IN VITRO STARCH DIGESTION OF FLAT DOUGH PIECES WITH AND WITHOUT FIBER

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ABSTRACT

IN VITRO STARCH DIGESTION OF FLAT DOUGH PIECES WITH AND WITHOUT FIBER

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The digestive behavior of starch, which supplies most of our daily energy needs, is vital for health. Starch-rich foods that provoke a high glycaemic response are alterable risk factors for obesity, type-2 diabetes, and cardiovascular disease. Therefore, it is crucial to promote staple foods that provide a controlled glucose release in the blood. Incorporating different cooking methods and dietary fiber into regularly eaten products is a food design strategy that leads to several advantages to decrease chronic disease by changing starch digestibility. This study aimed to investigate the effect of psyllium fiber addition on *in vitro* starch digestibility of steamed and roasted wheat-based flat dough pieces. Doughs were prepared as control and fiber-enriched samples, where wheat flour was replaced with 10 % psyllium fiber. Specimens were steamed at 100˚C for two different times (2 min and 10 min) and roasted for 2 min at two different temperatures (100˚C and 250˚C) separately. Fiber addition significantly lowered rapidly digestible starch (RDS) fractions in steamed and roasted samples. Adding psyllium fiber increased the SDS fractions for only the samples roasted at 100 °C and samples steamed for 2 min. Roasted samples had a lower RDS fraction than the steamed samples only for the

fiber added samples. This study showed that processing method, time, temperature, and psyllium fiber addition affected *in vitro* starch digestion. The processing method could alter the starch gelatinization, development of the gluten network, and structure. Then, this structure and psyllium fiber could affect the enzyme's accessibility to the substrates.

Keywords: Psyllium Fiber, Roasting, Steaming, Starch Digestibility

ÖZ

LİFLİ VE LİFSİZ DÜZ HAMUR PARÇALARININ İN VİTRO NİŞASTA SİNDİRİMİ

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Günlük enerji ihtiyacımızın büyük bir bölümünü karşılayan nişastanın sindirim davranışı sağlık için oldukça önemlidir. Kanda yüksek glisemik yanıt oluşturan nişasta açışından zengin gıdalar obezite, tip 2 diyabet ve kardiyovasküler hastalıklar için değiştirilebilir risk faktörlerdir. Bu nedenle kanda kontrollü bir glikoz salınımı sağlayan temel gıdaların teşvik edilmesi oldukça önemlidir. Düzenli olarak tüketilen ürünlere farklı işleme yöntemleri ve diyet lifi eklemek, nişasta sindirilebilirliğini değiştirerek kronik hastalıkları azaltmak için çeşitli avantajlar sağlayan bir gıda ürünü tasarım stratejisidir. Bu çalışmanın amacı, diyet lifi (pisilyum lifi) ilavesinin ve farklı işlem yöntemlerinin (buharda pişirme ve tavlama) uygulanmasının buğday bazlı düz hamur parçalarının *in vitro* nişasta sindirilebilirliği üzerine etkisini araştırmaktır. Hamurlar, buğday ununun %10 pisilyum lifi ile değiştirildiği kontrol ve lifle zenginleştirilmiş numuneler olarak hazırlanmıştır. Numuneler ayrı ayrı 100˚C'de iki farklı sürede (2 dk ve 10dk) buharda pişirilmiş ve iki farklı sıcaklıkta (100˚C ve 250˚C) 2 dakika kavrulmuştur. Lif ilavesi, buharda pişirilmiş ve kavrulmuş numunelerde hızla sindirilebilir nişasta (RDS) fraksiyonlarını önemli ölçüde azaltmıştır. Pisilyum lifi eklenmesi, sadece 100 °C'de kavrulmuş numuneler ile 2 dakika boyunca buharda pişirilmiş numuneler

için SDS fraksiyonlarını arttırmıştır. Kavrulmuş numuneler, yalnızca lif ilave edilmiş numuneler için buharda pişirilmiş numunelerden daha düşük bir RDS fraksiyonuna sebep olmuştur. Bu çalışma, işleme yöntemi, zaman, sıcaklık ve pisilyum lif ilavesinin in vitro nişasta sindirimini etkilediğini göstermiştir. Pişirme yöntemi nişasta jelatinleşmesini, glüten ağının gelişimini ve yapısını değiştirebilir. Daha sonra, bu yapı ve pisilyum lifi, enzimin substratlara erişimini etkileyebilir.

Anahtar Kelimeler: Pisilyum Lifi, Kavurma ile Isıtma İşlemi, Buhar ile Isıtma İşlemi, Nişasta Sindirilebilirliği

To the ones who truly believed in me, mostly my lovely family

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ABBREVIATIONS

AUC : Area under the curve

DF : Dietary fiber

DM : Dry matter

DP : Degree of polymerization

DSC : Differential scanning calorimeter

DWF: Dry wheat flour

FSG : Free sugar glucose

GI : Glycemic index

HI : Hydrolysis index

IDF : Insoluble dietary fiber

RAG : Rapidly available glucose

RDS : Rapidly digestible starch

RS : Resistant starch

SAG : Slowly available glucose

SDF : Soluble dietary fiber

SDS : Slowly digestible starch

SEM : Scanning electron microscope

TG : Total glucose

TS : Total starch

CHAPTER 1

INTRODUCTION

1.1 Starch

1.1.1 Starch Structure

Starch in its native form occurs as semi-crystalline granules fundamentally composed of two polyglucans: amylopectin and amylose (Vamadevan & Bertoft, 2014). These polymers are deposited in granules of different sizes, large A, medium B, and small C types, and shapes, as disk-like and spherical (Singh et al.,2010). Amylopectin is the major component in most starches. It has a higher molecular weight (7.08–9.88 x 107), and its cluster-like structure implies a heavy branching (Mua & Jackson, 1997). It consists of short chains of α-(1,4)-linked D-glucosyl units that are connected through α-(1,6)-linkages (Cornejo-Ramírez et al., 2018). Short chains of amylopectin form double-helices, which crystalize and contribute to the semi-crystalline structure of the starch granules (Vamadevan & Bertoft, 2014). On the other hand, amylose is a polymer of low molecular weight (1.03–4.89 x 105) and minor component, which is 15–35% of the starch weight, in native cereal starches (Ball et al.,1996). It is a primarily linear molecule and has much longer chains than in amylopectin. Amylose affects the packing of amylopectin into crystallites and the organization of the crystalline lamella in starch granules. This is important to water uptake as swelling and gelatinization (Copeland et al.,2009). Besides amylopectin and amylose, starch granules also contain proteins, fatty acids, and minerals in small quantities which are effective on the properties of starch (Vamadevan & Bertoft, 2014). The main sources of starch

are maize, potato, cassava (also named tapioca and manioc), wheat and other sources are rice, sweet potato, sorghum, and barley, etc. Also, waxy samples with little or no amylose (e.g. waxy maize or potato) and high-amylose starches (e.g. amylomaize) are of commercial value (Vamadevan & Bertoft, 2014).

In general, cereal grains consist of greater proportions A and B type granules than the others (Ao & Jane, 2007). While the A-type (>15 μm) starch granules are disclike shape, B- (5–15 μm) and C- (<5 μm) type starch granules are spherical (Singh et al., 2010). B-type granules comprise up to 99% of granules within the wheat endosperm, whereas A-type granules constitute the majority of the starch (50-87%) by weight.

1.1.2 Starch Swelling and Gelatinization

The starch granule is insoluble in water and can be hydrated at high temperatures. Therefore, the starch granules hydrate and swell after a thermal disordering of the crystal structure occurs (Brites et al., 2007). Changes in swelling power, viscosity and gelatinization capacity determine the interaction of starch granules with water at high temperatures. Hydrogen bonds stabilize the double helices structure of amylose and lateral chains of amylopectin (Cornejo-Ramírez et al., 2018). During the hydration of starch granules at high temperatures, the hydrogen bonds are broken and bind with water molecules. The swelling capacity of starch granules depends on the water holding capacity of starch granules through hydrogen bonding which can be affected by amylose content, lateral chains of amylopectin, the presence of phospholipids, granule size, and the presence of holes and channels (Cornejo-Ramírez et al., 2018). The phospholipids in the starch granules may form a complex with the amylose, which causes lower swelling power and viscosity by preventing water binding at high temperatures. In contrast, high amylopectin content means higher swelling power and viscosity at low temperatures (Song & Jane, 2000). In addition, holes and channels inside the starch granules accelerate the entrance of reagents and enzymes, which cause starch hydrolysis, and

hydrolyzed starches could swell more than native starches (Cornejo-Ramírez et al., 2018).

The smallest starch granules have the highest swelling power. However, the waxy starch granules have higher swelling power because of short chains of amylopectin (Singh et al., 2010). While amylose, amylose lipid complex, and long lateral amylopectin chains can form helical bonds instead of connecting with water molecules, short chains of amylopectin can easily bind with water molecules (Ao & Jane, 2007). Since B-type starch granules have low amylose and higher surface area/starch weight ratio, they are capable of higher hydration and swelling capacity than A-type starch granules. The swelling capacity of starch granules allows them to increase their viscosity and gel formation. In addition, amylopectin with short chains and small starch granule sizes are advantageous for swelling capacities (Cornejo-Ramírez et al., 2018).

Hydration and the disruption of crystallinity start from the hilum area by partially swelling. As temperature increases with time, disruption of crystallinity and loss of birefringence increase. Swelling expands from the hilum to the outer of the granules, and it also directly increases the viscosity (Cai & Wei, 2013; Cai et al., 2014; et al., Brites et al., 2007). Different times and temperatures are required for this process change due to physicochemical characteristics of the starch granules of each botanical source.

Gelatinization of starch granules starts when they are no longer able to bind water molecules. Therefore, swelling is accompanied by partial rupture of granules. Then small amylose molecules leached from starch granules, and other amylose and amylopectin are dispersed in the solution which increases in viscosity (Cornejo-Ramírez et al., 2018). The larger starch granules need more time to gel, and they reach higher gelatinization temperatures than smaller granules since the smaller granules have more hydration and swelling capacity (Brites et al., 2007). Generally, the quantity of amylose is inversely related to the gelatinization capacity, and high amylose starches have resulted in high gelatinization temperature because double

helices of amylose require high temperature and energy to be disrupted (Shi et al., 1998). Also, starches with higher amylopectin contents and shorter branches have lower gelatinization times (Koch & Jane, 2000). In addition, pores and channels increase the swelling and gelatinization capacity of starch granules (Nor Nadiha et al., 2010). After completion of gelatinization, amylose quantity and the proportion of lateral amylopectin chains are the most common things that affect the gel structure (Tang et al., 2002).

1.2 Starch Digestion

Starch is made of two polyglucans are amylose and amylopectin. These two polysaccharides are hydrolyzed by salivary and pancreatic α-amylase. However, salivary α-amylase is inactivated in the acid environment of the stomach. Alpha-amylase only hydrolyzes the internal α-1,4-glycosidic bonds, and α-1,6-glycosidic linkages of amylopectin stay uncleaved. Oligosaccharides containing that uncleaved branch side are called α-limit dextrins (Priebe et al., 2018). After α-amylase hydrolysis, the starch, maltose, maltotriose, and α-limit dextrins have occurred. These remaining products are further converted into glucose in the small intestine by enzyme complexes (sucrose-isomaltase and maltase-glucoamylase) in the brush border membrane (Lin et al., 2012). Alpha-amylase and brush border enzymes are called α-glucosidases. The rate and extent of starch digestion depend on the reaching of α-glucosidases to starch.

1.2.1 In vitro Starch Digestion

Starch digestion has been associated with a glycemic index (GI) to evaluate the nutritional quality of foods. It is an indicator of the postprandial glucose response of starch-based food products (Zhang & Hamaker, 2009). In other words, it is a tool for the characterization and classification of food products in terms of physiological response. Generally, food is separated into three categories

depending on GI values which are high (GI>70), low (GI<55), and intermediate GI (Brand et al.,1991). However, this method has been demonstrated as difficult and expensive due to the demands of a long time, and facilities that are essential for this type of study are not always present in food research laboratories (Goñi et al., 2007; Van Hung et al., 2016). Consequently, in vitro digestion tests were decided to be used for measuring the starch digestion rate. One of these methods was progressed by Granfeldt et al.(1994); this method estimates the starch digestion rate of whole food in a manner of hydrolysis index (HI) which is calculated as the outcome between the area under the curve (AUC) of food and AUC of reference food, white bread. It is represented as a percentage. However, this method still needs humans to chew the sample before measurement of HI as in vivo methods.

Further, Go˜ni et al.(1997) introduced an in vitro assay that consists of proteolytic enzymes in combination with amylases rather than other assays that only use amylase. They explained the hydrolytic process with a mathematical first-order kinetic equation that indicates the percentage of total starch hydrolysis at any time with close estimation of the GI of a food product. However, even GI seemed to be a sufficient indicator of nutritional quality of food, interest in determining whether the digestion rate affected the glycemic response was increased (Zhang & Hamaker, 2009). Therefore, Englyst et al.(1992) decided to classify the starch into three types based on its digestion rate. These are rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS). In this method, the most important enzyme is α-amylase to measure the starch digestion fraction. Other enzymes (amyloglucosidase and invertase) are essentially used for turning amylase degradation products and sucrose into monomers to prevent their potential inhibitory effect on α-amylase (Zhang & Hamaker, 2009).

1.2.1.1 Starch Digestion Fractions (RDS , SDS and RS)

Rapidly digestible starch (RDS) is mostly found in gelatinized waxy starch and most processed starchy foods. It is rapidly digested and absorbed in the duodenum and proximal regions of the small intestine. Thus, it causes a rapid increase in blood glucose and the subsequent case of hypoglycemia. This large change in blood glucose can generate high stress on the regulatory system of glucose homeostasis (Ludwig, 2002), which may cause cell and organ damages further (Brownlee, 2001). On the other hand, resistant starch (RS) is not digested in the upper gastrointestinal tract but is fermented in the colon and produces short-chain fatty acids (SCFA), which are beneficial for colonic health (Topping & Clifton,2001). Between RDS and RS, there is an intermediate fraction which is SDS. SDS is slowly digested throughout the entire small intestine, and it promotes slow and prolonged glucose release in the body (Zhang & Hamaker, 2009).

Further, RS can be divided into five groups. RS1 is the starch that is physically inaccessible to be digested due to entrapment in the non-digestible matrix. RS2 is composed of native starch granules of different selected botanical sources. RS3 is retrograded starch and it is formed by the retrogradation process after gelatinization. RS4 is formed by chemical modifications, and RS5 is an amylose-lipid complex where the helical structure is hard to be digested by enzymes (Tian et al., 2020).

According to Englyst et al.'s (1992) method, RDS is the digested part within the initial 20 min digestion, RS is the remaining portion after 120 min, and SDS is digested portion between 20 and 120 min. Depending on the observed rate of starch hydrolysis in vitro, the logic for choosing 20 min digestion as the RDS portion was because that starch, such as in white bread or homogenized cooked starch, is converted into glucose in the first 10 min, and only 5–10% in the next 10 min (Zhang & Hamaker, 2009). Furthermore, the cut-off point, which is 120 min, was decided by comparing with in vivo studies using ileostomy subjects and enough time that obtains extended-release of glucose (Zhang & Hamaker, 2009). In

addition, this experimental result-oriented classification shows that portions of RDS, SDS, and RS are not necessarily of distinct chemical nature.

1.3 Dietary Fiber

Dietary fiber (DF) has been known for its health benefits and has been implemented in a wide diversity of food applications (Oh et al., 2014). DFs can regulate intestinal functions, protect intestinal walls and constipation, decrease cholesterol absorption, and control blood glucose levels (Chen et al., 2016). Non-digestible carbohydrates plus lignin, including all carbohydrate components occurring in foods that are non-digestible in the human small intestine and pass into the large intestine are called dietary fiber ("Scientific Opinion on Dietary Reference Values for Carbohydrates and Dietary Fibre," 2010).

Depending on their solubility in water, dietary fibers have been classified into soluble dietary fiber (SDF) and insoluble dietary fiber (IDF). SDFs have been connected to reducing cholesterol in the blood and decreasing the intestinal absorption of glucose, while IDFs are associated with water absorption and intestinal regulation (Angioloni & Collar, 2011). SDFs increase total transit time via delaying gastric emptying due to their viscosity effects which decrease the accessibility of hydrolytic enzymes to its substrates (Leclère et al., 1994; Slavin, 2005), and/or a slowed diffusion rate of digested carbohydrates (i.e. α -limit dextrins and oligosaccharides) towards the small intestine surface for glucogenesis and glucose absorption (Briani et al., 1987), whereas non-viscous soluble fibers essentially act as a substrate for microbial fermentation in the colon (El Khoury et al., 2012).

SDFs include pectins, gums, inulin-type fructans, β-glucans (oat and barley grains), alginate, and psyllium, while IDFs include cellulose and some hemicellulose, lignin, and resistant starch. This study used psyllium fiber to study the effect of fiber addition in wheat-based flat dough products.

1.3.1 Psyllium Fiber

Psyllium is a soluble fiber found in the husk of Plantago ovata seeds used commercially to produce mucilage (Theuwissen & Mensink, 2008). In addition, the term psyllium can be used not only for the seed husk but also for the seed and the entire plant. Psyllium gum is mostly comprised of arabinose (22%), xylose (57%), and uronic acids (10–15%) (w/w), with minor quantities of galactose, rhamnose, glucose, and mannose. It's a high-molecular-weight acidic arabinoxylan with a heavily branching structure (1500 kDa) (Cui et al., 2013).

Psyllium is the worlds' fourth most used hydrocolloid in the formulation of gluten-free bread after hydroxypropyl methylcellulose (HPMC), xanthan gum, and guar gum (Roman et al., 2019). Psyllium has several health benefits for constipation, diarrhea, diabetes, irritable bowel syndrome, hypercholesterolemia, and colon cancer (Singh et al., 2007). These health benefits have been associated with the viscous character of psyllium. Psyllium has a 10-fold greater water retention capacity than cellulose and 5-fold greater than apple fiber (Dello Staffolo et al., 2017).

It is well known that viscous fiber such as psyllium, pectins, gums, and β-glucans can change the viscosity of digesta, which in turn can decrease the absorption of nutrients such as glucose and cholesterol (Mackie et al., 2016). Even though numerous studies have examined the interactions of starch and hydrocolloids, fewer studies documented psyllium and starch interactions, especially the effects of psyllium on starch digestion.

1.4 Factors Affecting Starch Digestibility

1.4.1 Molecular Structure of Starch

As mentioned before, starch is a semi-crystalline glucose polymer that is synthesized as spherical granules in plant tissue. Most granules consist of alternating less-ordered amorphous and ordered and dense crystalline layers. Crystalline regions are formed by amylopectin chains with a double-helical arrangement. Chains are categorized according to their degree of polymerization (DP) which are short chains (12< DP < 20), long chains (30 < DP< 45) and very long chains (DP > 60) (Zhang & Hamaker, 2009). According to wide-range X-ray diffraction scattering studies, native starch is classified as A, B, C, and V types due to the arrangement and length of amylopectin chains (Miao et al., 2013). While, cereal starches are mostly A type; potatoes, other root starches, amylomazie, and retrograded starches are placed in B type. C type is a combination of A and B-type starches and is mostly found in smooth pea and various bean starches. On the other hand, V type can be found only in amylose helical complex starches after gelatinization and complex formation with lipids or related compounds (Miao et al., 2013).

