%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked			
1:1 WS	N	Mean	Grouping
50	3	11,9	A
0	3	10,5	B

Means that do not share a letter are significantly different.

Table A. 60 One way ANOVA and Tukey's Comparison Test with 95% confidence level for SDS/TS for raw wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: SDS/TS versus Raw WS

Factor	Type	Levels	Values
Raw WS	fixed	2	0; 50

Analysis of Variance for SDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Raw WS	1	1611,8	1611,8	1611,8	13320,60	0,000
Error	4	0,5	0,5	0,1		
Total	5	1612,3				

S = 0,347851 R-Sq = 99,97% R-Sq(adj) = 99,96%

Grouping Information Using Tukey Method and 95,0% Confidence

Raw WS	N	Mean	Grouping
0	3	53,4	A
50	3	20,6	B

Means that do not share a letter are significantly different.

Table A. 61 One way ANOVA and Tukey's Comparison Test with 95% confidence level for SDS/TS depending on the water concentration for wheat starch without psyllium fiber

General Linear Model: SDS/TS versus WS-water conc

Factor	Type	Levels	Values
WS-water conc	fixed	4	0; 1; 2; 5

Analysis of Variance for SDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-water conc	3	4343,6	4343,6	1447,9	7508,67	0,000
Error	8	1,5	1,5	0,2		
Total	11	4345,1				

S = 0,439118 R-Sq = 99,96% R-Sq(adj) = 99,95%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-water conc	N	Mean	Grouping
0	3	53,4	A
1	3	10,5	B
2	3	9,5	B
5	3	8,4	C

Means that do not share a letter are significantly different.

Table A. 62 One way ANOVA and Tukey's Comparison Test with 95% confidence level for SDS/TS depending on the water concentration for wheat starch with psyllium fiber

General Linear Model: SDS/TS versus WS-/W PSYLLIUM

Factor	Type	Levels	Values
WS-/W PSYLLIUM	fixed	4	0; 1; 2; 5

Analysis of Variance for SDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-/W PSYLLIUM	3	216,841	216,841	72,280	701,41	0,000
Error	8	0,824	0,824	0,103		
Total	11	217,665				

S = 0,321014 R-Sq = 99,62% R-Sq(adj) = 99,48%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-/W PSYLLIUM	N	Mean	Grouping
0	3	20,6	A
1	3	11,9	B
2	3	11,9	B
5	3	9,4	C

Means that do not share a letter are significantly different.

Table A. 63 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RS/TS for cooked 1:5 wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: RS/TS versus Cooked 1:5 WS

Factor	Type	Levels	Values
Cooked 1:5 WS	fixed	2	0; 50

Analysis of Variance for RS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:5 WS	1	826,97	826,97	826,97	1167,21	0,000
Error	4	2,83	2,83	0,71		
Total	5	829,80				

S = 0,841724 R-Sq = 99,66% R-Sq(adj) = 99,57%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked 1:5 WS	N	Mean	Grouping
50	3	42,9	A
0	3	19,4	B

Means that do not share a letter are significantly different.

Table A. 64 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RS/TS for cooked 1:2 wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: RS/TS versus Cooked 1:2 WS

Factor Type Levels Values
 Cooked 1:2 WS fixed 2 0; 50

Analysis of Variance for RS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:2 WS	1	1245,0	1245,0	1245,0	2468,33	0,000
Error	4	2,0	2,0	0,5		
Total	5	1247,0				

S = 0,710211 R-Sq = 99,84% R-Sq(adj) = 99,80%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked	N	Mean	Grouping
1:2 WS			
50	3	51,2	A
0	3	22,4	B

Means that do not share a letter are significantly different.

Table A. 65 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RS/TS for cooked 1:1 wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: RS/TS versus Cooked 1:1 WS

Factor Type Levels Values
 Cooked 1:1 WS fixed 2 0; 50

Analysis of Variance for RS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:1 WS	1	1740,1	1740,1	1740,1	3874,26	0,000
Error	4	1,8	1,8	0,4		
Total	5	1741,9				

S = 0,670187 R-Sq = 99,90% R-Sq(adj) = 99,87%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked	N	Mean	Grouping
1:1 WS			
50	3	59,9	A
0	3	25,8	B

Means that do not share a letter are significantly different.

Table A. 66 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RS/TS for raw wheat starch with (50%) and without (0%) psyllium fiber

General Linear Model: RS/TS versus Raw WS

Factor Type Levels Values
Raw WS fixed 2 0; 50

Analysis of Variance for RS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Raw WS	1	3289,6	3289,6	3289,6	18030,00	0,000
Error	4	0,7	0,7	0,2		
Total	5	3290,3				

S = 0,427142 R-Sq = 99,98% R-Sq(adj) = 99,97%

Grouping Information Using Tukey Method and 95,0% Confidence

Raw WS	N	Mean	Grouping
50	3	73,9	A
0	3	27,1	B

Means that do not share a letter are significantly different.