Slow digestion is related to the X-ray diffraction pattern, chain length, and branching points, as well as the starch botanical source (Ao et al., 2007). According to Zhang et al.(2006), raw cereal starches are an ideal SDS due to their structure. When the starch granules are treated with amylolytic enzymes, they migrate via channels inside the granules. Therefore it causes slower digestion due to inside out and side-by-side digestion (Zhang & Hamaker,2009). Zhang et al.(2006) reported that the A-type structure of native cereal starches with a high level of short chains and branches clarify its slow digestion properties. Miao et al.(2009) examined the effect of debranching time and concentration of debranching enzyme, which is pullulanase, on the structural properties of high-amylopectin starch. They found that increase in the enzyme concentration and a decrease in the debranching caused

the increase in the SDS content due to the production of linear chains from the amorphous region and residual crystalline sections (Zhang & Hamaker,2009). As a result, native starches, especially those with a high branching density and A-type pattern, can show slow digestion properties. Differences in the crystalline structure due to acid hydrolysis and following esterification to produce crosslinking between short amylopectin chains causes an increase in RS content of starch (Van Hung et al.,2016).

1.4.2 Food Matrix

Interaction between starch and non-starch food components guides the production of new chemical or physical structures, and this may cause a change in starch digestibility.

1.4.2.1 Effect of Protein

Protein is the second abundant macronutrient in wheat. After water hydration of wheat flour, e.g.dough formation, a continuous proteinaceous matrix surrounding starch granules can be formed (Li et al., 2021). After hydration, the matrix includes starch granules and gluten, inherently formed by uncross-linked monomeric gliadins and polymeric (cross-linked) glutenins. Through hydrogen bonds and hydrophobic effects, stable interactions with starch could be developed (Dhital et al.,2019). Surface proteins of starch granules could play an intermediary role by networking with other proteins through charge-charge interactions that are pH-dependent. The binding of α-amylase to gluten could also inhibit starch digestion (Bhattarai et al., 2016). Although it is proven that the gluten network has been effective, it would not be expected to completely prevent the diffusion of α-amylase due to larger pores than the length scale of α-amylase. In addition, hydrothermal treatment with excess water denatures the protein and causes starch gelatinization and consequently higher starch digestibility (Li et al., 2020). In

contrast, pasta dried at high temperature, and low moisture led to a lower starch digestibility due to a much stronger protein network which prevents the enzymatic attack (Aravind et al., 2012).

1.4.2.2 Effect of Lipids

Similar to protein, lipids can prevent the binding of enzymes to starch molecules. They can interact with amylose after thermal processing and cause less swelling and solubility of starch granules (Björck et al., 1984). Whether native or processed amylose-lipid complexes, amylose interacted with lipid has more resistance to digestion than a single amylose chain (Holm et al., 1983). According to in vivo animal model (dog) research, serum glucose, and insulin levels decreased when an amylose-lipid complex-containing diet was preferred over maltodextrin containing control diet (Murray et al., 1998). In addition, the structural properties of lipids can have a different effect on starch digestion. Lipid properties such as lipid chain lengths and degree of unsaturation also impact the digestibility of amylose-lipid complexes. The longer the fatty acid chain is, the greater the stability, and the lower the digestive rate of amylose-lipid complexes (Ai, Hasjim, & Jane, 2013).

1.4.2.3 Effect of Dietary Fiber

Dietary fibers can affect starch digestion by decreasing the rate of starch degradation and preventing excess glucose absorption (Brennan, 2005). Dietary fibers can entrap starch granules and restrict the water availability for starch granules or may limit the enzyme accessibility to the starch granules under human digestion which results in lowering of the glycemic index (Angioloni & Collar, 2011). However, in vitro studies show different results depending on the kind of dietary fiber used. For instance, pea fiber appears to increase the overall glucose release of pasta, whereas both inulin and guar fiber reduces the overall glucose from the sample (Tudorică et al., 2001). It is also known that dietary fiber affects

the GI of food which is a tool useful in determining the rate of glucose when carbohydrates in food are digested. For instance, in another study on pasta, it is observed that SDF inclusion reduced the amount of starch digested over 300 min period. Consequently, the extent of starch degradation resulted in a reduction in the predicted glycemic index (PGI) of a sample (Symons & Brennan, 2004).

1.5 Processing Methods Used in the Research

Different thermal processes cause different changes in starch structure at numerous levels due to diverse heat and mass transfer mechanisms. Therefore, products with different physicochemical, sensory, and nutritional properties are formed.

1.5.1 Steaming

Steaming is a thermal processing method that cooks food through a combination of conduction and convection processes using vaporized water as a medium. When steam is applied, surface temperature rises and causes heat to penetrate the product's interior (N. Zhang et al., 2018). Depending on the temperature and pressure application, steam can be categorized as saturated steam and superheated steam (Alfy et al., 2014). Saturated steam occurs when water is heated to a cooking point and then vaporized. The temperature in saturated steam heating remains around 100 ˚C since it is still in contact with liquid water. On the other hand, in superheated steam, saturated steam is heated above the cooking point of water, such as in a pressure cooker. Steaming is accepted as a relatively healthy process technique since it does not involve oil and many nutrients endure inside the food after the process. In the steaming process, the leaching of water-soluble nutrients and bioactive substances is greatly reduced due to not having direct contact with water (Y. Wang et al., 2021).

1.5.2 Roasting

Roasting is a food processing technique used to heat food products evenly and increase sensory aspects of food by developing color, aroma, taste active compounds, and antioxidants. Fundamentally, it gelatinizes and expands or puffs the food product and turns them into a more appealing form. In this process, the generally intense temperature is applied between the 150-300˚C range. Roasting causes heat-induced changes at the surface of the food, thereby retaining moisture in the interior of the food, producing desirable quality features (Sruthi et al., 2021). Several conventional roasting methods apply heat at high temperatures and in a short time, such as pan roasting, oven roasting, and sand roasting. Besides conventional methods, recent advanced roasting methods also contribute to the industry, such as microwave roasting, roasting, infrared roasting, etc (Sruthi et al., 2021).

In this study, the traditional pan method was used since it is widely used for several food products. In the pan method, the surface of the food directly contacts with heat from the hot plate. Therefore, the surface temperature of the product is higher than the core, which may cause over roasting of the surface without considerable effect on the core. Higher temperatures and a short time cause a decreased rate of conversion of water to vapor and puffing that creates voids in the cellular matrix.

1.6 Objectives

Over the last decade, the increasing occurrence of type 2 diabetes, obesity, and cardiovascular disease associated with excess starchy foods have become a nutritional concern (Aller et al., 2011). Due to these health problems, the demand for health-promoting functional foods that attenuate postprandial blood glucose responses were significantly increased. And this led to much research on how structural and functional properties of starch, interactions between starch and other

components such as dietary fibers, and starch gelatinization affect the rate and extent of starch digestion.

This study aimed to investigate the effects of psyllium fiber addition on *in vitro* starch digestion of wheat-based flat dough samples cooked at different conditions, steamed or roasted.

CHAPTER 2

MATERIAL AND METHODS

2.1 Materials

Wheat flour was supplied by Söke Değirmencilik Sanayi ve Ticaret A.Ş. (Aydın, Turkey) and psyllium fiber was purchased from Tunçkaya Kimyevi Maddeleri (Istanbul ,Turkey). Psyllium has 95% purity and was passed through a 40 mesh sieve. Distilled water was used for making the doughs. For in vitro digestion, amyloglucosidase (EC 3.2.1.3) 10,000 U/ml from, Aspergillus niger, pepsin (EC 3.4.23.1.) 800–2500 U/mg, from porcine gastric mucosa, and pancreatin 8 x USP/g from porcine pancreas, calcium chloride dehydrate ($CaCl2 \cdot 2H2O$), and guar gum powder were purchased from Sigma-Aldrich Chemical Company (St. Louis, MO, USA). Invertase (EC 3.2.1.26) 11,600 U/ml, from Saccharomyces cerevisiae, was purchased from Fisher Scientific (Waltham, MA, USA), and glucose oxidase peroxidase (GOPOD) assay kit was purchased from Megazyme (Megazyme International Ireland Ltd., Bray, Ireland). Ethanol ($C2H5OH$), methanol ($CH3OH$), potassium hydroxide (KOH), hydrochloric acid fuming 37% (HCl), acetic acid (CH_3COOH) were analytical grade, and they are purchased from Isolab (Wertheim, Germany).

2.2 Methods

2.2.1 Sample Preparation

Samples were prepared as control and fiber-enriched. The control dough formulation consisted of 100 g wheat flour and 50 g distilled water. Fiber-enriched samples were produced by replacing 10 % of wheat flour with psyllium fiber, and 50 g distilled water was added, same as the control samples. The dry ingredients (wheat flour and psyllium fiber) are mixed by a mixer (Kitchen Aid Artisan Series Mixer, Greenville, OH, USA) for one minute at speed level one. After mixing the dry ingredients, distilled water was added, and the mixing continued for 1 minute at speed level one, 3 minutes at speed level four, and 1 minute at speed level two. After the mixing process, dough samples were kneaded for a few minutes to obtain proper texture. Then, the dough samples were wrapped by stretch film and rested for about 30 minutes at room temperature. The dough samples were flattened by a pasta maker (Maxilife, SD-08, China). The roller of the pasta maker reduced the thickness of samples to 0.6 mm. Then they were cut as square pieces (3 cm x 3 cm) and placed in plastic bags to be kept in the freezer (-20 °C) until use.

Figure 2. 1 Dough samples with and without psyllium fiber (3x3 cm)

2.2.1.1 Cooking of Samples

Control and fiber-enriched flat dough samples were cooked with two methods which were steaming and roasting.

2.2.1.1.1 Steaming

Flat dough pieces (3 cm x 3 cm) were taken from the freezer and thawed for about 5-6 minutes at room temperature. A steamer basket was inserted into a pot with 70 mL boiling water. When the water boiled at 100˚C, thawed samples were placed on the steamer basket without touching each other. The lid was closed as soon as the samples were placed. Flat dough samples were steamed at 100˚C for 2 and 10 minutes separately.

Figure 2. 2 Samples with and without fiber steamed for 10 min at 100˚C

2.2.1.1.2 Roasting

Samples (3 cm x 3 cm) were taken from the freezer and thawed for about 5-6 minutes at room temperature. Thawed samples were roasted according to Yıldız and Bilgiçli (2012) with some modifications. Each control and fiber-enriched flat dough sample were placed on a hot plate (Witeg, SMHS-3/6, Wertheim, Germany) and roasted for a total of 2 min at different temperatures (100˚C and 250˚C) separately. The hot plate temperature was checked by an infrared thermometer

(Wintact, WT300, Shenzhen, China) to ensure a constant temperature. Each face of the sample was heated equally for 1 minute at each temperature.

Figure 2. 3 Samples with and without fiber roasted at 100 ˚C for 2 min

Figure 2. 4 Samples with and without fiber roasted at 250 ˚C for 2 min

2.2.1.2 Sample Preparation for the Analysis

After the steaming and roasting processes, samples were cut into smaller square pieces (3 mm ± 0.5), put into plastic bags, and kept in the freezer (-20 °C) overnight to be used for *in vitro* digestion simulations.

The flat dough samples, raw and cooked, used in DSC and SEM analysis were freeze-dried at -80˚C for 24 h (Martin Christ, Alpha 2-4 LD Plus, Osterode am Harz, Germany) after being frozen at -20 ˚C overnight. Freeze-dried samples were ground for 6 s (Sinbo SCM- 2934, Istanbul, Turkey) and sieved (Endecotts Ltd, perforated plate with 1 mm round hole, London, UK). Then the ground samples

were stored in plastic bags until the analysis. Grinding was not applied when the surface SEM image of wheat flour and some of the cooked samples were examined (Appendix A). The samples' and ingredients' moisture contents were analyzed by a moisture analyzer (MIX-50, A&D Company Ltd. Tokyo, Japan).

Figure 2. 5 Control samples roasted at 100˚C (on the right) and 250 ˚C (on the left)

Figure 2. 6 Psyllium added samples roasted at 100˚C (on the left) and 250 ˚C (on the right)

Figure 2. 7 Samples with and without fiber steamed for 10 min at 100 ˚C.

2.2.2 In Vitro Digestion Simulation

In vitro digestion simulation of samples for the stomach and small intestine was conducted according to Englyst et al. (1992), as described below.

2.2.2.1 Preparation of Enzyme Solutions

2.2.2.1.1 Enzyme Solution I

0.6 g guar gum was put into a beaker and wetted with 1 ml ethanol absolute. Then, 120 ml of 0.05 M HCl was added to wet guar gum, and this solution was stirred on the magnetic stirrer (JeioTech-Multichannel Stirrer, MS-52 M, Daejeon, Republic of Korea) for a few minutes. While mixing, 0.6 g pepsin (EC 3.4.23.1, Sigma-Alrich, St. Louis, USA) was added. After the pepsin addition, the enzyme solution I was used within 20 minutes.

2.2.2.1.2 Enzyme Solution II

0.3 g pancreatin (Sigma-Aldrich, St.Louis, USA) was weighed and put into three 50 ml tubes separately. 20 ml calcium chloride was added to each of the tubes. After shaking the tubes by hand for a few seconds, magnetic bars were added to each tube, and the tubes were placed on the magnetic stirrer (JeioTech-Multichannel Stirrer, MS-52 M, Daejeon, Republic of Korea) for 10 minutes mixing. After the mixing, magnetic bars were taken out with the help of a stirring bar remover, and tubes were centrifuged (2-16PK, Sigma Laborzentrifugen, Germany) at 1500xg at room temperature for 10 minutes. 17 ml of the supernatant was taken from each tube and put into a beaker with a magnetic bar in it. After adding 4 ml amyloglucosidase and 2 ml invertase into the beaker with a total of 51 mL supernatant, they were mixed on the magnetic stirrer for a few minutes. Later

the solution was placed into the water bath (JSR, JSSB, Gongju, Republic of Korea) at 37˚C. The enzyme solution II was used within one hour after preparation.

2.2.2.2 Preparation of Samples

Steamed and roasted samples were taken out of the freezer and thawed to reach room temperature for a few minutes. They were weighted between 0.5 and 4 g to the nearest 0.1 mg into 50 ml screw-cap polypropylene tubes to obtain 500 mg available carbohydrate for each tube

2.2.2.3 Incubation with Pepsin

10 ml of solution I (pepsin-guar gum) was put into each sample tube, vortex mixed, and were placed in a water bath (JSR, JSSB, Gongju, Republic of Korea) 37 °C for 30 minutes.

2.2.2.4 Enzymatic Hydrolysis of Starch

After the incubation, samples were removed from the water bath, and 5 ml of 0.5 M sodium acetate was added into each tube. The pH of the blank tube was checked to control whether it was between 5.2-5.3. Five glass balls with 1.5 cm diameter were added into each tube to assist with mechanical disruption during the incubation. 5 ml of enzyme II solution was added into each tube with 1 min intervals, and they were capped and shaken by hand. As soon as enzyme solution II was added to each tube and they were shaken, tubes were immediately placed parallel to the direction of movement in a 37 °C shaking water bath.

2.2.2.5 Taking G20 and G120 Fraction

At 20 and 120 minutes after the enzyme solution II addition, tubes were removed from the water bath, and 0.2 ml subsample from each tube was transferred into the 8 ml methanol in one-minute intervals. After taking G20 from a tube, it was immediately returned to a water bath and incubated until 120 minutes. When G120 fractions were taken from each tube, they were not returned to the water bath, and *in vitro* starch digestion analysis was completed. The removed tubes were used for total glucose analysis.

Sample preparation used for SEM imaging: In vitro digestion simulations were completed until the G20 point for some selected samples. These G20 samples were collected into methanol-containing tubes and centrifuged at 1500xg for 5 minutes. The supernatants were discarded, and the pellets were freeze-dried after staying in a freezer (-20˚C) overnight. Freeze-dried pellets were ground with a grinder (Sinbo SCM- 2934, Istanbul, Turkey) before the SEM imaging.

2.2.2.6 Total Glucose Analysis

2.2.2.6.1 Dispersion of Resistant Starch

After removing all the tubes from the shaking water bath, they were vortex mixed vigorously to break up large particles and put into a boiling water bath. After 30 minutes, tubes were removed, vortex-mixed, and placed in ice water until thoroughly chilled. 10 ml of 7 M KOH was added to each chilled tube, and they were submerged horizontally in a shaking water bath (JSR, JSSB, Gongju, Republic of Korea) containing ice water for 30 minutes.

2.2.2.6.2 Hydrolysis of Starch to Glucose

Tubes were removed from the water bath, and immediately 1 ml of the contents were transferred into a 50 ml tube containing 10 mL of 0.5 M acetic acid. Then, 0.2 ml of amyloglucosidase (EC 3.2.1.3., Sigma-Alrich, St.Louis, USA) solution was added to each tube and were placed in a water bath (JSR, JSSB, Gongju, Republic of Korea) at 70˚C to activate the enzyme. After 30 min, the tubes were removed and put into a boiling water bath for 10 min. After 10 min, tubes were cooled to room temperature, and 40 ml of distilled water was added to each tube. They were capped and mixed by vigorously shaking with a hand up-and-down motion. This was the TG portion to be measured by a spectrophotometer (Shimadzu, UV-1700 Visible Spectrophotometer, Japan).

2.2.2.7 Free Sugar Glucose Analysis (FSG)

2.2.2.7.1 Sample Preparation

As in the main procedure, roasted and steamed samples at room temperature were weighted between 0.5 and 4 g to the nearest 0.1 mg, into 50 ml screw-cap polypropylene tubes to provide 500 mg available carbohydrate. A blank tube, treated the same as the sample tubes, was also included in the analysis.

2.2.2.7.2 Dispersion of Sample

20 ml water and 0.25 ml of 1M sodium acetate with pH 4.5 were added to each sample tube, and they were capped and vortex mixed vigorously to disperse the sample. Then tubes were placed in a boiling water bath for 30 min.

2.2.2.7.3 Hydrolysis of Sucrose

After 30 minutes, tubes were removed from the water bath, vortex mixed, and cooled to 37˚C at room conditions. Then 0.2 ml invertase was added to each tube. Tubes are immersed horizontally in a 37 °C shaking water bath (JSR, JSSB, Gongju, Republic of Korea). After 30 minutes, tubes were taken at one-minute intervals from the water bath, and 1 ml of the contents was transferred from each tube to 2 ml of methanol contained 15 ml tubes. This was the free glucose (FG) portion to be measured by a spectrophotometer (Shimadzu, UV-1700 Visible Spectrophotometer, Japan).