Table A. 67 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RS/TS depending on the water concentration for wheat starch without psyllium fiber

General Linear Model: RS/TS versus WS-water conc

Factor Type Levels Values
WS-water conc fixed 4 0; 1; 2; 5

Analysis of Variance for RS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-water conc	3	107,549	107,549	35,850	58,45	0,000
Error	8	4,907	4,907	0,613		
Total	11	112,456				

S = 0,783151 R-Sq = 95,64% R-Sq(adj) = 94,00%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-water conc	N	Mean	Grouping
0	3	27,1	A
1	3	25,8	A
2	3	22,4	B
5	3	19,4	C

Means that do not share a letter are significantly different.

Table A. 68 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RS/TS depending on the water concentration for wheat starch with psyllium fiber

General Linear Model: RS/TS versus WS-/W PSYLLIUM

Factor	Type	Levels	Values
WS-/W PSYLLIUM	fixed	4	0; 1; 2; 5

Analysis of Variance for RS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
WS-/W PSYLLIUM	3	1578,19	1578,19	526,06	1702,88	0,000
Error	8	2,47	2,47	0,31		
Total	11	1580,66				

S = 0,555810 R-Sq = 99,84% R-Sq(adj) = 99,79%

Grouping Information Using Tukey Method and 95,0% Confidence

WS-/W PSYLLIUM	N	Mean	Grouping
0	3	73,9	A
1	3	59,9	B
2	3	51,2	C
5	3	42,9	D

Means that do not share a letter are significantly different.

Table A. 69 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RDS/TS for cooked 1:5 potato starch with (50%) and without (0%) psyllium fiber

General Linear Model: RDS/TS versus Cooked 1:5 PS

Factor	Type	Levels	Values
Cooked 1:5 PS	fixed	2	0; 50

Analysis of Variance for RDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:5 PS	1	941,25	941,25	941,25	1441,32	0,000
Error	4	2,61	2,61	0,65		
Total	5	943,87				

S = 0,808115 R-Sq = 99,72% R-Sq(adj) = 99,65%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked 1:5 PS	N	Mean	Grouping
0	3	64,2	A
50	3	39,1	B

Means that do not share a letter are significantly different.

Table A. 70 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RDS/TS for cooked 1:2 potato starch with (50%) and without (0%) psyllium fiber

General Linear Model: RDS/TS versus Cooked 1:2 PS

Factor	Type	Levels	Values
Cooked 1:2 PS	fixed	2	0; 50

Analysis of Variance for RDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:2 PS	1	1480,8	1480,8	1480,8	3904,61	0,000
Error	4	1,5	1,5	0,4		
Total	5	1482,3				

S = 0,615833 R-Sq = 99,90% R-Sq(adj) = 99,87%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked 1:2 PS	N	Mean	Grouping
0	3	58,5	A
50	3	27,1	B

Means that do not share a letter are significantly different.

Table A. 71 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RDS/TS for cooked 1:1 potato starch with (50%) and without (0%) psyllium fiber

General Linear Model: RDS/TS versus Cooked 1:1 PS

Factor	Type	Levels	Values
Cooked 1:1 PS	fixed	2	0; 50

Analysis of Variance for RDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:1 PS	1	1515,9	1515,9	1515,9	7730,27	0,000
Error	4	0,8	0,8	0,2		
Total	5	1516,7				

S = 0,442832 R-Sq = 99,95% R-Sq(adj) = 99,94%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked 1:1 PS	N	Mean	Grouping
0	3	50,6	A
50	3	18,8	B

Means that do not share a letter are significantly different.

Table A. 72 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RDS/TS for raw potato starch with (50%) and without (0%) psyllium fiber

General Linear Model: RDS/TS versus Raw PS

Factor Type Levels Values
Raw PS fixed 2 0; 50

Analysis of Variance for RDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Raw PS	1	135,57	135,57	135,57	550,26	0,000
Error	4	0,99	0,99	0,25		
Total	5	136,55				

S = 0,496353 R-Sq = 99,28% R-Sq(adj) = 99,10%

Grouping Information Using Tukey Method and 95,0% Confidence

Raw PS	N	Mean	Grouping
0	3	14,1	A
50	3	4,6	B

Means that do not share a letter are significantly different.

Table A. 73 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RDS/TS depending on the water concentration for potato starch without psyllium fiber

General Linear Model: RDS/TS versus PS-water conc.

Factor Type Levels Values
PS-water conc. fixed 4 0; 1; 2; 5

Analysis of Variance for RDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PS-water conc.	3	4566,4	4566,4	1522,1	3408,67	0,000
Error	8	3,6	3,6	0,4		
Total	11	4570,0				

S = 0,668244 R-Sq = 99,92% R-Sq(adj) = 99,89%

Grouping Information Using Tukey Method and 95,0% Confidence

PS-water conc.	N	Mean	Grouping
5	3	64,2	A
2	3	58,5	B
1	3	50,6	C
0	3	14,1	D

Means that do not share a letter are significantly different.

Table A. 74 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RDS/TS depending on the water concentration for potato starch with psyllium fiber

General Linear Model: RDS/TS versus PS-/w psyllium

Factor Type Levels Values
 PS-/w psyllium fixed 4 0; 1; 2; 5

Analysis of Variance for RDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PS-/w psyllium	3	1893,77	1893,77	631,26	2170,51	0,000
Error	8	2,33	2,33	0,29		
Total	11	1896,10				

S = 0,539290 R-Sq = 99,88% R-Sq(adj) = 99,83%

Grouping Information Using Tukey Method and 95,0% Confidence

PS-/w psyllium	N	Mean	Grouping
5	3	39,1	A
2	3	27,1	B
1	3	18,8	C
0	3	4,6	D

Means that do not share a letter are significantly different.

Table A. 75 One way ANOVA and Tukey's Comparison Test with 95% confidence level for SDS/TS for cooked 1:5 potato starch with (50%) and without (0%) psyllium fiber

General Linear Model: SDS/TS versus Cooked 1:5 PS

Factor Type Levels Values
 Cooked 1:5 PS fixed 2 0; 50

Analysis of Variance for SDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:5 PS	1	7,3262	7,3262	7,3262	41,80	0,003
Error	4	0,7010	0,7010	0,1753		
Total	5	8,0272				

S = 0,418629 R-Sq = 91,27% R-Sq(adj) = 89,08%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked 1:5 PS	N	Mean	Grouping
50	3	11,2	A
0	3	9,0	B

Means that do not share a letter are significantly different.

Table A. 76 One way ANOVA and Tukey's Comparison Test with 95% confidence level for SDS/TS for cooked 1:2 potato starch with (50%) and without (0%) psyllium fiber

General Linear Model: SDS/TS versus Cooked 1:2 PS

Factor	Type	Levels	Values
Cooked 1:2 PS	fixed	2	0; 50

Analysis of Variance for SDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:2 PS	1	5,4150	5,4150	5,4150	28,41	0,006
Error	4	0,7624	0,7624	0,1906		
Total	5	6,1774				

S = 0,436578 R-Sq = 87,66% R-Sq(adj) = 84,57%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked	N	Mean	Grouping
1:2 PS			
50	3	11,4	A
0	3	9,5	B

Means that do not share a letter are significantly different.

Table A. 77 One way ANOVA and Tukey's Comparison Test with 95% confidence level for SDS/TS for cooked 1:1 potato starch with (50%) and without (0%) psyllium fiber

General Linear Model: SDS/TS versus Cooked 1:1 PS

Factor	Type	Levels	Values
Cooked 1:1 PS	fixed	2	0; 50

Analysis of Variance for SDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:1 PS	1	6,1206	6,1206	6,1206	39,07	0,003
Error	4	0,6266	0,6266	0,1566		
Total	5	6,7472				

S = 0,395790 R-Sq = 90,71% R-Sq(adj) = 88,39%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked	N	Mean	Grouping
1:1 PS			
50	3	10,7	A
0	3	8,7	B

Means that do not share a letter are significantly different.

Table A. 78 One way ANOVA and Tukey's Comparison Test with 95% confidence level for SDS/TS for raw potato starch with (50%) and without (0%) psyllium fiber

General Linear Model: SDS/TS versus Raw PS

Factor Type Levels Values
Raw PS fixed 2 0; 50

Analysis of Variance for SDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Raw PS	1	1291,0	1291,0	1291,0	184,44	0,000
Error	4	28,0	28,0	7,0		
Total	5	1319,0				

S = 2,64562 R-Sq = 97,88% R-Sq(adj) = 97,35%

Grouping Information Using Tukey Method and 95,0% Confidence

Raw PS	Raw PS	N	Mean	Grouping
0	0	3	39,0	A
50	50	3	9,6	B

Means that do not share a letter are significantly different.

Table A. 79 One way ANOVA and Tukey's Comparison Test with 95% confidence level for SDS/TS depending on the water concentration for potato starch without psyllium fiber

General Linear Model: SDS/TS versus PS-water conc.

Factor Type Levels Values
PS-water conc. fixed 4 0; 1; 2; 5

Analysis of Variance for SDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PS-water conc.	3	2014,20	2014,20	671,40	3934,95	0,000
Error	8	1,37	1,37	0,17		
Total	11	2015,57				

S = 0,413068 R-Sq = 99,93% R-Sq(adj) = 99,91%

Grouping Information Using Tukey Method and 95,0% Confidence

PS-water conc.	N	Mean	Grouping
0	3	39,0	A
2	3	9,5	B
5	3	9,0	B
1	3	8,7	B

Means that do not share a letter are significantly different.

Table A. 80 One way ANOVA and Tukey's Comparison Test with 95% confidence level for SDS/TS depending on the water concentration for potato starch with psyllium fiber

General Linear Model: SDS/TS versus PS-/w psyllium

Factor	Type	Levels	Values
PS-/w psyllium	fixed	4	0; 1; 2; 5

Analysis of Variance for SDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PS-/w psyllium	3	5,499	5,499	1,833	0,51	0,686
Error	8	28,722	28,722	3,590		
Total	11	34,222				

S = 1,89480 R-Sq = 16,07% R-Sq(adj) = 0,00%

Unusual Observations for SDS/TS

Obs	SDS/TS	Fit	SE Fit	Residual	St Resid
12	5,3400	9,6433	1,0940	-4,3033	-2,78 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95,0% Confidence

PS-/w psyllium	N	Mean	Grouping
2	3	11,4	A
5	3	11,2	A
1	3	10,7	A
0	3	9,6	A

Means that do not share a letter are significantly different.