2.2.3 Determination of Starch Fractions

G0, G20, and G120 fraction tubes, total glucose tubes, and free glucose tubes were centrifuged at 500xg for 5 min to pellet any precipitate before determining the glucose contents. After centrifugation, 0.1 ml of the supernatants were put into 15 ml screwcap polypropylene tubes, which consisted of a 3 ml GOPOD reagent. The blank reagent was prepared by mixing 0.1 ml distilled water with a 3 ml GOPOD reagent. The standard reagent was prepared by mixing 0.1 ml D - glucose standard with 3 ml GOPOD reagent. The tubes were incubated for 20 minutes at 47˚C in an incubation oven (Binder, E028-230V-T, Germany). After incubation, the absorbance of each tube was measured by a spectrophotometer (Shimadzu, UV1700 Visible Spectrophotometer, Japan) at 510 nm against a blank, and the amount of glucose in each tube was determined. Starch fractions, rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS) fractions were calculated according to the equations below (Englyst et al., 1992).

$$RDS = 0.9 \times (G20 - FSG) \quad (1)$$

$$SDS = 0.9 \times (G120 - G20) \quad (2)$$

$$TS = 0.9 \times (TG - FSG) \quad (3)$$

$$RS = 0.9 \times (TG - G120) \quad (4)$$

2.2.4 Differential Scanning Calorimetry (DSC)

Thermal properties (gelatinization enthalpy (ΔH), gelatinization onset (T_{onset}), peak (T_{peak}), and end temperatures (T_{end})) of raw and cooked samples were measured using a Differential Scanning Calorimeter (PerkinElmer, DSC 4000, Massachusetts, ABD). About 5 mg (dry basis) samples and distilled water were added to obtain a sample: water ratio (w/v) of 1:4 in the stainless steel DSC pans (Brennan and Tudorica, 2008). The pans were hermetically sealed and allowed to equilibrate for 20 h at room temperature before the analysis. The pans were heated from 10˚C to 110˚C at a rate of 10 ˚C/min. An empty pan was used as a reference. Thermal properties were determined by Pyris software (Version 11.0.0.0449).

2.2.5 Scanning Electron Microscopy (SEM)

The microstructure analysis of the raw and cooked dough samples with selected digested samples was performed at the Central Laboratory at Middle East Technical University, Ankara, Turkey. The freeze-dried samples were mounted onto a stub with double sticky tape, coated with Au-Pd, and examined using Scanning Electron Microscope (Quanta 400F Field Emission SEM, FEI Company, Oregon, USA).

2.2.6 Statistical Analysis

All data were presented as mean ± standard deviation of triplicate unless otherwise specified. Statistical analysis was conducted using analysis of variance (ANOVA) with the general linear model approach followed by Tukey's Multiple Comparison Test at 95% confidence interval. Minitab 16 Statistical Software (Minitab Inc., State College, Pennsylvania) was used in statistical analysis.

CHAPTER 3

RESULTS AND DISCUSSION

3.1 Moisture Content

Moisture content during processing is one of the significant factors that affect starch digestion. In Table 3.1, moisture contents of the flat dough samples before and after processing were shown. Processing methods (steaming and roasting), process time, and temperature significantly affected the moisture content of the processed samples (Table 3.1). Samples steamed for a shorter time (2 min) had similar moisture content with the dough samples for the control and psyllium enriched samples. Using the longer time (10 min) for steamed samples increased the moisture content significantly for the control and psyllium added samples. As expected, roasted samples (with and without psyllium) had lower moisture contents compared to dough samples. In addition, increasing the temperature to 250 ℃ led to significantly higher moisture losses for the roasted samples.

Table 3. 1 Moisture contents of the raw and processed wheat-based flat dough pieces with and without psyllium fiber.

Processing Methods	Samples	Moisture Content (%)
Raw	Control Dough	32.60 ± 0.50^{cd}
	10% Psyllium Added Dough	35.74 ± 1.16^{bc}
Steaming	Control (100 ˚C, 2 min)	34.87 ± 1.93^{bc}
	Control (100 ˚C, 10 min)	43.20 ± 2.62^{a}
	10% Psyllium (100 ˚C, 2 min)	38.32 ± 1.65^{b}
	10% Psyllium (100 ˚C, 10 min)	45.37 ± 3.62^{a}
Roasting	Control (100 ˚C, 2 min)	27.99 ± 0.87^{e}
	Control (250 ˚C, 2 min)	22.45 ± 1.58^{f}
	10% Psyllium (100 ˚C, 2 min)	29.17 ± 0.80^{de}
	10% Psyllium (250 ˚C, 2min)	24.38 ± 0.16^{f}

Data are mean ± standard deviation. The means with the different superscripts are significantly different ($p<0.05$).

3.2 Differential Scanning Calorimetry (DSC)

The thermal properties of the raw and cooked flat dough samples were presented in Table 3.2. The samples' endothermic energies (ΔH) during the DSC analysis for the raw and cooked samples with wheat flour were given in two forms, as J/g dry matter and J/g dry wheat flour weight in the samples (Table 3.2), to be able to observe dilution effect of fiber addition.

The used time and temperature combinations were not enough to completely gelatinize the starch in either the steamed or roasted samples. Therefore, cooked samples showed some endothermic peaks during the DSC analysis (Table 3.2). It was possible to see that steaming caused higher starch gelatinization than roasting when the samples (with and without fiber) were cooked at a similar time and temperature condition (2 min, 100 °C). During steaming, higher moisture penetration occurs, which leads to a reduction in ΔH (Saif et al., 2004). Due to the higher moisture content in steamed samples supported by the moisture data (Table 3.1), more swelling and gelatinization for starch granules could be observed than the roasted samples.

Increasing the time for steaming from 2 min to 10 min did not cause any significant change in the gelatinization enthalpies (Table 3.2). ΔH represents the melting enthalpy of starch crystallites in the sample that did not gelatinize during heating (Bredariol et al., 2019). Therefore, no significant difference in gelatinization enthalpies might indicate that steaming for 2 min was already enough to melt the significant number of starch crystallites of the samples, both control and psyllium enriched. Changing temperature from 100 °C to 250 °C for the roasting process caused a difference in gelatinization (Table 3.2). The remaining ungelatinized starch amounts were higher in the samples (control and fiber added) roasted at 100 °C compared to samples roasted at 250 °C due to lower temperatures for the same roasting time. Reduction in the used gelatinization energy could result from the degradation of some crystalline regions susceptible to heat (W. B. Miao et al., 2021). Therefore, an increase in roasting temperature caused more disrupted

crystalline structures in both control and psyllium added samples, even at a slightly lower moisture content. Yang et al. (2021) was also found a similar result. According to that study, the lowest enthalpy result was found in the tiger nut treated with the highest roasting temperature (Yang et al., 2021).

Transition temperatures of the steamed samples (with and without fiber) were lower than the control dough samples. Roasted samples showed higher transition temperatures in general than the control dough samples. The gelatinization peak temperature is mainly attributed to the molecular architecture of the crystalline region, which corresponds to the short-chain structure of amylopectin (Miao, Zhang, Mu, & Jiang, 2010). Compared to roasted samples, less crystalline region occurrence in steamed samples could be the reason for lower peak temperatures. In other words, higher moisture content during the steaming process might cause more starch hydration and effective swelling and melting of starch crystallites than the roasting process. Gelatinization temperature is related to short-chain structure and interaction between starch and non-starch components (Tester & Sommerville, 2003; Varela et al., 2016). Therefore, in the roasting process, the increased temperature might have enhanced the interactions between other components, e.g., amylose and lipids, resulting in repression of the mobility of starch chains within the amorphous lamellae (Pinto et al., 2015).

Psyllium fiber addition at the used concentration (10 %) did not cause any difference in gelatinization temperatures and the gelatinization enthalpy for the raw and the cooked samples. This result was also supported by the moisture data (Table 3.1) that showed no difference between the control and psyllium enriched dough samples. A similar result was also found in one study of wheat pasta enriched with psyllium seed husk (Renoldi et al., 2021). The added psyllium fiber at this concentration did not even cause any dilution effect on the measured enthalpy values.

Table 3. 2 Thermal Properties (DSC measurements) for raw and cooked wheat-based flat dough pieces with and without psyllium fiber.

	Sample	T_{onset} (˚C)	T_{peak} (˚C)	T_{endset} (˚C)	Enthalpy (ΔH, J/g DM)	Enthalpy (ΔH, J/g DWF)
	Wheat Flour	54.10 ±1.0	63.12 ±0.06	70.61 ±0.64	7.51 ±1.33	7.51 ±1.33
	Control Dough	55.52 ±0.21^{d}	63.13 ±0.13^{c}	70.09 ±0.40^{c}	7.11 ±0.45^{a}	7.11 ±1.39^{ab}
	10% Psyllium Dough	56.09 ±0.11^{cd}	63.76 ±0.19^{c}	70.46 ±0.46^{c}	6.43 ±0.62^{ab}	7.15 ±0.69^{a}
Steamed	Control (100 ˚C, 2 min)	43.20 ±0,95^{e}	50.55 ±1.09^{d}	59.88 ±1.25^{d}	1.29 ±0.27^{d}	1.29 ±0.27^{d}
	Control (100 ˚C, 10 min)	42.67 ±0.41^{e}	49.31 ±0.71^{d}	55.51 ±1.36^{e}	1.54 ±0.39^{d}	1.54 ±0.39^{d}
	10% Psyllium (100 ˚C, 2 min)	42.56 ±0.31^{e}	49.71 ±0.15^{d}	56.19 ±0.67^{e}	1.08 ±0.21^{d}	1.20 ±0.23^{d}
	10% Psyllium (100 ˚C, 10 min)	42.24 ±0.17^{e}	49.66 ±0.73^{d}	58.10 ±1.64^{de}	1.61 ±0.28^{d}	1.79 ±0.31^{d}
Roasted	Control (100 ˚C, 2 min)	57.40 ±0.73^{bc}	64.80 ±0.02^{abc}	72.12 ±0.55^{bc}	5.61 ±0.35^{bc}	5.61 ±0.35^{bc}
	Control (250 ˚C, 2 min)	59.36 ±0.94^{a}	65.55 ±0.46^{ab}	74.98 ±1.41^{ab}	1.13 ±0.31^{d}	1.13 ±0.31^{d}
	10% Psyllium (100 ˚C, 2 min)	57.83 ±0.27^{ab}	64.35 ±0.22^{bc}	70.91 ±0.40^{c}	4.79 ±1.09^{c}	5.33 ±1.22^{c}
	10% Psyllium (250 ˚C, 2min)	58.50 ±0.84^{ab}	66.34 ±1.04^{a}	75.44 ±1.04^{a}	1.68 ±0.06^{d}	1.88 ±0.07^{d}

Data are mean ± standard deviation. Within columns, means with different subscript are significantly different ($p<0.05$).

3.3 Scanning Electron Microscopy (SEM)

SEM images of wheat flour, psyllium fiber, and raw and cooked flat dough samples, steamed or roasted at different conditions, with and without fiber, were illustrated (Figures 3.1, 3.2, 3.3). In addition, SEM images of *in vitro* digested samples for selected conditions with digested wheat flour were presented (Figures 3.4, 3.5, 3.6). SEM images of digested samples were taken from the G20 fractions, where significant but not complete digestion occurred.

SEM images of wheat flour and psyllium fiber were presented in Figure 3.1. For wheat flour, spherical and flat circular-shaped starch granules were highly detectable. Psyllium fiber was in irregular-flat shape and had a high surface area for hydration and gelling (Kaialy et al., 2013).

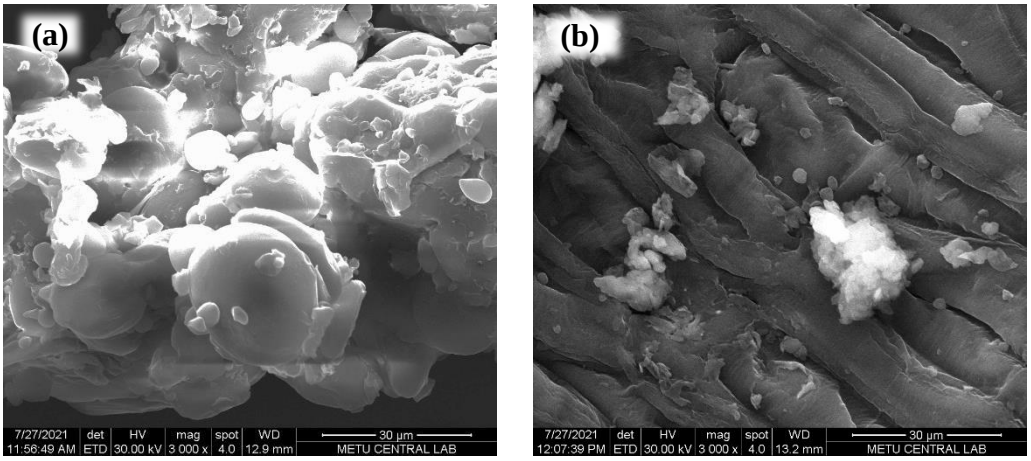
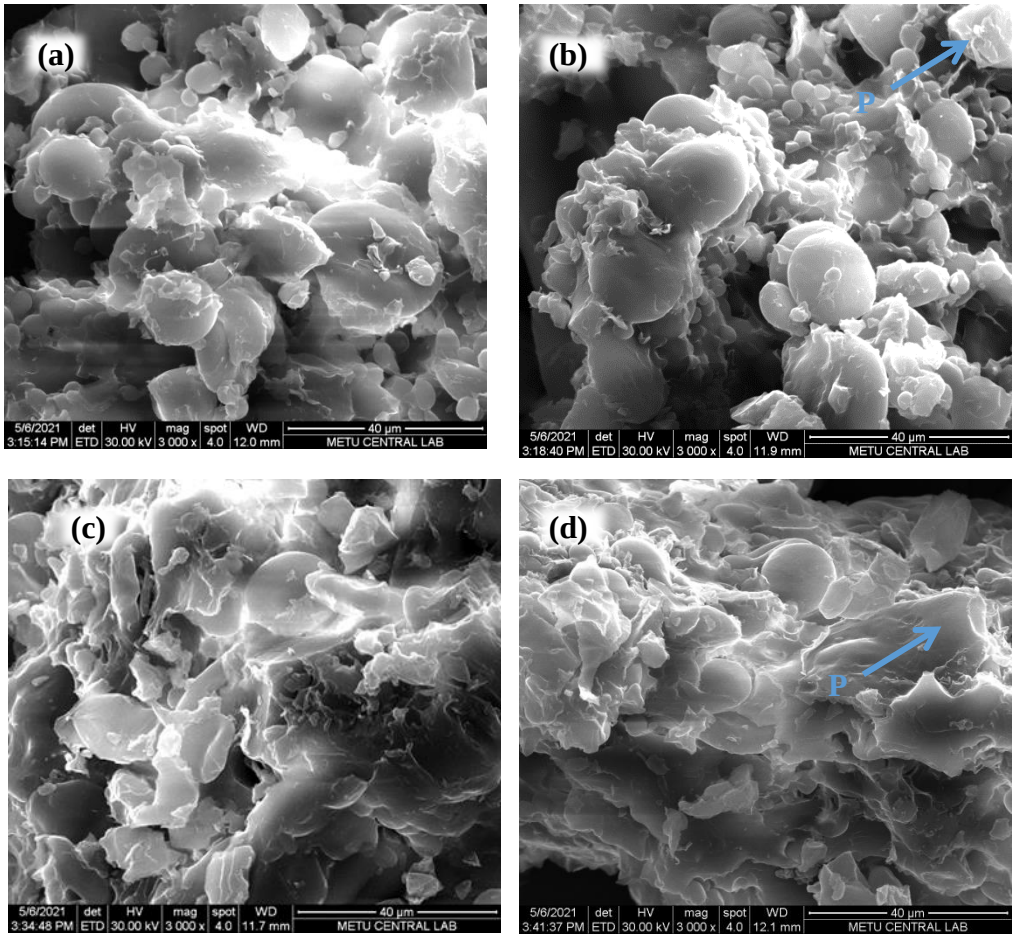


Figure 3.1 SEM micrographs(x3000) of raw materials: (a) wheat flour; (b) psyllium fiber.

With water addition to wheat flour for flat dough formation, starch granules became swollen and elongated, as shown in Figures 3.2 (a). Psyllium enriched dough samples showed similar appearances (Figure 3.2 b). SEM micrographs of steamed control samples showed that gelatinized starch granules appeared to be

integrated into a developed protein matrix (Figure 3.2 c and e). There were still visible starch granules that retained their granular identity even though they were fused with neighboring granules as part of a continuous network. This trend was also observed in steamed psyllium enriched samples. However, the structure of psyllium added samples was more compact than control samples (Figure 3.2 d and f), and starch granules appeared to be entrapped within the protein-fiber matrix.



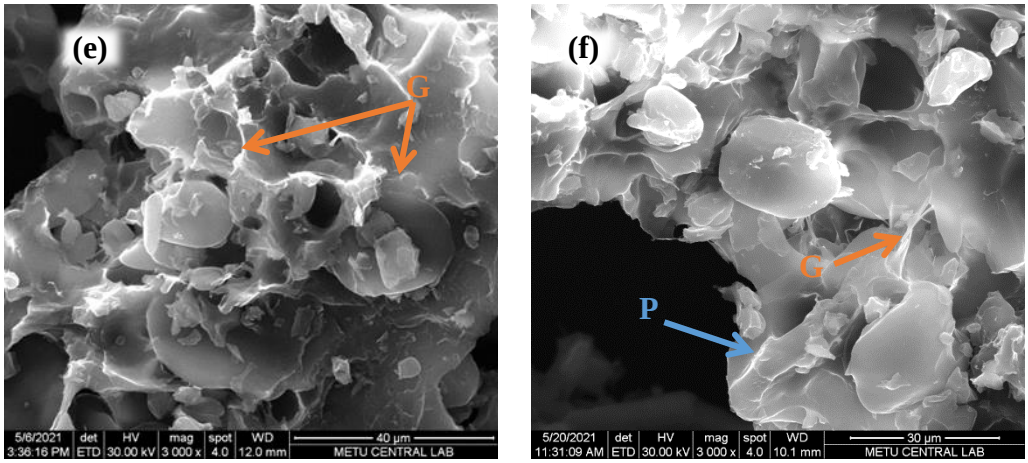


Figure 3.2. SEM micrographs (x3000) of raw and steamed samples at 100˚C: (a) control dough; (b) psyllium enriched dough; (c) steamed (2 min) control sample; (d) steamed (2 min) psyllium enriched sample (e) steamed (10 min) control sample;(f) steamed (10 min) psyllium enriched sample. G: Gluten network, P: Psyllium.

SEM micrographs of the roasted control samples showed that heating at lower temperature gave a similar structure with raw control samples in terms of visibility of starch granules (Figure 3.2 a and Figure 3.3 a, c). In roasted control samples, it could be seen that gelatinized starch was also integrated with the protein matrix. When the roasting temperature was increased, the protein matrix had a more collapsed appearance due to increased protein denaturation (Figure 3.3 e). An increase in protein denaturation led to an increase in the swelling of starch and starch gelatinization. This result could also be supported by the DSC results where control samples roasted at 250˚C had a higher starch gelatinization than control samples at 100˚C (Table 3.2). In psyllium added samples roasted at 100˚C, starch granules were also less fused and more visible like in the control samples roasted at 250˚C.

When processing methods, steaming and roasting, were compared for the same processing time and temperature (100˚C for 2 min) conditions, it was observed that more visible and less swelled starch granules appeared in the roasted samples (with or without fiber) (Figure 3.3 a and b). A denser network structure formation by starch and protein was observed in the roasted samples. In addition, it was easier to detect the psyllium fiber in the roasted samples than steamed samples since they were less expanded due to lower moisture content.

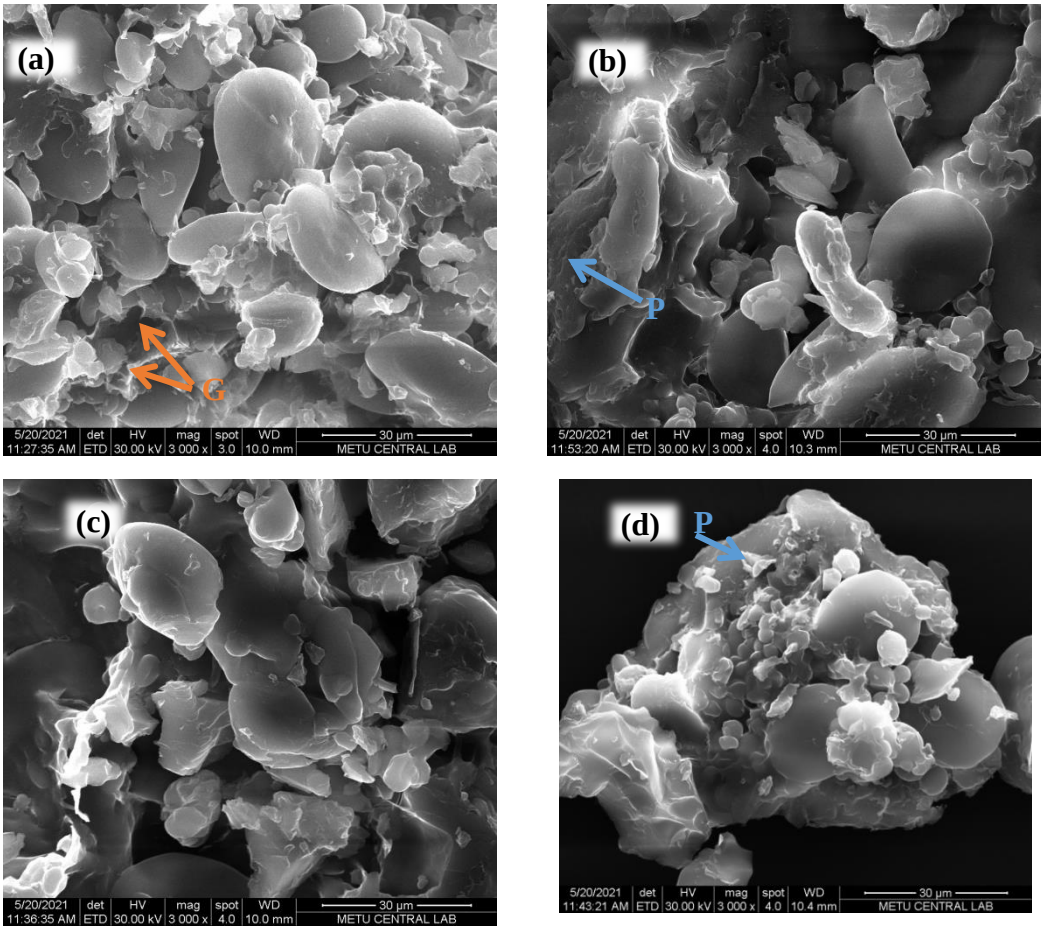


Figure 3.3. SEM micrographs (x 3000) of raw and roasted samples for 2 min: (a) roasted (100˚C) control sample; (b) roasted (100˚C) psyllium enriched sample; (c) roasted (250˚C) control sample; (d) roasted (250˚C) psyllium enriched sample. G: Gluten network, P: Psyllium.

SEM images of wheat flour before and after 20 min small intestine digestion simulation were shown in Figure 3.4. It was seen that the structure of wheat flour was broken down during digestion. Tiny holes and cracks shown by red circles were observed on the starch granules, demonstrating the enzymatic attacks (Figure 3.4 b). Protein in the wheat flour was digested as well by the pepsin enzyme, and its structure was broken down.

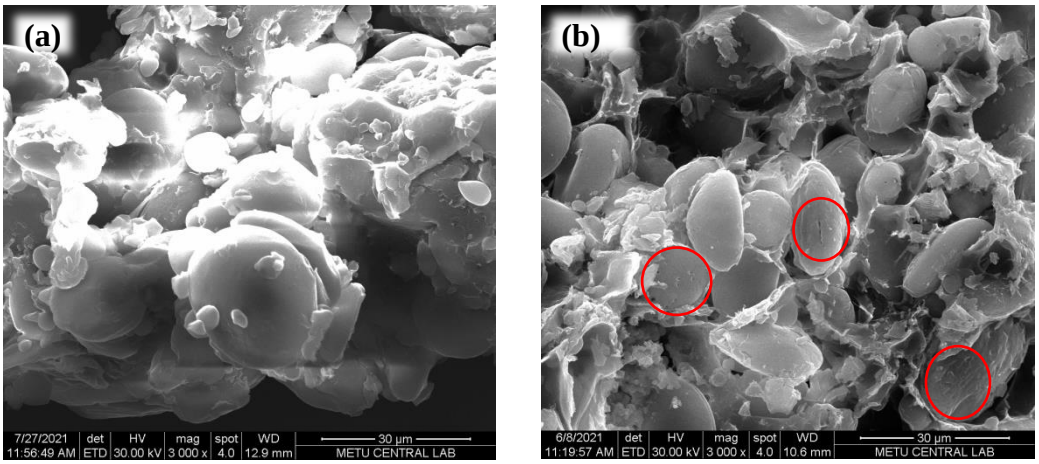


Figure 3.4. SEM micrographs (x3000) of wheat flour before and after 20 min of in vitro digestion: (a) wheat flour; (b) digested wheat flour.

After digestion (20 min), SEM micrographs of the steamed (100 ℃, 2 min) samples (with and without fiber) showed more attacked and fissured structures than the ones in wheat flour due to their cooked structure (Figure 3.4 and 3.5). In control and psyllium enriched samples, the integrity of the starch-protein-fiber matrix was

destroyed by digestive enzymes, and small holes and cracks shown with red circles were observed (Figure 3.5).

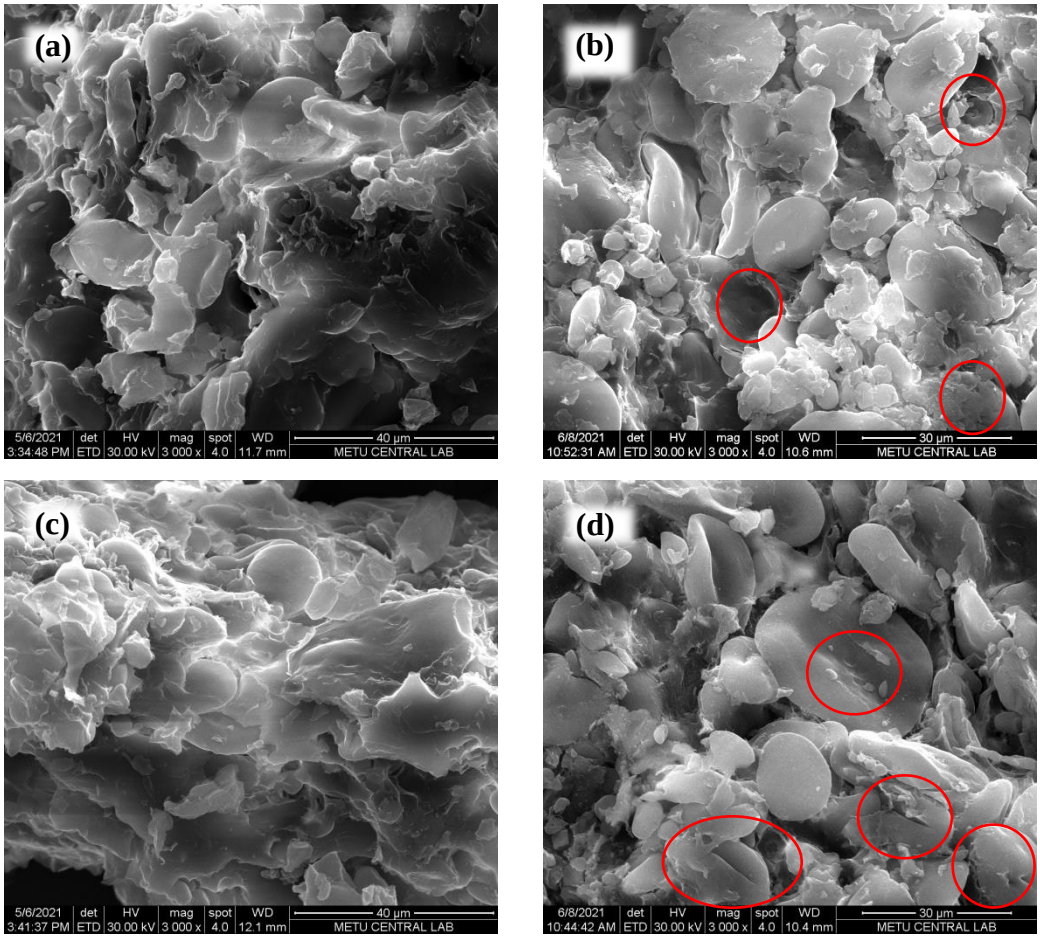
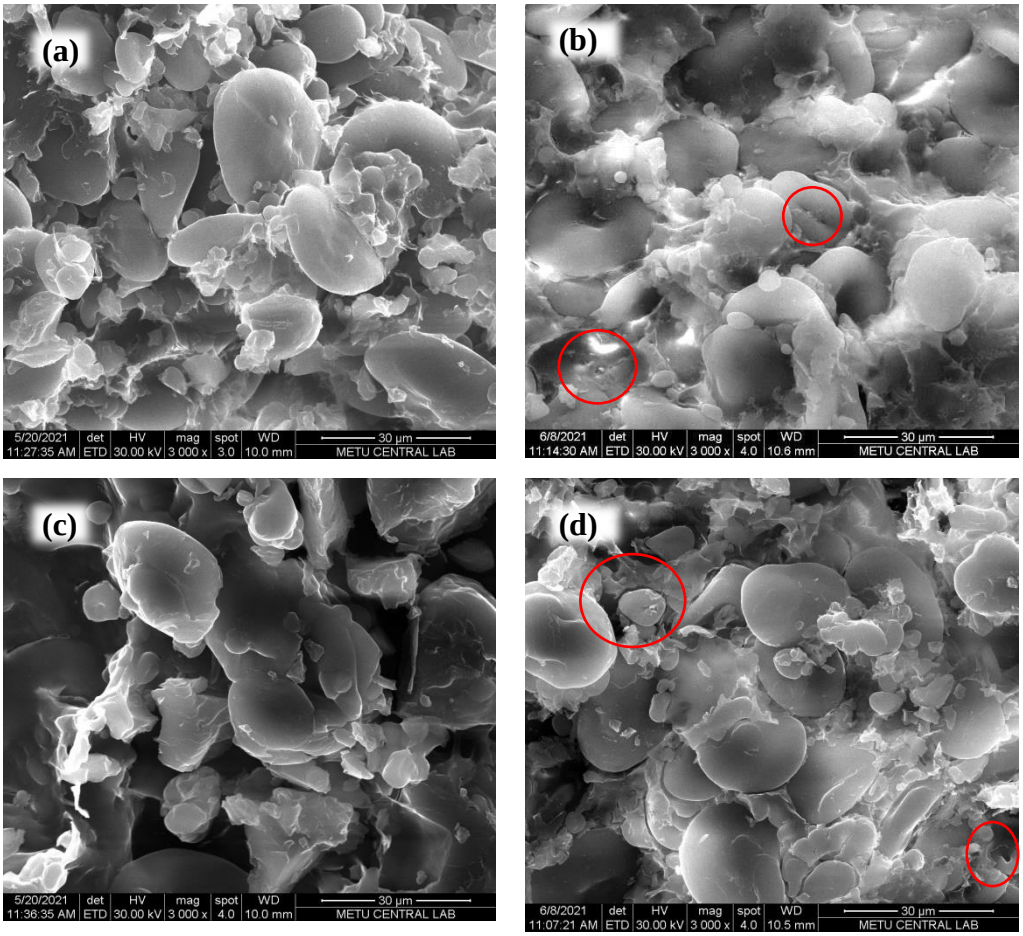


Figure 3.5. SEM micrographs (x3000) of steamed samples at 100˚C before and after 20 min of in vitro digestion: (a) steamed control sample (2 min) ; (b) steamed control sample (2 min) digested; (c) steamed psyllium enriched sample (2 min); (d) steamed psyllium enriched sample (2 min) digested.

In roasted samples (100 °C and 250 °C), enzymatic attacks on swollen starch granules were seen in control, and psyllium added samples. Also, the protein network was not continuous due to protein digestion by the pepsin enzyme. For the control samples roasted at 250 ˚C, more cavities were observed on the surface of the starch granules, which indicated extensive digestion (Figure 3.6 d). On the

other hand, starch granules of control samples roasted at 100 ˚C were visible, either intact or partially damaged. In other words, fewer cluster structures were observed for the samples roasted at a lower temperature. In psyllium added samples roasted at 100 ˚C, the least amount of enzymatic attacks and damaged starch granules appearance were observed due to being entrapped within the protein-fiber network (Figure 3.6 f).



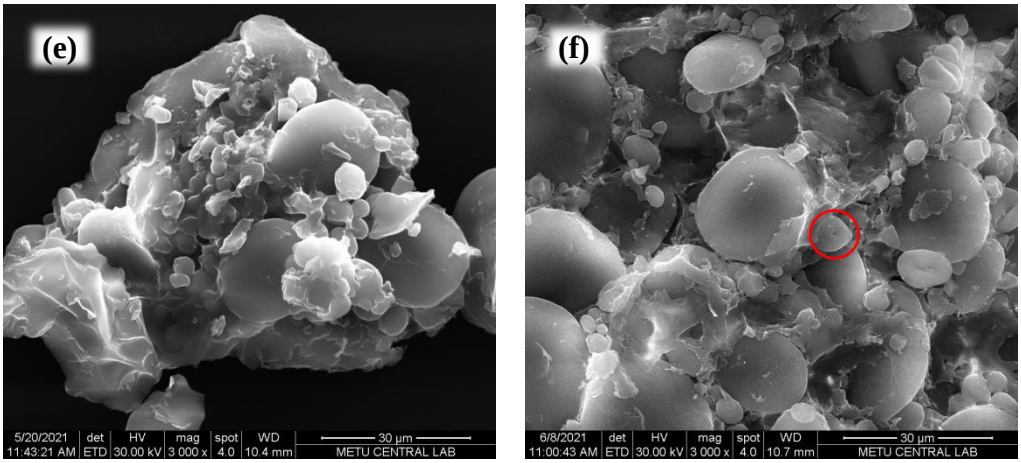


Figure 3.6. SEM micrographs (x3000) of roasted samples (2 min) before and after 20 min of in vitro digestion: (a) roasted control sample (100˚C) ; (b) roasted control sample (100˚C) digested; (c) roasted control sample (250 ˚C); (d) roasted control sample (250 ˚C) digested (e) roasted psyllium enriched sample (100˚C) (f) roasted psyllium enriched sample (100˚C) digested.

Comparing the steaming and roasting process at 100 ˚C for 2 min showed that wrinkles and cracks on starch granules were higher on the steamed samples compared to roasted samples. As observed with DSC data, less gelatinization was observed in roasted samples than steamed samples for that time temperature configuration. Also, more swelling of starch granules was observed in steamed samples due to high moisture content (Figure 3.4). Starch swelling enlarges the surface area for enzyme binding and disrupts the protein network. Therefore, a less integrated protein-starch network and more damaged starch granules were observed in steamed control and psyllium added samples than roasted ones (Figure 3.5 b and d , 3.6 b and f).

3.4 In Vitro Starch Digestion

Starch digestion fractions (RDS, SDS, RS) were presented in three forms (Table 3.3). Starch fractions were presented as percentages of TS (measured total starch), DM (dry matter), and DWF (dry wheat flour) contents in the samples (Table 3.3). Obtained numerical values were highest for the starch fractions when they were presented as percentages of TS because TS represented the starch content in the used wheat flour (DWF) (Table 3.3). The differences seen in the starch fractions when they were presented as percentages of DM compared to DWF for psyllium added samples depicted the dilution caused by the psyllium replacement.

For clarity, only normalized data presented as percentages of starch fractions in DWF were used in the discussions hereafter. Compared to processed products (steamed or roasted), wheat flour showed lower RDS and higher SDS and RS fractions (Table 3.4). It was clear that processing either steaming or roasting increased the starch digestibility (Table 3.3 and Table 3.4).

During steaming, changing time from 2 min to 10 min did not cause any change in RDS, SDS, and RS fractions for either control or psyllium added samples (Table 3.3). Psyllium fiber addition reduced the RDS fractions for both 2, and 10 min steamed samples. An increase in SDS fraction was only significant for 2 min steamed control samples. Psyllium addition did not cause any statistically significant differences in RS fractions.

During roasting, changing temperature from 100 °C to 250 °C did not cause any change in RDS, SDS, and RS fractions for the control samples. However, for psyllium added samples, changing temperature from 100 °C to 250 °C increased

the RDS fraction but did not cause any significant change for SDS and RS fractions. Psyllium fiber addition reduced the RDS fractions for both samples roasted at 100 °C and 250 °C. However, fiber addition increased the SDS fraction only for the samples roasted at 100 °C; there was no difference for the samples roasted at 250 °C due to added fiber. RS fractions were not affected by psyllium fiber addition for the samples roasted at both temperatures.

The DSC data also supported not seeing a significant difference in RDS, SDS, and RS fractions by increasing steaming time (Table 3.2). Used energies for gelatinization of the remaining starch granules were not significantly different between the samples (with or without fiber) steamed for 2 min and 10 min. Furthermore, from the SEM images, it was possible to observe that the duration of heating did not cause apparent changes in granular morphology both in control and psyllium added samples (Figure 3.2 c-f).

According to the literature, certain dietary fibers were expected to help decrease RDS and increase SDS content. A study on three different mushroom powder inclusion to pasta showed that mushroom powder decreased pasta's RDS content and turned it into SDS (Lu et al.,2018). In addition, Chusak et al.(2020) showed that compared to control, the partial replacement of unripe and ripe gac fruit flour (5-15%) resulted in a significantly lower level of RDS ($p<0.05$) while SDS content did not significantly change. Psyllium fiber could decrease the swelling of starch granules and lead to decreased RDS and increased SDS fractions. The mucilage effect of the fiber covering the starch granules could be seen on the SEM micrographs in psyllium-added samples (Figure 3.2 d and f, Figure 3.3 b and d). However, it was challenging to dissociate whether the decrease in bulk elasticity or water absorption of fiber could decrease the swelling of starch granules (Peressini et al., 2020). Dietary fibers can build a strong physical barrier to limit swelling or reduce water availability in the system because of their higher water-binding capacity (Peressini et al., 2020). According to SEM images, structures of steamed

(2 min and 10 min) control and psyllium enriched samples were different from each other (Figure 3.2). The structure of the psyllium enriched sample was more compact than control samples steamed either time (2, 10 min), and starch granules appeared to be entrapped within the protein-fiber matrix (Figure 3.2 d and f).