Table A. 81 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RS/TS for cooked 1:5 potato starch with (50%) and without (0%) psyllium fiber

General Linear Model: RS/TS versus Cooked 1:5 PS

Factor	Type	Levels	Values
Cooked 1:5 PS	fixed	2	0; 50

Analysis of Variance for RS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:5 PS	1	783,18	783,18	783,18	1322,95	0,000
Error	4	2,37	2,37	0,59		
Total	5	785,55				

S = 0,769415 R-Sq = 99,70% R-Sq(adj) = 99,62%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked			
1:5 PS	N	Mean	Grouping
50	3	49,7	A
0	3	26,8	B

Means that do not share a letter are significantly different.

Table A. 82 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RS/TS for cooked 1:2 potato starch with (50%) and without (0%) psyllium fiber

General Linear Model: RS/TS versus Cooked 1:2 PS

Factor	Type	Levels	Values
Cooked 1:2 PS	fixed	2	0; 50

Analysis of Variance for RS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:2 PS	1	1306,3	1306,3	1306,3	2031,35	0,000
Error	4	2,6	2,6	0,6		
Total	5	1308,8				

S = 0,801904 R-Sq = 99,80% R-Sq(adj) = 99,75%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked			
1:2 PS	N	Mean	Grouping
50	3	61,5	A
0	3	32,0	B

Means that do not share a letter are significantly different.

Table A. 83 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RS/TS for cooked 1:1 potato starch with (50%) and without (0%) psyllium fiber

General Linear Model: RS/TS versus Cooked 1:1 PS

Factor	Type	Levels	Values
Cooked 1:1 PS	fixed	2	0; 50

Analysis of Variance for RS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:1 PS	1	1327,6	1327,6	1327,6	4872,80	0,000
Error	4	1,1	1,1	0,3		
Total	5	1328,7				

S = 0,521967 R-Sq = 99,92% R-Sq(adj) = 99,90%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked 1:1 PS	N	Mean	Grouping
50	3	70,4	A
0	3	40,7	B

Means that do not share a letter are significantly different.

Table A. 84 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RS/TS for raw potato starch with (50%) and without (0%) psyllium fiber

General Linear Model: RS/TS versus Raw PS

Factor	Type	Levels	Values
Raw PS	fixed	2	0; 50

Analysis of Variance for RS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Raw PS	1	2078,0	2078,0	2078,0	7165,49	0,000
Error	4	1,2	1,2	0,3		
Total	5	2079,2				

S = 0,538516 R-Sq = 99,94% R-Sq(adj) = 99,93%

Grouping Information Using Tukey Method and 95,0% Confidence

Raw PS	N	Mean	Grouping
50	3	84,1	A
0	3	46,9	B

Means that do not share a letter are significantly different.

Table A. 85 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RS/TS depending on the water concentration for potato starch without psyllium fiber

General Linear Model: RS/TS versus PS-water conc.

Factor	Type	Levels	Values
PS-water conc.	fixed	4	0; 1; 2; 5

Analysis of Variance for RS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PS-water conc.	3	718,98	718,98	239,66	402,79	0,000
Error	8	4,76	4,76	0,59		
Total	11	723,74				

S = 0,771362 R-Sq = 99,34% R-Sq(adj) = 99,10%

Grouping Information Using Tukey Method and 95,0% Confidence

PS-water conc.	N	Mean	Grouping
0	3	46,9	A
1	3	40,7	B
2	3	32,0	C
5	3	26,8	D

Means that do not share a letter are significantly different.

Table A. 86 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RS/TS depending on the water concentration for potato starch with psyllium fiber

General Linear Model: RS/TS versus PS-/w psyllium

Factor	Type	Levels	Values
PS-/w psyllium	fixed	4	0; 1; 2; 5

Analysis of Variance for RS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
PS-/w psyllium	3	1902,89	1902,89	634,30	2088,22	0,000
Error	8	2,43	2,43	0,30		
Total	11	1905,32				

S = 0,551135 R-Sq = 99,87% R-Sq(adj) = 99,82%

Grouping Information Using Tukey Method and 95,0% Confidence

PS-/w psyllium	N	Mean	Grouping
0	3	84,1	A
1	3	70,4	B
2	3	61,5	C
5	3	49,7	D

Means that do not share a letter are significantly different.

Table A. 87 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RDS/TS for cooked 1:5 tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: RDS/TS versus Cooked 1:5 TS

Factor	Type	Levels	Values
Cooked 1:5 TS	fixed	2	0; 50

Analysis of Variance for RDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:5 TS	1	1091,9	1091,9	1091,9	1540,03	0,000
Error	4	2,8	2,8	0,7		
Total	5	1094,7				

S = 0,842021 R-Sq = 99,74% R-Sq(adj) = 99,68%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked	1:5 TS	N	Mean	Grouping
0	3	70,5	A	
50	3	43,6	B	

Means that do not share a letter are significantly different.