The reduction in RDS fractions for both steamed and roasted samples due to added fiber could also be due to increased viscosity and hindered enzyme accessibility. Psyllium fiber might slow the mobility of the enzyme and glucose release by forming a viscous gel that may adhere to the starch granules within the food matrix. Adding psyllium fiber to samples increased the SDS fractions only for the samples roasted at 100 °C and the samples steamed for 2 min. According to the DSC result, fiber addition did not cause a significant difference in terms of gelatinization energy used for the steamed and roasted samples (Table 3.2). Thus, having a similar amount of ungelatinized starch granules could explain the limited effect of psyllium fiber on SDS fractions, even though psyllium-added samples had a more compact structure than control samples.

Only in the psyllium added samples increased temperature increased the RDS fraction for the roasted samples. DSC data showed that samples roasted at 250°C (with and without fiber) used similar energies for gelatinization, which were higher than the energies used by the samples roasted at 100˚C (Table 3.2). Thus, similar to fiber added samples, higher RDS values would be expected for the control samples roasted at higher temperatures. However, SEM images of the digested control samples (without fiber) showed similar appearance indicating the similar digestion behavior for the both roasting temperatures (Figure 3.5 b and d). These differing results indicated that gelatinization was not the only factor affecting the RDS fraction in the samples. Samples with added psyllium showed lower RDS fractions than their control samples. Furthermore, SEM images of the digested control samples indicated that enzyme digestion was already high in both samples roasted at 100 ˚C or 250 ˚C. This highly digested structure indicated that increasing

processing temperature did not significantly affect the digestibility of those highly gelatinized but fiber added samples only.

When the samples (with and without psyllium) steamed and roasted at similar conditions (2 min, 100 ˚C) were compared, there was a statistically significant difference only in the RDS fractions of the psyllium added samples. The roasted psyllium added samples (12.2 ± 3.3 %) had a lower RDS fraction than steamed fiber added samples (27.2 ± 5.7 %). Only psyllium added samples showed statistically significant differences due to the processing method using the same time and temperature combination. The steaming process caused higher gelatinization than roasting for the samples (Table 3.2). Thus, not having a significant difference in the other digestion fractions could indicate that other factors than gelatinization affected the starch's digestibility. The dispersion behavior, which was affected by the structure of the samples, could be another factor affecting the digestibility of the samples. Thus, it was seen that the processing method, time, temperature, psyllium fiber addition, and structure of the wheat-based flat dough product could affect *in vitro* starch digestion.

Table 3. 3 Starch fractions (RDS, SDS, RS) of cooked wheat based-flat dough pieces with and without fiber

	Steaming (100 ˚C)				Roasting (2 min)			
Starch Fraction (g starch/ g TS)x100	**Control (2 min)**	**Control (10 min)**	**10% Psyllium (2 min)**	**10% Psyllium (10 min)**	**Control (100˚C)**	**Control (250˚C)**	**10% Psyllium (100˚C)**	**10% Psyllium (250˚C)**
RDS (%)	47.7 ± 7.4^{Aa1}	53.2 ± 4.9^{Aa}	31.9 ± 3.0^{Ab1}	35.0 ± 4.9^{Ab}	39.3 ± 8.1^{Aa1}	44.6 ± 8.5^{Aa}	17.1 ± 0.3^{Bb2}	26.0 ± 2.9^{Ab}
SDS (%)	29.1 ± 5.6^{Ab1}	35.9 ± 1.8^{Aa}	45.1 ± 8.92^{Aa1}	42.3 ± 13.2^{Aa}	37.2 ± 4.0^{Ab1}	26.3 ± 12.7^{Aa}	56.1 ± 6.4^{Aa1}	46.2 ± 12.5^{Aa}
RS (%)	23.2 ± 6.3^{Aa1}	10.9 ± 4.7^{Ba}	23.1 ± 9.4^{Aa1}	22.7 ± 10.4^{Aa}	23.4 ± 4.5^{Aa1}	29.1 ± 6.9^{Aa}	26.9 ± 6.2^{Aa1}	27.8 ± 15.4^{Aa}
Starch Fraction (g starch/ g DM)x100	**Control (2 min)**	**Control (10 min)**	**10% Psyllium (2 min)**	**10% Psyllium (10 min)**	**Control (100˚C)**	**Control (250˚C)**	**10% Psyllium (100˚C)**	**10% Psyllium (250˚C)**
RDS (%)	40.2 ± 5.6^{Aa1}	42.9 ± 4.0^{Aa}	24.3 ± 5.1^{Ab1}	25.2 ± 6.5^{Ab}	31.0 ± 7.3^{Aa1}	36.5 ± 8.0^{Aa}	10.8 ± 3.0^{Bb2}	17.0 ± 3.1^{Ab}
SDS (%)	24.5 ± 5.2^{Aa1}	29.1 ± 3.3^{Aa}	33.5 ± 5.5^{Aa1}	29.7 ± 7.7^{Aa}	29.3 ± 4.0^{Aa1}	21.9 ± 10.8^{Aa}	35.9 ± 12.1^{Aa1}	29.9 ± 8.8^{Aa}
RS (%)	20.2 ± 8.1^{Aa1}	9.0 ± 4.7^{Aa}	17.9 ± 9.3^{Aa1}	16.5 ± 8.6^{Aa}	18.3 ± 3.4^{Aa1}	23.5 ± 3.7^{Aa}	16.9 ± 5.0^{Aa1}	18.4 ± 12.0^{Aa}
Starch Fraction (g starch/ g DWF)x100	**Control (2 min)**	**Control (10 min)**	**10% Psyllium (2 min)**	**10% Psyllium (10 min)**	**Control (100˚C)**	**Control (250˚C)**	**10% Psyllium (100˚C)**	**10% Psyllium (250˚C)**
RDS (%)	40.2 ± 5.6^{Aa1}	42.9 ± 4.0^{Aa}	27.2 ± 5.7^{Ab1}	27.7 ± 7.1^{Ab}	31.0 ± 7.3^{Aa1}	36.5 ± 8.0^{Aa}	12.2 ± 3.3^{Bb2}	19.0 ± 3.5^{Ab}
SDS (%)	24.5 ± 5.2^{Ab1}	29.1 ± 3.3^{Aa}	37.5 ± 6.2^{Aa1}	32.7 ± 8.5^{Aa}	29.3 ± 4.0^{Ab1}	21.9 ± 10.8^{Aa}	40.5 ± 13.7^{Aa1}	33.4 ± 9.9^{Aa}
RS (%)	20.2 ± 8.1^{Aa1}	9.0 ± 4.7^{Aa}	20.0 ± 10.4^{Aa1}	18.2 ± 9.5^{Aa}	18.3 ± 3.4^{Aa1}	23.5 ± 3.7^{Aa}	19.1 ± 5.6^{Aa1}	20.6 ± 1.43^{Aa}
TS/SW	1.00 ± 0.14	0.96 ± 0.10	1.00 ± 0.13	0.94 ± 0.12	0.93 ± 0.10	0.96 ± 0.10	0.84 ± 0.23	0.87 ± 0.13

* Different capital letters (A,B) in the same row indicate a statistical difference due to time (steamed) or a difference due to temperature (roasted) ($p<0.05$). Different lowercase letters (a, b) in the same row indicate statistical differences due to fiber addition ($p<0.05$). Different numbers (1, 2) in the same row indicate statistical differences due to processing type (2 min at 100 °C) ($p<0.05$). Data are mean ± standard deviation. TS: total starch content measured in the sample, DM: dry weight of the whole sample, DWF: dry weight of the wheat flour. SW: starch content of the wheat flour in the sample.

Table 3. 4 Starch fractions (RDS, SDS, RS) of wheat flour

Starch Fraction (g starch/ g DWF)x100	Wheat Flour
RDS (%)	15.30 ± 6.74
SDS (%)	39.90 ± 5.59
RS (%)	29.45 ± 5.51

Data are mean ± standard deviation.

CHAPTER 4

CONCLUSION AND RECOMMENDATIONS

Overall, this study showed that processing method, time, temperature, and psyllium fiber addition into a wheat-based flat dough could affect *in vitro* starch digestion. The processing method could alter the starch gelatinization, development of the gluten network, and structure. Then, this structure and psyllium fiber could affect the enzyme's accessibility to the substrates.

Future studies could consider food systems' quality and sensory aspects to expand the knowledge. The effects of food' dispersion behavior on *in vitro* starch digestion would add valuable insight. Different processing methods with the effect of food storage conditions could also be included in further investigations.

REFERENCES

Ai, Y., Hasjim, J., & Jane, J. L. (2013). Effects of lipids on enzymatic hydrolysis and physical properties of starch. Carbohydrate Polymers, 92(1), 120-127.

Alfy, A., Kiran, B. V., Jeevitha, G. C., & Hebbar, H. U. (2014). Recent Developments in Superheated Steam Processing of Foods—A Review. *Critical Reviews in Food Science and Nutrition*, *56*(13), 2191–2208. https://doi.org/10.1080/10408398.2012.740641

Aller, E. E. J. G., Abete, I., Astrup, A., Martinez, J. A., & Baak, M. A. V. (2011). Starches, Sugars and Obesity. Nutrients, 3(3), 341–369. https://doi.org/10.3390/nu3030341

Angioloni, A., & Collar, C. (2011). Physicochemical and nutritional properties of reduced-caloric density high-fibre breads. *LWT - Food Science and Technology*, *44*(3), 747–758. https://doi.org/10.1016/j.lwt.2010.09.008

Ao, Z., & Jane, J. (2007). Characterization and modeling of the A- and B-granule starches of wheat, triticale, and barley. *Carbohydrate Polymers*, *67*(1), 46–55. https://doi.org/10.1016/j.carbpol.2006.04.013

Ao, Z., Simsek, S., Zhang, G., Venkatachalam, M., Reuhs, B. L., & Hamaker, B. R. (2007). Starch with a Slow Digestion Property Produced by Altering Its Chain Length, Branch Density, and Crystalline Structure. *Journal of Agricultural and Food Chemistry*, *55*(11), 4540–4547. https://doi.org/10.1021/jf063123x

Aravind, N., Sissons, M., Egan, N., & Fellows, C. (2012). Effect of insoluble dietary fibre addition on technological, sensory, and structural properties of durum wheat spaghetti. *Food Chemistry*, *130*(2), 299–309. https://doi.org/10.1016/j.foodchem.2011.07.042

Ball, S., Guan, H. P., James, M., Myers, A., Keeling, P., Mouille, G., Buléon, A., Colonna, P., & Preiss, J. (1996). From Glycogen to Amylopectin: A Model for the Biogenesis of the Plant Starch Granule. *Cell*, *86*(3), 349–352. https://doi.org/10.1016/s0092-8674(00)80107-5

Bhattarai, R. R., Dhital, S., & Gidley, M. J. (2016). Interactions among macronutrients in wheat flour determine their enzymic susceptibility. *Food Hydrocolloids*, *61*, 415–425. https://doi.org/10.1016/j.foodhyd.2016.05.026

Björck, I., Asp, N. G., Birkhed, D., & Lundquist, I. (1984). Effects of processing on availability of starch for digestion in vitro and in vivo; I Extrusion cooking of wheat flours and starch. *Journal of Cereal Science*, *2*(2), 91–103. https://doi.org/10.1016/s0733-5210(84)80022-3

Brand, J. C., Colagiuri, S., Crossman, S., Allen, A., Roberts, D. C., & Truswell, A. S. (1991). Low-Glycemic Index Foods Improve Long-Term Glycemic Control in NIDDM. *Diabetes Care*, *14*(2), 95–101. https://doi.org/10.2337/diacare.14.2.95

Bredariol, P., Spatti, M., & Vanin, F. M. (2019). Different baking conditions may produce breads with similar physical qualities but unique starch gelatinization behaviour. LWT, 111, 737–743. https://doi.org/10.1016/j.lwt.2019.05.094

Brennan, C. S. (2005). Dietary fibre, glycaemic response, and diabetes. *Molecular Nutrition & Food Research*, *49*(6), 560–570. https://doi.org/10.1002/mnfr.200500025

Brennan, C. S., & Tudorica, C. M. (2008). Evaluation of potential mechanisms by which dietary fibre additions reduce the predicted glycaemic index of fresh pastas. *International Journal of Food Science & Technology*, *43*(12), 2151–2162. https://doi.org/10.1111/j.1365-2621.2008.01831.x

Briani, G., Bruttomesso, D., Bilardo, G., Giorato, C., Duner, E., Iori, E., Sgnaolin, E., Pedrini, P., & Tiengo, A. (1987). Guar-enriched pasta and guar gum in the dietary treatment of type II diabetes. Phytotherapy Research, 1(4), 177–179. https://doi.org/10.1002/ptr.2650010410

Brites, C. M., Santos, C. A. L. D., Bagulho, A. S., & Beirão-da-Costa, M. L. (2007). Effect of wheat puroindoline alleles on functional properties of starch. *European Food Research and Technology*, *226*(5), 1205–1212. https://doi.org/10.1007/s00217-007-0711-z

Brownlee, M. (2001). Biochemistry and molecular cell biology of diabetic complications. *Nature*, *414*(6865), 813–820. https://doi.org/10.1038/414813a

Cai, C., & Wei, C. (2013). In situ observation of crystallinity disruption patterns during starch gelatinization. *Carbohydrate Polymers*, *92*(1), 469–478. https://doi.org/10.1016/j.carbpol.2012.09.073

Cai, C., Zhao, L., Huang, J., Chen, Y., & Wei, C. (2014). Morphology, structure and gelatinization properties of heterogeneous starch granules from high-amylose maize. *Carbohydrate Polymers*, *102*, 606–614. https://doi.org/10.1016/j.carbpol.2013.12.010

Castells, M., Marín, S., Sanchis, V., & Ramos, A. J. (2005). Fate of mycotoxins in cereals during extrusion cooking: A review. *Food Additives & Contaminants*,*22*(2), 150–157. https://doi.org/10.1080/02652030500037969

Chen, C., Zeng, Y., Xu, J., Zheng, H., Liu, J., Fan, R., Zhu, W., Yuan, L., Qin, Y., Chen, S., Zhou, Y., Wu, Y., Wan, J., Mi, M., & Wang, J. (2016). Therapeutic effects of soluble dietary fiber consumption on type 2 diabetes mellitus. Experimental and Therapeutic Medicine, 12(2), 1232–1242. https://doi.org/10.3892/etm.2016.3377

Chiasson, J. L. (1994). The Efficacy of Acarbose in the Treatment of Patients with Non–Insulin-Dependent Diabetes Mellitus: A Multicenter, Controlled Clinical Trial. *Annals of Internal Medicine*, *121*(12),928. https://doi.org/10.7326/0003-4819-121-12-199412150-00004

Chusak, C., Chanbunyawat, P., Chumnumduang, P., Chantarasinlapin, P., Suantawee, T., & Adisakwattana, S. (2020). Effect of gac fruit (Momordica cochinchinensis) powder on in vitro starch digestibility, nutritional quality, textural and sensory characteristics of pasta. *LWT*, *118*, 108856. https://doi.org/10.1016/j.lwt.2019.108856

Coniff, R. F. (1994). Long-term efficacy and safety of acarbose in the treatment of obese subjects with non-insulin-dependent diabetes mellitus. *Archives of Internal Medicine*, *154*(21), 2442–2448. https://doi.org/10.1001/archinte.154.21.2442

Copeland, L., Blazek, J., Salman, H., & Tang, M. C. (2009). Form and functionality of starch. *Food Hydrocolloids*, *23*(6), 1527–1534. https://doi.org/10.1016/j.foodhyd.2008.09.016

Cornejo-Ramírez, Y. I., Martínez-Cruz, O., del Toro-Sánchez, C. L., Wong-Corral, F. J., Borboa-Flores, J., & Cinco-Moroyoqui, F. J. (2018). The structural characteristics of starches and their functional properties. *CyTA - Journal of Food*, *16*(1), 1003–1017. https://doi.org/10.1080/19476337.2018.1518343

Cui, S., Wu, Y., & Ding, H. (2013). The range of dietary fibre ingredients and a comparison of their technical functionality. Fibre-Rich and Wholegrain Foods, 96–119. https://doi.org/10.1533/9780857095787.1.96

de Pilli, T., & Alessandrino, O. (2018). Effects of different cooking technologies on biopolymers modifications of cereal-based foods: Impact on nutritional and quality characteristics review. *Critical Reviews in Food Science and Nutrition*, *60*(4), 556–565. https://doi.org/10.1080/10408398.2018.1544884

Dello Staffolo, M., Sato, A. C. K., & Cunha, R. L. (2017). Utilization of Plant Dietary Fibers to Reinforce Low-Calorie Dairy Dessert Structure. *Food and Bioprocess Technology*, *10*(5), 914–925. https://doi.org/10.1007/s11947-017-1872-9

Dhital, S., Brennan, C., & Gidley, M. J. (2019). Location and interactions of starches in planta: Effects on food and nutritional functionality. *Trends in Food Science & Technology*, *93*, 158–166. https://doi.org/10.1016/j.tifs.2019.09.011

El Khoury, D., Cuda, C., Luhovyy, B. L., & Anderson, G. H. (2012). Beta Glucan: Health Benefits in Obesity and Metabolic Syndrome. *Journal of Nutrition and Metabolism*, *2012*, 1–28. https://doi.org/10.1155/2012/851362

Gelders, G. G., Duyck, J. P., Goesaert, H., & Delcour, J. A. (2005). Enzyme and acid resistance of amylose-lipid complexes differing in amylose chain length, lipid and complexation temperature. *Carbohydrate Polymers*, *60*(3), 379–389. https://doi.org/10.1016/j.carbpol.2005.02.008

Golay, A., Schneider, H., Temler, E., & Felber, J. P. (1991). Effect of trestatin, an amylase inhibitor, incorporated into bread, on glycemic responses in normal and diabetic patients. *The American Journal of Clinical Nutrition*, *53*(1), 61–65. https://doi.org/10.1093/ajcn/53.1.61

Goñi, I., Brenes, A., Centeno, C., Viveros, A., Saura-Calixto, F., Rebolé, A., Arija, I., & Estevez, R. (2007). Effect of Dietary Grape Pomace and Vitamin E on Growth Performance, Nutrient Digestibility, and Susceptibility to Meat Lipid Oxidation in Chickens. *Poultry Science*, *86*(3), 508–516. https://doi.org/10.1093/ps/86.3.508

Goñi, I., Garcia-Alonso, A., & Saura-Calixto, F. (1997). A starch hydrolysis procedure to estimate glycemic index. *Nutrition Research*, *17*(3), 427–437. https://doi.org/10.1016/s0271-5317(97)00010-9

Granfeldt, Y., Björck, I., Drews, A., & Tovar, J. (1994). An in vitro procedure based on chewing to predict metabolic response to starch in cereal and legume products. *The American Journal of Clinical Nutrition*, *59*(3), 777S. https://doi.org/10.1093/ajcn/59.3.777s

Hiele, M., Ghoos, Y., Rutgeerts, P., & Vantrappen, G. (1992). Effects of acarbose on starch hydrolysis. *Digestive Diseases and Sciences*, *37*(7), 1057–1064. https://doi.org/10.1007/bf01300287

Holm, J., Björck, I., Ostrowska, S., Eliasson, A. C., Asp, N. G., Larsson, K., & Lundquist, I. (1983). Digestibility of Amylose-Lipid Complexes in-vitro

and in-vivo. *Starch - Stärke*, *35*(9), 294–297. https://doi.org/10.1002/star.19830350902

Inan Eroglu, E., & Buyuktuncer, Z. (2017). The effect of various cooking methods on resistant starch content of foods. *Nutrition & Food Science*, *47*(4), 522–533. https://doi.org/10.1108/nfs-10-2016-0154

Jogihalli, P., Singh, L., & Sharanagat, V. S. (2017). Effect of microwave roasting parameters on functional and antioxidant properties of chickpea (Cicer arietinum). *LWT - Food Science and Technology*, *79*, 223–233. https://doi.org/10.1016/j.lwt.2017.01.047

Kaialy, W., Emami, P., Asare-Addo, K., Shojaee, S., & Nokhodchi, A. (2013). Psyllium: a promising polymer for sustained release formulations in combination with HPMC polymers. *Pharmaceutical Development and Technology*, *19*(3), 269–277. https://doi.org/10.3109/10837450.2013.775156

Koch, K., & Jane, J. L. (2000). Morphological Changes of Granules of Different Starches by Surface Gelatinization with Calcium Chloride. *Cereal Chemistry Journal*, *77*(2), 115–120. https://doi.org/10.1094/cchem.2000.77.2.115

Leclère, C. J., Champ, M., Boillot, J., Guille, G., Lecannu, G., Molis, C., Bornet, F., Krempf, M., Delort-Laval, J., & Galmiche, J. P. (1994). Role of viscous guar gums in lowering the glycemic response after a solid meal. The American Journal of Clinical Nutrition, 59(4), 914–921. https://doi.org/10.1093/ajcn/59.4.914

Li, H. T., Li, Z., Fox, G. P., Gidley, M. J., & Dhital, S. (2020). Protein-starch matrix plays a key role in enzymic digestion of high-amylose wheat noodle. *Food Chemistry*, *336*, 127719. https://doi.org/10.1016/j.foodchem.2020.127719

Lin, A. H. M., Lee, B. H., Nichols, B. L., Quezada-Calvillo, R., Rose, D. R., Naim, H. Y., & Hamaker, B. R. (2012). Starch Source Influences Dietary Glucose Generation at the Mucosal α-Glucosidase Level. *Journal of Biological Chemistry*, *287*(44), 36917–36921. https://doi.org/10.1074/jbc.m112.378331

Lu, X., Brennan, M. A., Serventi, L., Liu, J., Guan, W., & Brennan, C. S. (2018). Addition of mushroom powder to pasta enhances the antioxidant content and modulates the predictive glycaemic response of pasta. *Food Chemistry*, *264*, 199–209. https://doi.org/10.1016/j.foodchem.2018.04.130

Ludwig, D. S. (2002). The Glycemic Index. *JAMA*, *287*(18), 2414. https://doi.org/10.1001/jama.287.18.2414

Ma, Y., Xu, D., Sang, S., Jin, Y., Xu, X., & Cui, B. (2021). Effect of superheated steam treatment on the structural and digestible properties of wheat flour. *Food Hydrocolloids*, *112*, 106362. https://doi.org/10.1016/j.foodhyd.2020.106362

Mackie, A., Bajka, B., & Rigby, N. (2016). Roles for dietary fibre in the upper GI tract: The importance of viscosity. *Food Research International*, *88*, 234–238. https://doi.org/10.1016/j.foodres.2015.11.011

Martínez, M. M., & Gómez, M. (2017). Rheological and microstructural evolution of the most common gluten-free flours and starches during bread fermentation and baking. *Journal of Food Engineering*, *197*, 78–86. https://doi.org/10.1016/j.jfoodeng.2016.11.008

Miao, M., Jiang, B., Cui, S. W., Zhang, T., & Jin, Z. (2013). Slowly Digestible Starch—A Review. *Critical Reviews in Food Science and Nutrition*, *55*(12), 1642–1657. https://doi.org/10.1080/10408398.2012.704434

Miao, M., Jiang, B., & Zhang, T. (2009). Effect of pullulanase debranching and recrystallization on structure and digestibility of waxy maize starch. *Carbohydrate Polymers*, *76*(2), 214–221. https://doi.org/10.1016/j.carbpol.2008.10.007

Miao, W. B., Ma, S. Y., Peng, X. G., Qin, Z., Liu, H. M., Cai, X. S., & Wang, X. D. (2021). Effects of various roasting temperatures on the structural and functional properties of starches isolated from tigernut tuber. LWT, 151, 112149. https://doi.org/10.1016/j.lwt.2021.112149

Mondragón, M., Bello-Pérez, L. A., Agama-Acevedo, E., Betancur-Ancona, D., & Peña, J. L. (2004). Effect of Cooking Time, Steeping and Lime Concentration on Starch Gelatinization of Corn During Nixtamalization. *Starch - Stärke*, *56*(6), 248–253. https://doi.org/10.1002/star.200200190

Mua, J. P., & Jackson, D. S. (1997). Fine Structure of Corn Amylose and Amylopectin Fractions with Various Molecular Weights†. *Journal of Agricultural and Food Chemistry*, *45*(10), 3840–3847. https://doi.org/10.1021/jf960877a

Murray, S. M., Patil, A. R., Fahey, G. C., Merchen, N. R., Wolf, B. W., Lai, C. S., & Garleb, K. A. (1998). Apparent Digestibility of a Debranched Amylopectin-Lipid Complex and Resistant Starch Incorporated into Enteral Formulas Fed to Ileal-Cannulated Dogs. *The Journal of Nutrition*, *128*(11), 2032–2035. https://doi.org/10.1093/jn/128.11.2032

Nor Nadiha, M., Fazilah, A., Bhat, R., & Karim, A. A. (2010). Comparative susceptibilities of sago, potato and corn starches to alkali treatment. *Food Chemistry*, *121*(4), 1053–1059. https://doi.org/10.1016/j.foodchem.2010.01.048

Oh, I. K., Bae, I. Y., & Lee, H. G. (2014). In vitro starch digestion and cake quality: Impact of the ratio of soluble and insoluble dietary fiber. *International Journal of Biological Macromolecules*, *63*, 98–103. https://doi.org/10.1016/j.ijbiomac.2013.10.038

Peressini, D., Cavarape, A., Brennan, M. A., Gao, J., & Brennan, C. S. (2020). Viscoelastic properties of durum wheat doughs enriched with soluble dietary fibres in relation to pasta-making performance and glycaemic response of spaghetti. *Food Hydrocolloids*, *102*, 105613. https://doi.org/10.1016/j.foodhyd.2019.105613

Pinto, V. Z., Vanier, N. L., Deon, V. G., Moomand, K., el Halal, S. L. M., Zavareze, E. D. R., Lim, L. T., & Dias, A. R. G. (2015). Effects of single and dual physical modifications on pinhão starch. Food Chemistry, 187, 98–105. https://doi.org/10.1016/j.foodchem.2015.04.037

Priebe, M. G., Eelderink, C., Wachters-Hagedoorn, R. E., & Vonk, R. J. (2018). Starch Digestion and Applications of Slowly Available Starch. *Starch in Food*, 805–826. https://doi.org/10.1016/b978-0-08-100868-3.00021-4

Rathod, R. P., & Annapure, U. S. (2016). Effect of extrusion process on antinutritional factors and protein and starch digestibility of lentil splits. *LWT - Food Science and Technology*, *66*, 114–123. https://doi.org/10.1016/j.lwt.2015.10.028

Renoldi, N., Brennan, C. S., Lagazio, C., & Peressini, D. (2021). Evaluation of technological properties, microstructure and predictive glycaemic response of durum wheat pasta enriched with psyllium seed husk. LWT, 151, 112203. https://doi.org/10.1016/j.lwt.2021.112203

Roman, L., Belorio, M., & Gomez, M. (2019). Gluten-Free Breads: The Gap Between Research and Commercial Reality. *Comprehensive Reviews in Food Science and Food Safety*, *18*(3), 690–702. https://doi.org/10.1111/1541-4337.12437

Saif, S. M., Suter, D. A., & Lan, Y. (2004). Effects of Processing Conditions and Environmental Exposure on the Tensile Properties of Parboiled Rice. Biosystems Engineering, 89(3), 321–330. https://doi.org/10.1016/j.biosystemseng.2004.08.010

Scientific Opinion on Dietary Reference Values for carbohydrates and dietary fibre. (2010). EFSA Journal, 8(3). https://doi.org/10.2903/j.efsa.2010.1462

Sharma, S., Singh, N., & Singh, B. (2015). Effect of extrusion on morphology, structural, functional properties and in vitro digestibility of corn, field pea and kidney bean starches. *Starch - Stärke*, *67*(9–10), 721–728. https://doi.org/10.1002/star.201500021

Shi, Y. C., Capitani, T., Trzasko, P., & Jeffcoat, R. (1998). Molecular Structure of a Low-Amylopectin Starch and Other High-Amylose Maize Starches. *Journal of Cereal Science*, *27*(3), 289–299. https://doi.org/10.1006/jcrs.1997.9998

Singh, B. (2007). Psyllium as therapeutic and drug delivery agent. *International Journal of Pharmaceutics*, *334*(1–2), 1–14. https://doi.org/10.1016/j.ijpharm.2007.01.028

Singh, S., Gamlath, S., & Wakeling, L. (2007). Nutritional aspects of food extrusion: a review. *International Journal of Food Science & Technology*, *42*(8), 916–929. https://doi.org/10.1111/j.1365-2621.2006.01309.x

Singh, S., Singh, N., Isono, N., & Noda, T. (2010). Relationship of Granule Size Distribution and Amylopectin Structure with Pasting, Thermal, and Retrogradation Properties in Wheat Starch. *Journal of Agricultural and Food Chemistry*, *58*(2), 1180–1188. https://doi.org/10.1021/jf902753f

Slavin, J. L. (2005). Dietary fiber and body weight. Nutrition, 21(3), 411–418. https://doi.org/10.1016/j.nut.2004.08.018

Song, Y., & Jane, J. (2000). Characterization of barley starches of waxy, normal, and high amylose varieties. *Carbohydrate Polymers*, *41*(4), 365–377. https://doi.org/10.1016/s0144-8617(99)00098-3

Sruthi, N., Premjit, Y., Pandiselvam, R., Kothakota, A., & Ramesh, S. (2021). An overview of conventional and emerging techniques of roasting: Effect on food bioactive signatures. *Food Chemistry*, *348*, 129088. https://doi.org/10.1016/j.foodchem.2021.129088

Symons, L. J., & Brennan, C. S. (2004). The Effect of Barley β-Glucan Fiber Fractions on Starch Gelatinization and Pasting Characteristics. *Journal of Food Science*, *69*(4), FCT257–FCT261. https://doi.org/10.1111/j.1365-2621.2004.tb06325.x

Tang, H., Watanabe, K., & Mitsunaga, T. (2002). Structure and functionality of large, medium and small granule starches in normal and waxy barley endosperms. *Carbohydrate Polymers*, *49*(2), 217–224. https://doi.org/10.1016/s0144-8617(01)00329-0

Theuwissen, E., & Mensink, R. P. (2008). Water-soluble dietary fibers and cardiovascular disease. *Physiology & Behavior*, *94*(2), 285–292. https://doi.org/10.1016/j.physbeh.2008.01.001

Tian, Y., Li, M., Tang, A., Jane, J. L., Dhital, S., & Guo, B. (2020). RS Content and eGI Value of Cooked Noodles (I): Effect of Cooking Methods. *Foods*, *9*(3), 328. https://doi.org/10.3390/foods9030328

Topping, D. L., & Clifton, P. M. (2001). Short-Chain Fatty Acids and Human Colonic Function: Roles of Resistant Starch and Nonstarch Polysaccharides. *Physiological Reviews*, *81*(3), 1031–1064. https://doi.org/10.1152/physrev.2001.81.3.1031

Tudorică, C. M., Kuri, V., & Brennan, C. S. (2001). Nutritional and Physicochemical Characteristics of Dietary Fiber Enriched Pasta. *Journal of Agricultural and Food Chemistry*, *50*(2), 347–356. https://doi.org/10.1021/jf0106953

Vamadevan, V., & Bertoft, E. (2014). Structure-function relationships of starch components. *Starch - Stärke*, *67*(1–2), 55–68. https://doi.org/10.1002/star.201400188

Van Hung, P., Chau, H. T., & Phi, N. T. L. (2016). In vitro digestibility and in vivo glucose response of native and physically modified rice starches varying amylose contents. *Food Chemistry*, *191*, 74–80. https://doi.org/10.1016/j.foodchem.2015.02.118

Varela, M. S., Navarro, A. S., & Yamul, D. K. (2016). Effect of hydrocolloids on the properties of wheat/potato starch mixtures. Starch - Stärke, 68(7–8), 753–761. https://doi.org/10.1002/star.201400257

Wang, S., Wang, S., Guo, P., Liu, L., & Wang, S. (2016). Multiscale Structural Changes of Wheat and Yam Starches during Cooking and Their Effect on in Vitro Enzymatic Digestibility. *Journal of Agricultural and Food Chemistry*, *65*(1), 156–166. https://doi.org/10.1021/acs.jafc.6b04272

Wang, Y., Chen, L., Yang, T., Ma, Y., McClements, D. J., Ren, F., Tian, Y., & Jin, Z. (2021). A review of structural transformations and properties changes in starch during thermal processing of foods. *Food Hydrocolloids*, *113*, 106543. https://doi.org/10.1016/j.foodhyd.2020.106543

Waramboi, J. G., Gidley, M. J., & Sopade, P. A. (2014). Influence of extrusion on expansion, functional and digestibility properties of whole sweetpotato flour. *LWT - Food Science and Technology*, *59*(2), 1136–1145. https://doi.org/10.1016/j.lwt.2014.06.016

Xue, C., Fukuoka, M., & Sakai, N. (2010). Prediction of the degree of starch gelatinization in wheat flour dough during microwave heating. *Journal of Food Engineering*, *97*(1), 40–45. https://doi.org/10.1016/j.jfoodeng.2009.09.013

Yang, Z., Zhang, Y., Wu, Y., & Ouyang, J. (2021). The role of drying methods in determining the in vitro digestibility of starch in whole chestnut flour. LWT, 153, 112583. https://doi.org/10.1016/j.lwt.2021.112583

Yıldız, G., & Bilgiçli, N. (2012). Effects of whole buckwheat flour on physical, chemical, and sensory properties of flat bread, Lavaş. *Czech Journal of Food Sciences*, *30*(No. 6), 534–540. https://doi.org/10.17221/10/2012-cjfs

Zhang, G., Ao, Z., & Hamaker, B. R. (2006). Slow Digestion Property of Native Cereal Starches. *Biomacromolecules*, *7*(11), 3252–3258. https://doi.org/10.1021/bm060342i

Zhang, G., & Hamaker, B.R. (2009). Slowly Digestible Starch: Concept, Mechanism, and Proposed Extended Glycemic Index. *Critical Reviews in Food Science and Nutrition*, *49*(10), 852–867. https://doi.org/10.1080/10408390903372466

Zhang, N., Gao, Y., Tong, L., & Li, Z. (2018). Superheated steam processing improved the qualities of oats flour and noodles. *Journal of Cereal Science*, *83*, 96–100. https://doi.org/10.1016/j.jcs.2018.07.017

APPENDICES

A. Surface SEM micrographs(x3000) of wheat flour and some cooked samples at 20 min of in vitro digestion

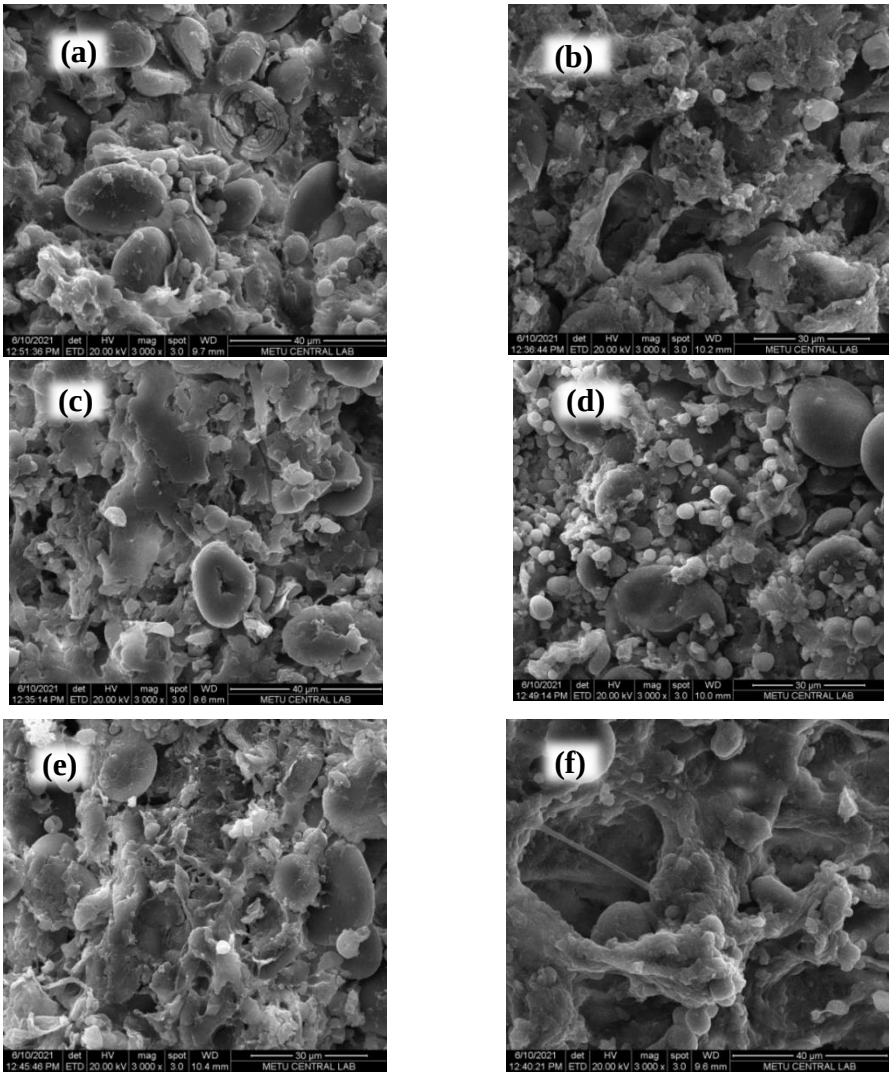


Figure A. 1 Surface SEM micrographs(x3000) of wheat flour and cooked samples at 20 min of *in vitro* digestion: (a) wheat flour digested; (b) Steamed control sample (100˚C,2 min) digested; (c) steamed psyllium enriched sample digested (100˚C, 2 min); (d) roasted control sample digested (100˚C,2 min); (e) roasted control sample digested (250˚C,2 min); (f) roasted psyllium enriched sample digested(100˚C, 2min)