Table A. 88 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RDS/TS for cooked 1:2 tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: RDS/TS versus Cooked 1:2 TS

Factor	Type	Levels	Values
Cooked 1:2 TS	fixed	2	0; 50

Analysis of Variance for RDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:2 TS	1	1706,6	1706,6	1706,6	2937,04	0,000
Error	4	2,3	2,3	0,6		
Total	5	1708,9				

S = 0,762266 R-Sq = 99,86% R-Sq(adj) = 99,83%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked	1:2 TS	N	Mean	Grouping
0	3	65,9	A	
50	3	32,2	B	

Means that do not share a letter are significantly different.

Table A. 89 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RDS/TS for cooked 1:1 tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: RDS/TS versus Cooked 1:1 TS

Factor	Type	Levels	Values
Cooked 1:1 TS	fixed	2	0; 50

Analysis of Variance for RDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:1 TS	1	2112,8	2112,8	2112,8	10508,59	0,000
Error	4	0,8	0,8	0,2		
Total	5	2113,6				

S = 0,448386 R-Sq = 99,96% R-Sq(adj) = 99,95%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked 1:1 TS	N	Mean	Grouping
0	3	58,0	A
50	3	20,5	B

Means that do not share a letter are significantly different.

Table A. 90 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RDS/TS for raw tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: RDS/TS versus Raw TS

Factor	Type	Levels	Values
Raw TS	fixed	2	0; 50

Analysis of Variance for RDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Raw TS	1	154,64	154,64	154,64	1426,31	0,000
Error	4	0,43	0,43	0,11		
Total	5	155,07				

S = 0,329267 R-Sq = 99,72% R-Sq(adj) = 99,65%

Grouping Information Using Tukey Method and 95,0% Confidence

Raw TS	N	Mean	Grouping
0	3	15,6	A
50	3	5,4	B

Means that do not share a letter are significantly different.

Table A. 91 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RDS/TS depending on the water concentration for tapioca starch without psyllium fiber

General Linear Model: RDS/TS versus TS-water conc.

Factor	Type	Levels	Values
TS-water conc.	fixed	4	0; 1; 2; 5

Analysis of Variance for RDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-water conc.	3	5703,0	5703,0	1901,0	3383,16	0,000
Error	8	4,5	4,5	0,6		
Total	11	5707,5				

S = 0,749600 R-Sq = 99,92% R-Sq(adj) = 99,89%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-water conc.	N	Mean	Grouping
5	3	70,5	A
2	3	65,9	B
1	3	58,0	C
0	3	15,6	D

Means that do not share a letter are significantly different.

Table A. 92 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RDS/TS depending on the water concentration for tapioca starch with psyllium fiber

General Linear Model: RDS/TS versus TS-/w Psyllium

Factor	Type	Levels	Values
TS-/w Psyllium	fixed	4	0; 1; 2; 5

Analysis of Variance for RDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-/w Psyllium	3	2398,99	2398,99	799,66	3361,93	0,000
Error	8	1,90	1,90	0,24		
Total	11	2400,89				

S = 0,487707 R-Sq = 99,92% R-Sq(adj) = 99,89%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-/w Psyllium	N	Mean	Grouping
5	3	43,6	A
2	3	32,2	B
1	3	20,5	C
0	3	5,4	D

Means that do not share a letter are significantly different.

Table A. 93 One way ANOVA and Tukey's Comparison Test with 95% confidence level for SDS/TS for cooked 1:5 tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: SDS/TS versus Cooked 1:5 TS

Factor	Type	Levels	Values
Cooked 1:5 TS	fixed	2	0; 50

Analysis of Variance for SDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:5 TS	1	6,4896	6,4896	6,4896	24,75	0,008
Error	4	1,0490	1,0490	0,2622		
Total	5	7,5386				

S = 0,512104 R-Sq = 86,08% R-Sq(adj) = 82,61%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked 1:5 TS	N	Mean	Grouping
50	3	9,7	A
0	3	7,7	B

Means that do not share a letter are significantly different.

Table A. 94 One way ANOVA and Tukey's Comparison Test with 95% confidence level for SDS/TS for cooked 1:2 tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: SDS/TS versus Cooked 1:2 TS

Factor	Type	Levels	Values
Cooked 1:2 TS	fixed	2	0; 50

Analysis of Variance for SDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:2 TS	1	2,0184	2,0184	2,0184	10,83	0,030
Error	4	0,7456	0,7456	0,1864		
Total	5	2,7640				

S = 0,431741 R-Sq = 73,02% R-Sq(adj) = 66,28%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked 1:2 TS	N	Mean	Grouping
50	3	9,6	A
0	3	8,4	B

Means that do not share a letter are significantly different.

Table A. 95 One way ANOVA and Tukey's Comparison Test with 95% confidence level for SDS/TS for cooked 1:1 tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: SDS/TS versus Cooked 1:1 TS

Factor	Type	Levels	Values
Cooked 1:1 TS	fixed	2	0; 50

Analysis of Variance for SDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:1 TS	1	12,790	12,790	12,790	83,87	0,001
Error	4	0,610	0,610	0,153		
Total	5	13,400				

S = 0,390512 R-Sq = 95,45% R-Sq(adj) = 94,31%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked 1:1 TS	N	Mean	Grouping
50	3	10,0	A
0	3	7,1	B

Means that do not share a letter are significantly different.