B. Differential Scanning Calorimeter (DSC) Thermograms

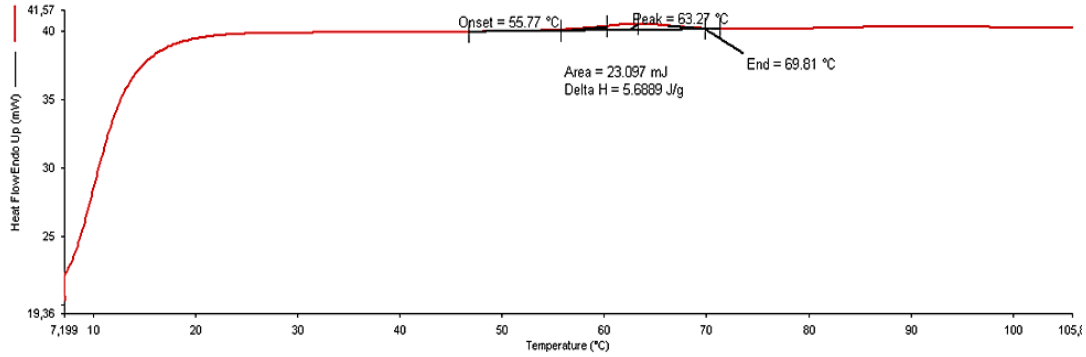


Figure B. 1 DSC thermogram of control dough sample

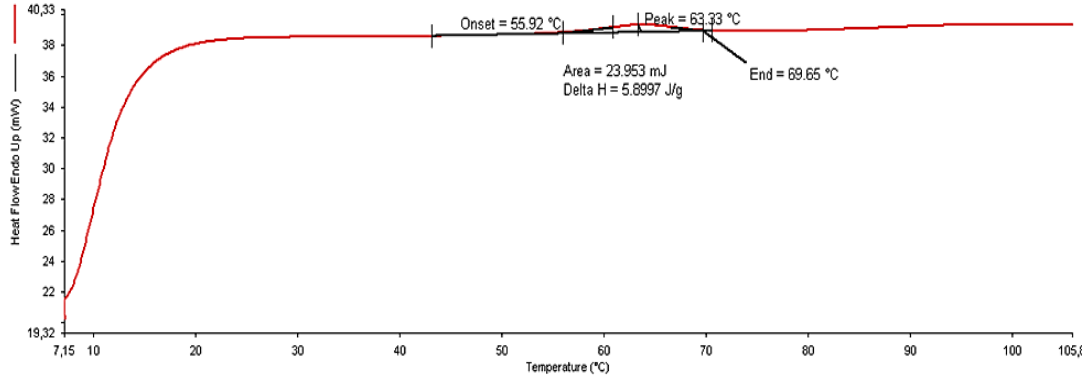


Figure B. 2 DSC thermogram of psyllium enriched dough sample

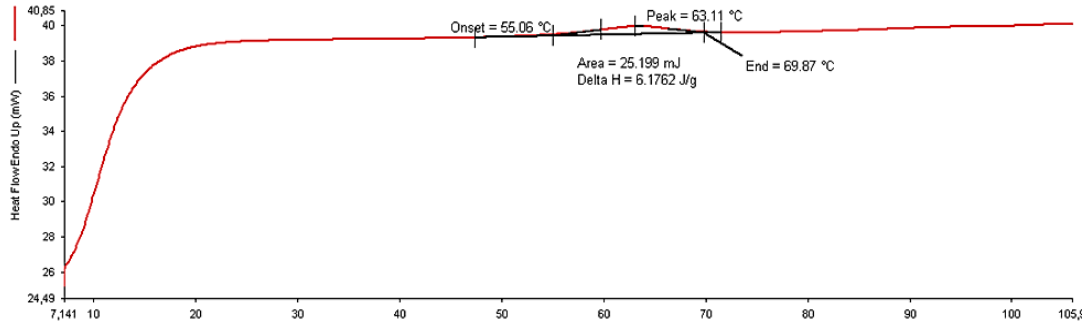


Figure B. 3 DSC thermogram of wheat flour

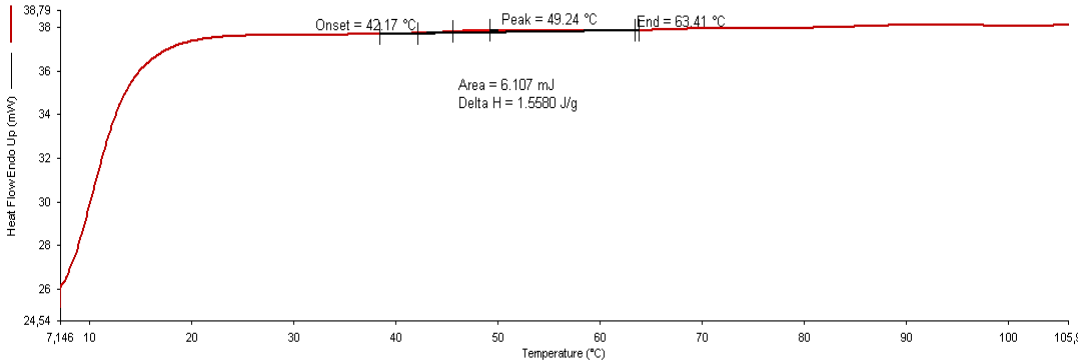


Figure B. 4 DSC thermogram of steamed control sample (2 min, 100 ˚C)

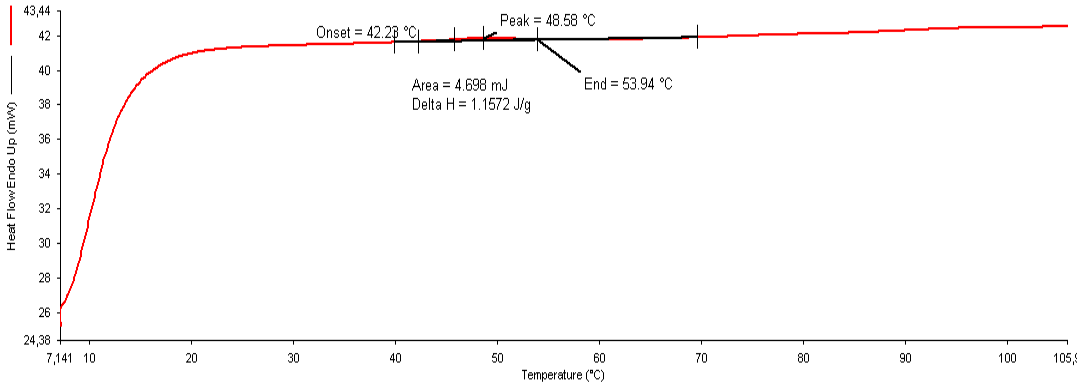


Figure B. 5 DSC thermogram of steamed control sample (10 min, 100 ˚C)

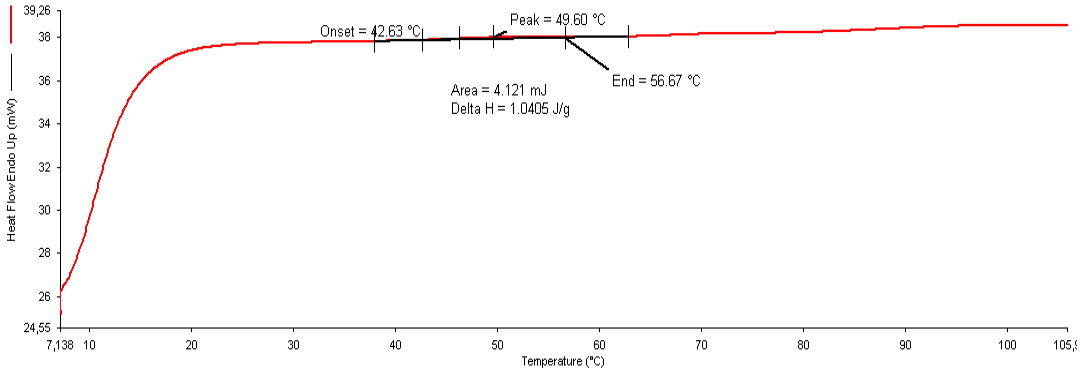


Figure B. 6 DSC thermogram of steamed psyllium enriched sample (2 min, 100 ˚C)

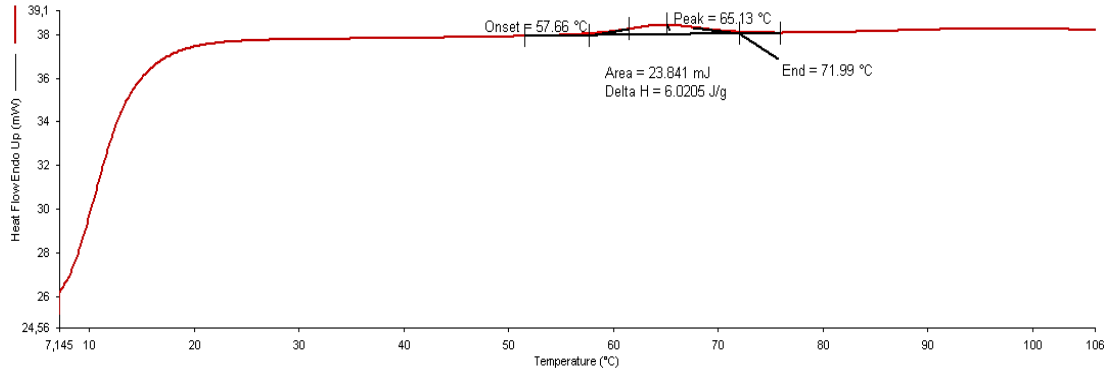


Figure B. 7 DSC thermogram of roasted control sample (2 min, 100 ˚C)

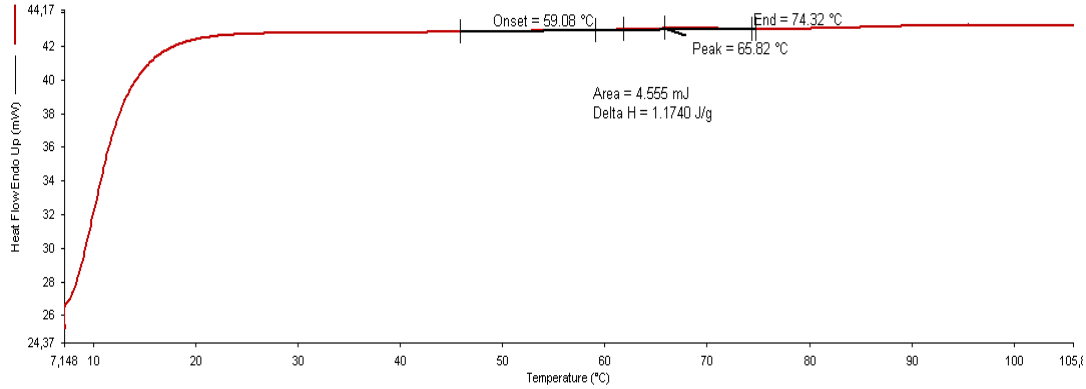


Figure B. 8 DSC thermogram of roasted control sample (2 min, 250 ˚C)

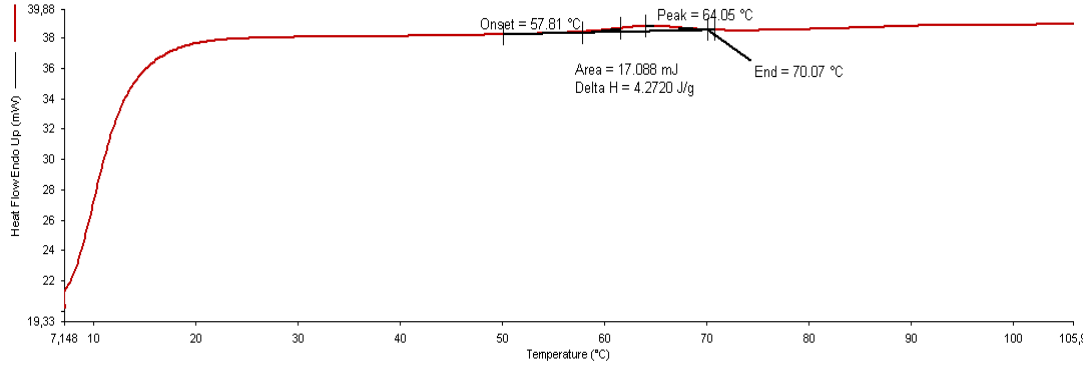


Figure B. 9 DSC thermogram of roasted psyllium enriched sample (2 min, 100 ˚C)

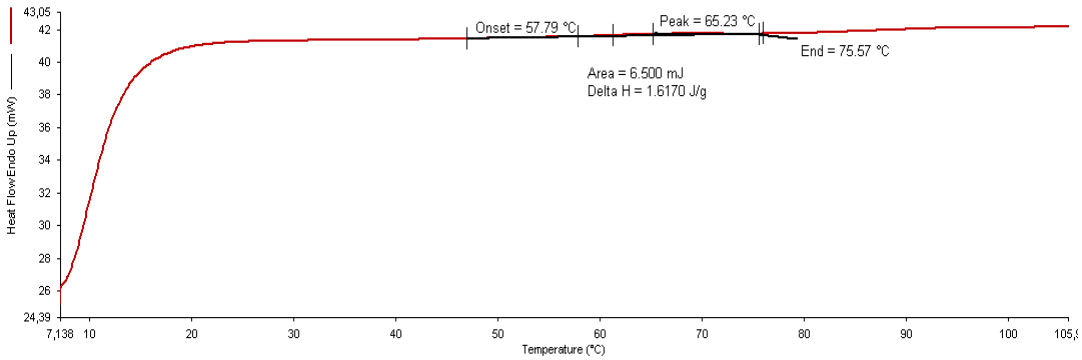


Figure B. 10 DSC thermogram of roasted psyllium enriched sample (2 min,250 ˚C)

C. Statistical Analysis

Table C. 1 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing moisture content of steamed and roasted samples

General Linear Model: Moisture Results versus Samples

Factor	Type	Levels	Values
Sample	Fixed	8	10% Psyllium Added Dough; Cotrol Dough Roasted 10% Psyllium (100˚C); Roasted 10% Psyllium (250˚C); Roasted Control (100˚C); Roasted Control (250˚C); Steamed 10% Psyllium(10 min); Steamed 10% Psyllium(2 min); Steamed Control(10 min); Steamed Control(2 min)

Analysis of Variance for Moisture

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Sample	9	2000.33	2000.33	222.6	70.16	0.000
Error	30	95.04	95.04	3.17		
Total	39	2095.37				

Model Summary

S = 1.77988 R-Sq = 95.46% R-Sq(adj) = 94.10%

Comparisions for Moisture Reults

Tukey Pairwise Comparisons:Samples

Grouping Information Using Tukey Method and 95,0% Confidence

Sample	N	Mean	Grouping
Steamed 10% Psyllium(10 min)	4	45.3	A
Steamed Control(10 min)	4	43.2	A
Steamed 10% Psyllium(2 min)	4	38.3	B
10%Psyllium Added Dough	4	35.7	BC
Steamed Control(2 min)	4	34.9	BC
Roasted 10% Psyllium (100˚C)	4	29.4	DE
Control Dough	4	32.6	CD
Roasted Control (100˚C)	4	28.2	E
Roasted 10% Psyllium (250˚C)	4	23.9	F
Roasted Control (250˚C)	4	23.5	F

Means that do not share a letter are significantly different.

Table C. 2 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing thermal properties of raw and cooked samples

General Linear Model: Thermal Properties versus Samples

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Sample	Fixed	10	Control Dough; 10% Psyllium Dough; Roasted Control(100˚C); Roasted Control (250˚C); Roasted 10% Psysllium(100˚C); Roasted 10%Psyllium(250˚C);Steamed Control(2 min); Steamed Control(10 min); Steamed 10% Psyllium (2 min); Steamed 10%Psyllium(10 min)

Analysis of Variance for T_{onset}

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Sample	9	1606.49	1606.49	178.50	516.43	0.000
Error	20	6.91	6.91	0.35		
Total	29	1613.41				

Model Summary
S = 0.587914 R-Sq = 99.57% R-Sq(adj) = 99.38%

Analysis of Variance for T_{peak}

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Sample	9	1610.83	1610.83	178.98	492.42	0.000
Error	20	7.27	7.27	0.36		
Total	29	1618.10				

Model Summary
S = 0.602886 R-Sq = 99.55% R-Sq(adj) = 99.35%

Analysis of Variance for T_{endset}

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Sample	9	1717.38	1717.38	190.82	182.29	0.000
Error	20	20.94	20.94	1.05		
Total	29	1678.20				

Model Summary
S = 1.02312 R-Sq = 98.80% R-Sq(adj) = 98.25%

Analysis of Variance for ΔH(J/DM)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Sample	9	162.127	162.127	18.014	76.62	0.000
Error	20	4.702	4.702	0.235		
Total	29	166.829				

Model Summary
S = 0.484885 R-Sq = 97.18% R-Sq(adj) = 95.91%

Analysis of Variance for ΔH(J/DWF)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Sample	9	177.868	177.868	19.763	71.62	0.000
Error	20	5.519	5.519	0.276		
Total	29	183.387				

Model Summary

S = 0.525311 R-Sq = 96.99% R-Sq(adj) = 95.64%

Comparisions for DSC Results

Tukey Pairwise Comparisons:Samples

Grouping Information Using Tukey Method and 95,0% Confidence for T_{onset}

Sample	N	Mean	Grouping
Roasted Control (250˚C)	3	59.4	A
Roasted 10%Psyllium(250˚C)	3	58.5	A B
Roasted 10% Psysllium(100˚C);	3	57.8	A B
Roasted Control(100˚C);	3	57.4	BC
Control Dough	3	55.5	CD
10% Psyllium Dough	3	56.1	D
Steamed Control(10 min)	3	42.7	E
Steamed Control(2 min);	3	43.2	E
Steamed 10% Psyllium (2 min)	3	42.6	E
Steamed 10%Psyllium(10 min)	3	42.2	E

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Samples

Grouping Information Using Tukey Method and 95,0% Confidence for T peak

Sample	N	Mean	Grouping
Roasted 10%Psyllium(250˚C)	3	66.3	A
Roasted Control (250˚C)	3	65.6	A B
Roasted Control(100˚C)	3	64.8	A B C
Roasted 10% Psysllium(100˚C)	3	64.3	B C
10% Psyllium Dough	3	63.8	C
Control Dough	3	63.1	C
Steamed Control(2 min)	3	50.5	D
Steamed 10%Psyllium(10 min)	3	49.7	D
Steamed 10% Psyllium (2 min)	3	49.7	D
Steamed Control(10 min)	3	49.3	D

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Samples

Grouping Information Using Tukey Method and 95,0% Confidence for T_{endse}

Sample	N	Mean	Grouping
Roasted 10%Psyllium(250˚C)	3	75.4	A
Roasted Control (250˚C)	3	75.0	AB
Roasted Control(100˚C)	3	72.1	BC
Roasted 10% Psysllium(100˚C)	3	70.9	C
10% Psyllium Dough	3	70,5	C
Control Dough	3	70.1	C
Steamed Control(2 min)	3	59.9	D
Steamed 10%Psyllium(10 min)	3	58.1	DE
Steamed 10% Psyllium (2 min)	3	56.2	E
Steamed Control(10 min)	3	55.5	E

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons:Samples
Grouping Information Using Tukey Method and 95,0% Confidence for ΔH(J/DM)

Sample	N	Mean	Grouping
10% Psyllium Dough	3	7.1	A
Control Dough	3	6.4	AB
Roasted Control(100˚C)	3	5.6	BC
Roasted 10% Psysllium(100˚C)	3	4.8	C
Steamed 10%Psyllium(10 min)	3	1.6	D
Roasted 10%Psyllium(250˚C)	3	1.7	D
Steamed Control(10 min)	3	1.5	D
Steamed Control(2 min)	3	1.3	D
Roasted Control (250˚C)	3	1.1	D
Steamed 10% Psyllium (2 min)	3	1.1	D

Means that do not share a letter are significantly different

Tukey Pairwise Comparisons:Samples
Grouping Information Using Tukey Method and 95,0% Confidence for ΔH(J/DWF)

Sample	N	Mean	Grouping
10% Psyllium Dough	3	7.2	A
Control Dough	3	7.1	AB
Roasted 10% Psysllium(100˚C)	3	5.3	BC
Roasted Control(100˚C)	3	5.6	C
Roasted 10%Psyllium(250˚C)	3	1.9	D
Steamed 10%Psyllium(10 min)	3	1.8	D
Steamed Control(2 min)	3	1.3	D
Steamed Control(10 min)	3	1.5	D
Roasted Control (250˚C)	3	1.1	D
Steamed 10% Psyllium (2 min)	3	1.2	D

Means that do not share a letter are significantly different.