Table A. 96 One way ANOVA and Tukey's Comparison Test with 95% confidence level for SDS/TS for raw tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: SDS/TS versus Raw TS

Factor	Type	Levels	Values
Raw TS	fixed	2	0; 50

Analysis of Variance for SDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Raw TS	1	1189,5	1189,5	1189,5	5888,51	0,000
Error	4	0,8	0,8	0,2		
Total	5	1190,3				

S = 0,449444 R-Sq = 99,93% R-Sq(adj) = 99,92%

Grouping Information Using Tukey Method and 95,0% Confidence

Raw TS	N	Mean	Grouping
0	3	43,3	A
50	3	15,2	B

Means that do not share a letter are significantly different.

Table A. 97 One way ANOVA and Tukey's Comparison Test with 95% confidence level for SDS/TS depending on the water concentration for tapioca starch without psyllium fiber

General Linear Model: SDS/TS versus TS-water conc.

Factor	Type	Levels	Values
TS-water conc.	fixed	4	0; 1; 2; 5

Analysis of Variance for SDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-water conc.	3	2856,40	2856,40	952,13	4391,25	0,000
Error	8	1,73	1,73	0,22		
Total	11	2858,13				

S = 0,465645 R-Sq = 99,94% R-Sq(adj) = 99,92%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-water conc.	N	Mean	Grouping
0	3	43,3	A
2	3	8,4	B
5	3	7,7	B C
1	3	7,1	C

Means that do not share a letter are significantly different.

Table A. 98 One way ANOVA and Tukey's Comparison Test with 95% confidence level for SDS/TS depending on the water concentration for tapioca starch with psyllium fiber

General Linear Model: SDS/TS versus TS-/w Psyllium

Factor	Type	Levels	Values
TS-/w Psyllium	fixed	4	0; 1; 2; 5

Analysis of Variance for SDS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-/w Psyllium	3	65,876	65,876	21,959	118,86	0,000
Error	8	1,478	1,478	0,185		
Total	11	67,354				

S = 0,429826 R-Sq = 97,81% R-Sq(adj) = 96,98%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-/w Psyllium	N	Mean	Grouping
0	3	15,2	A
1	3	10,0	B
5	3	9,7	B
2	3	9,6	B

Means that do not share a letter are significantly different.

Table A. 99 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RS/TS for cooked 1:5 tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: RS/TS versus Cooked 1:5 TS

Factor	Type	Levels	Values
Cooked 1:5 TS	fixed	2	0; 50

Analysis of Variance for RS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:5 TS	1	929,27	929,27	929,27	1002,18	0,000
Error	4	3,71	3,71	0,93		
Total	5	932,98				

S = 0,962938 R-Sq = 99,60% R-Sq(adj) = 99,50%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked 1:5 TS	N	Mean	Grouping
50	3	46,7	A
0	3	21,8	B

Means that do not share a letter are significantly different.

Table A. 100 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RS/TS for cooked 1:2 tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: RS/TS versus Cooked 1:2 TS

Factor	Type	Levels	Values
Cooked 1:2 TS	fixed	2	0; 50

Analysis of Variance for RS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:2 TS	1	1589,3	1589,3	1589,3	2749,57	0,000
Error	4	2,3	2,3	0,6		
Total	5	1591,6				

S = 0,760263 R-Sq = 99,85% R-Sq(adj) = 99,82%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked			
1:2 TS	N	Mean	Grouping
50	3	58,3	A
0	3	25,7	B

Means that do not share a letter are significantly different.

Table A. 101 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RS/TS for cooked 1:1 tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: RS/TS versus Cooked 1:1 TS

Factor	Type	Levels	Values
Cooked 1:1 TS	fixed	2	0; 50

Analysis of Variance for RS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cooked 1:1 TS	1	1797,8	1797,8	1797,8	5581,55	0,000
Error	4	1,3	1,3	0,3		
Total	5	1799,1				

S = 0,567539 R-Sq = 99,93% R-Sq(adj) = 99,91%

Grouping Information Using Tukey Method and 95,0% Confidence

Cooked			
1:1 TS	N	Mean	Grouping
50	3	69,5	A
0	3	34,9	B

Means that do not share a letter are significantly different.

Table A. 102 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RS/TS for raw tapioca starch with (50%) and without (0%) psyllium fiber

General Linear Model: RS/TS versus Raw TS

Factor	Type	Levels	Values
Raw TS	fixed	2	0; 50

Analysis of Variance for RS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Raw TS	1	2208,4	2208,4	2208,4	6823,38	0,000
Error	4	1,3	1,3	0,3		
Total	5	2209,7				

S = 0,568902 R-Sq = 99,94% R-Sq(adj) = 99,93%

Grouping Information Using Tukey Method and 95,0% Confidence

Raw TS	N	Mean	Grouping
50	3	79,5	A
0	3	41,1	B

Means that do not share a letter are significantly different.

Table A. 103 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RS/TS depending on the water concentration for tapioca starch without psyllium fiber

General Linear Model: RS/TS versus TS-water conc.

Factor	Type	Levels	Values
TS-water conc.	fixed	4	0; 1; 2; 5

Analysis of Variance for RS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-water conc.	3	690,95	690,95	230,32	326,25	0,000
Error	8	5,65	5,65	0,71		
Total	11	696,60				

S = 0,840208 R-Sq = 99,19% R-Sq(adj) = 98,89%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-water conc.	N	Mean	Grouping
0	3	41,1	A
1	3	34,9	B
2	3	25,7	C
5	3	21,8	D

Means that do not share a letter are significantly different.

Table A. 104 One way ANOVA and Tukey's Comparison Test with 95% confidence level for RS/TS depending on the water concentration for tapioca starch with psyllium fiber

General Linear Model: RS/TS versus TS-/w Psyllium

Factor	Type	Levels	Values
TS-/w Psyllium	fixed	4	0; 1; 2; 5

Analysis of Variance for RS/TS, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
TS-/w Psyllium	3	1806,46	1806,46	602,15	1629,42	0,000
Error	8	2,96	2,96	0,37		
Total	11	1809,42				

S = 0,607906 R-Sq = 99,84% R-Sq(adj) = 99,78%

Grouping Information Using Tukey Method and 95,0% Confidence

TS-/w Psyllium	N	Mean	Grouping
0	3	79,5	A
1	3	69,5	B
2	3	58,3	C
5	3	46,7	D

Means that do not share a letter are significantly different.

B. FTIR SPECTRA OF STARCH SAMPLES

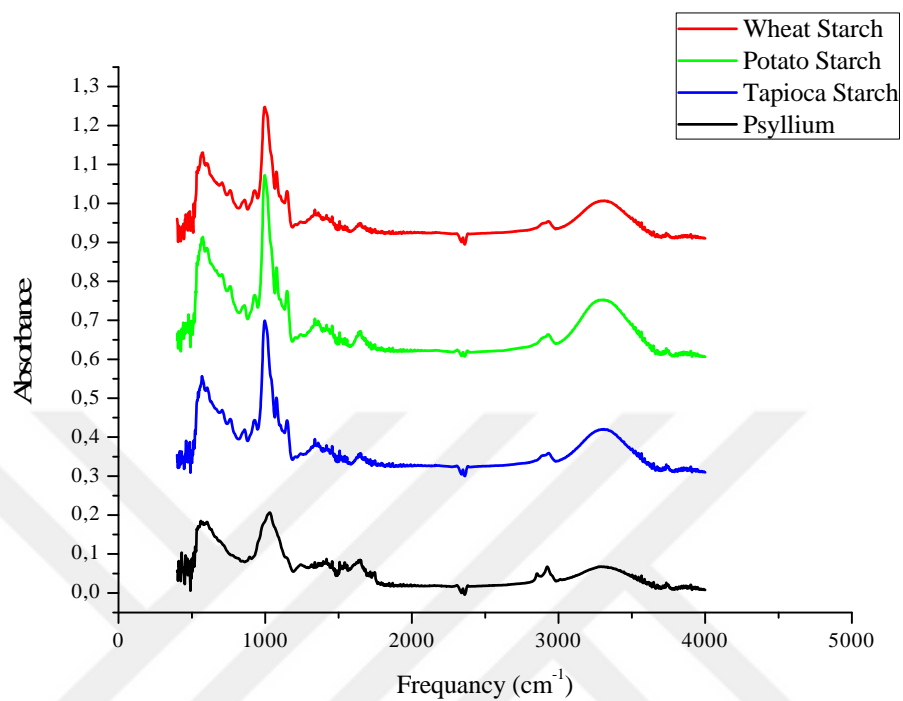


Figure B. 1 FTIR Spectra of Raw Starches & Psyllium

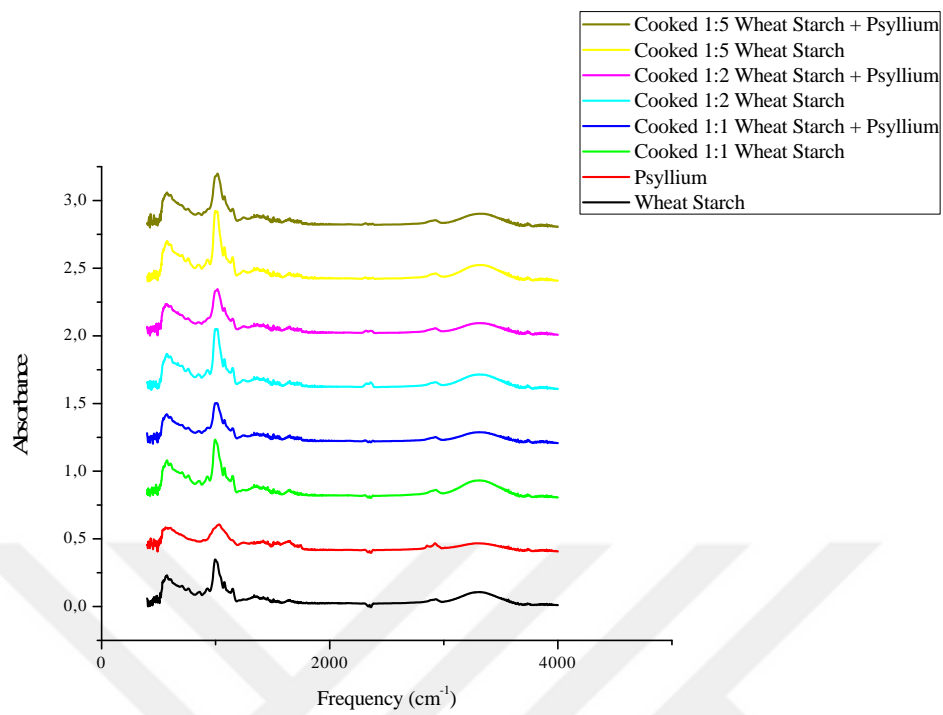


Figure B. 2 FTIR Spectra of Wheat Starch

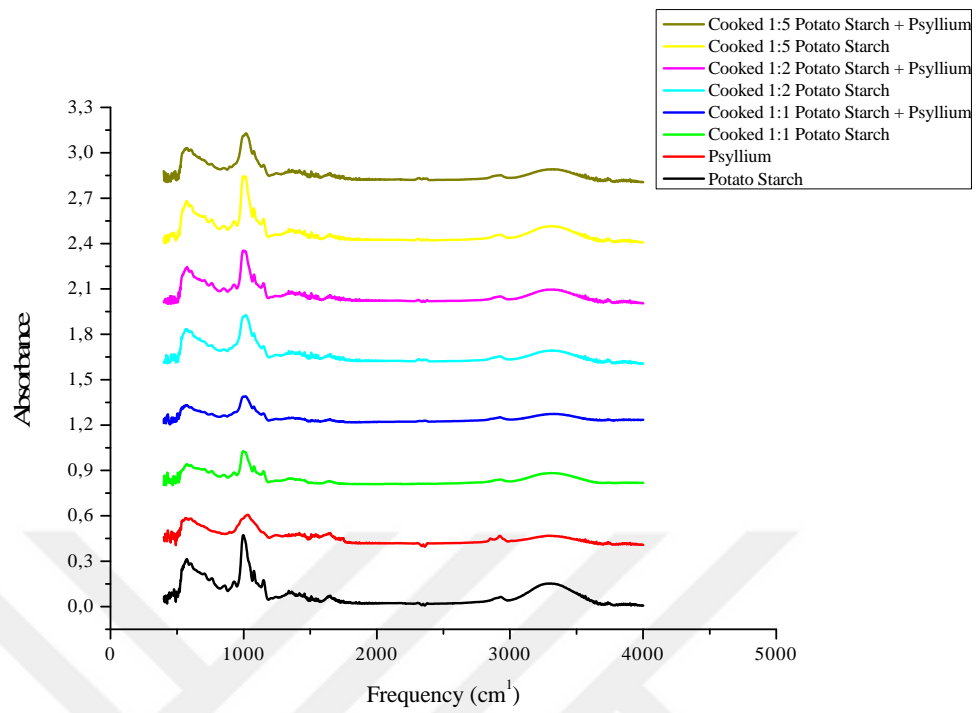


Figure B. 3 FTIR Spectra of Potato Starch

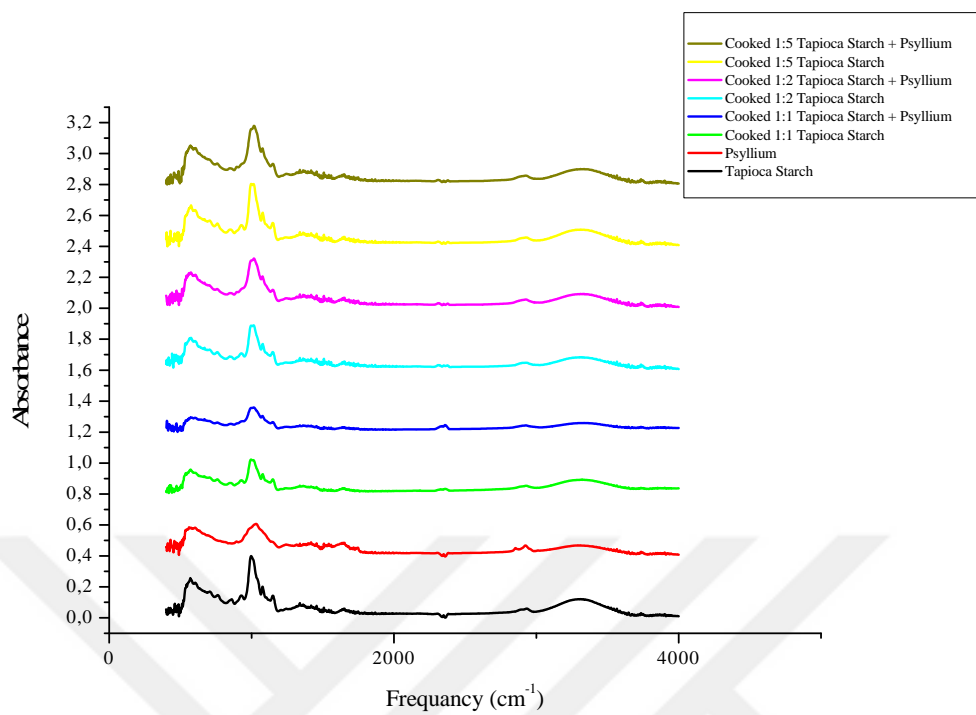


Figure B. 4 FTIR Spectra of Tapioca Starch