Table C. 3 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/TS, SDS/TS, RS/TS) versus fiber in control and psyllium enriched samples steamed at 100 ˚C for 2 min

General Linear Model: Starch Type Ratio Results (RDS/TS, SDS/TS, RS/TS) versus Fiber

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Fiber	Fixed	2	Control; Fiber

Analysis of Variance for RDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	503,53	503,53	503,53	15,96	0,007
Error	6	189,28	189,28	31,55		
Total	7	692,81				

Model Summary

S = 5,61669 R-Sq = 72,68% R-Sq(adj) = 68,13%

Analysis of Variance for SDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	510,34	510,34	510,34	6,88	0,039
Error	6	445,36	445,36	74,23		
Total	7	955,69				

Model Summary

S = 8,61548 R-Sq = 53,40% R-Sq(adj) = 45,63%

Analysis of Variance for RS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	0,02	0,02	0,02	0,00	0,986
Error	6	384,15	384,15	64,03		
Total	7	384,18				

Model Summary

S = 8,00161 R-Sq = 0,01% R-Sq(adj) = 0,00%

Comparisons for Starch Type Ratios

Tukey Pairwise Comparisons: Fiber

Grouping Information Using Tukey Method and 95,0% Confidence for RDS/TS

Fiber	N	Mean	Grouping
Control	4	47.7	A
Fiber	4	31.9	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Fiber

Grouping Information Using Tukey Method and 95,0% Confidence for SDS/TS

Fiber	N	Mean	Grouping
Control	4	29.1	A
Fiber	4	45.1	B

Tukey Pairwise Comparisons: Fiber

Grouping Information Using Tukey Method and 95,0% Confidence for RS/TS

Fiber	N	Mean	Grouping
Fiber	4	23.1	A
Control	4	23.2	A

Table C. 4 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/TS, SDS/TS, RS/TS) versus fiber in control and psyllium enriched samples steamed at 100 ˚C for 10 min

General Linear Model: Starch Type Ratio Results (RDS/TS, SDS/TS, RS/TS) versus Fiber

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Fiber	Fixed	2	Control; Fiber

Analysis of Variance for RDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	665,16	665,16	665,16	27,63	0,002
Error	6	144,45	144,45	24,08		
Total	7	809,61				

Model Summary
S = 4,90668 R-Sq = 82,16% R-Sq(adj) = 79,18%

Analysis of Variance for SDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	81,80	81,80	81,80	0,93	0,373
Error	6	530,50	530,50	88,42		
Total	7	612,30				

Model Summary
S = 9,40298 R-Sq = 13,36% R-Sq(adj) = 0,00%

Analysis of Variance for RS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	280,44	280,44	280,44	4,30	0,083
Error	6	391,06	391,06	65,18		
Total	7	671,51				

Model Summary
S = 8,07326 R-Sq = 41,76% R-Sq(adj) = 32,06%

Comparisons for Starch Type Ratios
Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95,0% Confidence for RDS/TS

Fiber	N	Mean	Grouping
Control	4	53.2	A
Fiber	4	35.0	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95,0% Confidence for SDS/TS

Fiber	N	Mean	Grouping
Fiber	4	42.3	A
Control	4	35.9	B

Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95,0% Confidence for RS/TS

Fiber	N	Mean	Grouping
Fiber	4	22.7	A
Control	4	10.9	A

Table C. 5 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/TS, SDS/TS, RS/TS) versus time in control samples steamed at 100 ˚C

General Linear Model: Starch Type Ratio (RDS/TS, SDS/TS, RS/TS) versus Time

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Time	Fixed	2	Time (2 min); Time (10 min)

Analysis of Variance for RDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Time	1	59.20	59.20	59.20	1.50	0.266
Error	6	236.51	236.51	39.42		
Total	7	295.71				

Model Summary
S = 6.27836 R-Sq = 20.02% R-Sq(adj) = 6.69%

Analysis of Variance for SDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Time	1	94.01	94.01	94.01	4.14	0.088
Error	6	136.40	136.40	22.73		
Total	7	230.41				

Model Summary
S = 4.76794 R-Sq = 40.80% R-Sq(adj) = 30.93%

Analysis of Variance for RS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Time	1	302.41	302.41	302,41	9.77	0.020
Error	6	185.69	185.69	30.95		
Total	7	488.10				

Model Summary
S = 5.56312 R-Sq = 61.96% R-Sq(adj) = 55.62%

Comparisons for Starch Type Ratio Results

Tukey Pairwise Comparisons: Time
Grouping Information Using Tukey Method and 95,0% Confidence for RDS/TS

Time	N	Mean	Grouping
Time(10 min)	4	53.2	A
Time(2 min)	4	47.7	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Time
Grouping Information Using Tukey Method and 95,0% Confidence for SDS/TS

Time	N	Mean	Grouping
Time(10 min)	4	35.9	A
Time(2 min)	4	29.1	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Time
Grouping Information Using Tukey Method and 95,0% Confidence for RS/TS

Time	N	Mean	Grouping
Time(2 min)	8	23.2	A
Time(10 min)	8	10.9	B

Means that do not share a letter are significantly different.

Table C. 6 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/TS, SDS/TS, RS/TS) versus time in psyllium enriched samples steamed at 100 ˚C

General Linear Model: Starch Type Ratio (RDS/TS, SDS/TS, RS/TS) versus Time

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Time	Fixed	2	Time (2 min); Time (10 min)

Analysis of Variance for RDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Time	1	18.86	18.86	18.86	1.16	0.322
Error	6	97.23	97.23	16.20		
Total	7	116.09				

Model Summary
S = 4.02553 R-Sq = 16.25% R-Sq(adj) = 2.29%

Analysis of Variance for SDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Time	1	14.8	14.8	14.8	0.11	0.756

Error	6	839.5	839.5	139.9
Total	7	854.3		

Model Summary

S = 11.8283 R-Sq = 1.74% R-Sq(adj) = 0.00%

Analysis of Variance for RS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Time	1	0.24	0.24	0.24	0.00	0.962
Error	6	589.53	589.53	98.25		
Total	7	589.77				

Model Summary

S = 9.91236 R-Sq = 0.04% R-Sq(adj) = 0.00%

Comparisons for Starch Type Ratio Results

Tukey Pairwise Comparisons: Time

Grouping Information Using Tukey Method and 95.0% Confidence for RDS/TS

Time	N	Mean	Grouping
Time(10 min)	4	35.0	A
Time(2 min)	4	31.9	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Time

Grouping Information Using Tukey Method and 95.0% Confidence for SDS/TS

Time	N	Mean	Grouping
Time(10 min)	4	42.3	A
Time(2 min)	4	45.1	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Time

Grouping Information Using Tukey Method and 95.0% Confidence for RS/TS

Time	N	Mean	Grouping
Time(2 min)	4	23.1	A
Time(10 min)	4	22.7	A

Means that do not share a letter are significantly different.

Table C. 7 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DM, SDS/DM, RS/DM) versus fiber in control and psyllium enriched samples steamed at 100 ˚C, 2 min.

General Linear Model: Starch Type Ratios Reults (RDS/DM, SDS/DM, RS/DM) versus Time,Fiber

Method

Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Fiber	Fixed	2	Control; Fiber

Analysis of Variance for RDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	503.32	503.32	503.32	17.55	0.006
Error	6	172.08	172.08	28.68		
Total	7	675.41				

Model Summary

S = 5.35540 R-Sq = 74.52% R-Sq(adj) = 70.28%

Analysis of Variance for SDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	162.21	162.21	162.21	5.62	0.055
Error	6	173.11	173.11	28.85		
Total	7	335.32				

Model Summary

S = 5.37145 R-Sq = 48.37% R-Sq(adj) = 39.77%

Analysis of Variance for RS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	10.64	10.64	10.64	0.14	0.722
Error	6	459.53	459.53	76.59		
Total	7	470.18				

Model Summary

S = 8.75151 R-Sq = 2.26% R-Sq(adj) = 0.00%

Comparisons for Starch Type Ratio Results

Tukey Pairwise Comparisons: Fiber

Grouping Information Using Tukey Method and 95.0% Confidence for RDS/DM

Fiber	N	Mean	Grouping
Control	4	40.2	A
Fiber	4	24.3	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Fiber

Grouping Information Using Tukey Method and 95.0% Confidence for SDS/DM

Fiber	N	Mean	Grouping
Fiber	4	33.5	A
Control	4	24.5	A

Means that do not share a letter are significantly different.

.**Tukey Pairwise Comparisons: Fiber**

Grouping Information Using Tukey Method and 95.0% Confidence for RS/DM

Fiber	N	Mean	Grouping
Control	4	20.2	A
Fiber	4	17.9	A

Means that do not share a letter are significantly different.

Table C. 8 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DM, SDS/DM, RS/DM) versus fiber in control and psyllium enriched samples steamed at 100 ˚C, 10 min.

General Linear Model: Starch Type Ratios Reults (RDS/DM, SDS/DM, RS/DM) versus Fiber

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Fiber	Fixed	2	Control; Fiber

Analysis of Variance for RDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	630.16	630.16	630.16	21.78	0.003
Error	6	173.59	173.59	28.93		
Total	7	803.75				

Model Summary
S = 5.37879 R-Sq = 78.40% R-Sq(adj) = 74.80%

Analysis of Variance for SDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	0.59	0.59	0.59	0.02	0.901
Error	6	210.75	210.75	35.12		
Total	7	211.34				

Model Summary
S = 5.92662 R-Sq = 0.28% R-Sq(adj) = 0.00%

Analysis of Variance for RS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	10.64	10.64	10.64	0.14	0.722
Error	6	459.53	459.53	76.59		
Total	7	470.18				

Model Summary
S = 6.95150 R-Sq = 28.19% R-Sq(adj) = 16.22%

Comparisons for Starch Type Ratio Results
Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for RDS/DM

Fiber	N	Mean	Grouping
Control	4	42.9	A
Fiber	4	25.2	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for SDS/DM

Fiber	N	Mean	Grouping
Fiber	4	29.7	A
Control	4	29.1	A

Means that do not share a letter are significantly different.

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Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for RS/DM

Fiber	N	Mean	Grouping
Fiber	4	16.5	A
Control	4	9.0	A

Means that do not share a letter are significantly different.

Table C. 9 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DM, SDS/DM, RS/DM) versus time in control samples steamed at 100 ˚C

General Linear Model: Starch Type Ratio (RDS/DM, SDS/DM, RS/DM) versus Time

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Time	Fixed	2	Time (2 min); Time (10 min)

Analysis of Variance for RDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Time	1	15.23	15.23	15.23	0.65	0.452
Error	6	141.50	141.50	23.58		
Total	7	156.73				

Model Summary
S = 4.85632 R-Sq = 9.71% R-Sq(adj) = 0.00%

Analysis of Variance for SDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Time	1	43.21	43.21	43.21	2.28	0.182
Error	6	113.74	113.74	18.96		
Total	7	156.95				

Model Summary
S = 2.10019 R-Sq = 94.32% R-Sq(adj) = 93.37%

Analysis of Variance for RS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Time	1	250.32	250.32	250.32	5.66	0.055
Error	6	265.37	265.37	44.23		
Total	7	515.70				

Model Summary

S = 6.65047 R-Sq = 48.54% R-Sq(adj) = 39.96%

Comparisons for Starch Type Ratio Results

Tukey Pairwise Comparisons: Time

Grouping Information Using Tukey Method and 95.0% Confidence for RDS/DM

Time	N	Mean	Grouping
Time(10 min)	4	42.9	A
Time(2 min)	4	40.2	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Time

Grouping Information Using Tukey Method and 95.0% Confidence for SDS/DM

Time	N	Mean	Grouping
Time(10 min)	4	29.1	A
Time(2 min)	4	24.5	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Time

Grouping Information Using Tukey Method and 95.0% Confidence for RS/DM

Time	N	Mean	Grouping
Time(2 min)	4	20.2	A
Time(10 min)	4	9.0	A

Means that do not share a letter are significantly different.

Table C. 10 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DM, SDS/DM, RS/DM) versus time in psyllium enriched samples steamed at 100 ˚C

General Linear Model: Starch Type Ratio (RDS/DM, SDS/DM, RS/DM) versus Time

Method

Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Time	Fixed	2	Time (2 min); Time (10 min)

Analysis of Variance for RDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Time	1	1.52	1.52	1.52	0.04	0.839

Error	6	204.17	204.17	34.03
Total	7	205.69		

Model Summary

S = 5.83334 R-Sq = 0.74% R-Sq(adj) = 0.00%

Analysis of Variance for SDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Time	1	29.12	29.12	29.12	0.65	0.452
Error	6	270.12	270.12	45.02		
Total	7	299.24				

Model Summary

S = 6.70973 R-Sq = 9.73% R-Sq(adj) = 0.00%

Analysis of Variance for RS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Time	1	3.58	3.58	3.58	0.04	0.840
Error	6	484.10	484.10	80.68		
Total	7	487.68				

Model Summary

S = 8.98241 R-Sq = 0.73% R-Sq(adj) = 0.00%

Comparisons for Starch Type Ratio Results

Tukey Pairwise Comparisons: Time

Grouping Information Using Tukey Method and 95.0% Confidence for RDS/DM

Time	N	Mean	Grouping
Time(10 min)	4	25.2	A
Time(2 min)	4	24.3	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Time

Grouping Information Using Tukey Method and 95.0% Confidence for SDS/DM

Time	N	Mean	Grouping
Time(2 min)	4	33.5	A
Time(10 min)	4	29.7	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Time

Grouping Information Using Tukey Method and 95.0% Confidence for RS/DM

Time	N	Mean	Grouping
Time(2 min)	4	17.9	A
Time(10 min)	4	16.5	A

Means that do not share a letter are significantly different.

Table C. 11 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DWF, SDS/DWF, RS/DWF) versus fiber in control and psyllium enriched samples steamed at 100 ˚C, 2 min.

General Linear Model: Starch Type Ratios Reults (RDS/DWF, SDS/DWF, RS/DWF) versus Fiber

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Fiber	Fixed	2	Control; Fiber

Analysis of Variance for RDS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	336.85	336.85	336.85	10.53	0.018
Error	6	191.93	191.93	31.99		
Total	7	528.79				

Model Summary
S = 5.65587 R-Sq = 63.70% R-Sq(adj) = 57.65%

Analysis of Variance for SDS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	336.99	336.99	336.99	10.30	0.018
Error	6	196.26	196.26	32.71		
Total	7	533.25				

Model Summary
S = 5.71926 R-Sq = 63.20% R-Sq(adj) = 57.06%

Analysis of Variance for RS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	0.07	0.07	0.07	0.00	0.979
Error	6	524.99	524.99	87.50		
Total	7	525.05				

Model Summary
S = 9.35401 R-Sq = 0.01% R-Sq(adj) = 0.00%

Comparisons for Starch Type Ratio Results
Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for RDS/DWF

Fiber	N	Mean	Grouping
Control	4	40.2	A
Fiber	4	27.2	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for SDS/DWF

Fiber	N	Mean	Grouping
Fiber	4	37.5	A
Control	4	24.5	B

Means that do not share a letter are significantly different.

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Tukey Pairwise Comparisons: Fiber

Grouping Information Using Tukey Method and 95.0% Confidence for RS/DWF

Fiber	N	Mean	Grouping
Control	4	20.2	A
Fiber	4	20.0	A

Means that do not share a letter are significantly different.

Table C. 12 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DWF, SDS/DWF, RS/DWF) versus fiber in control and psyllium enriched samples steamed at 100 ˚C, 10 min.

General Linear Model: Starch Type Ratios Reults (RDS/DWF, SDS/DWF, RS/DWF) versus Fiber

Method

Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Fiber	Fixed	2	Control; Fiber

Analysis of Variance for RDS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	463,96	463,96	463,96	13,93	0,010
Error	6	199,88	199,88	33,31		
Total	7	663,84				

Model Summary

S = 5,77176 R-Sq = 69,89% R-Sq(adj) = 64,87%

Analysis of Variance for SDS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	24,65	24,65	24,65	0,60	0,469
Error	6	248,14	248,14	41,36		
Total	7	272,79				

Model Summary

S = 6,43090 R-Sq = 9,04% R-Sq(adj) = 0,00%

Analysis of Variance for RS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	169,19	169,19	169,19	3,01	0,133
Error	6	336,92	336,92	56,15		
Total	7	506,11				

Model Summary
S = 7,49356 R-Sq = 33,43% R-Sq(adj) = 22,33%

Comparisons for Starch Type Ratio Results
Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95,0% Confidence for RDS/DWF

Fiber	N	Mean	Grouping
Control	4	42.9	A
Fiber	4	27.7	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95,0% Confidence for SDS/DWF

Fiber	N	Mean	Grouping
Fiber	4	32.7	A
Control	4	29.1	A

Means that do not share a letter are significantly different.
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Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95,0% Confidence for RS/DWF

Fiber	N	Mean	Grouping
Fiber	4	18.2	A
Control	4	9.0	A

Means that do not share a letter are significantly different.

Table C. 13 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DWF, SDS/DWF, RS/DWF) versus time in control samples steamed at 100 ˚C.

General Linear Model: Starch Type Ratio (RDS/DM, SDS/DM, RS/DM) versus Time

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Time	Fixed	2	Time (2 min); Time (10 min)

Analysis of Variance for RDS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Time	1	15.23	15.23	15.23	0.65	0.452
Error	6	141.50	141.50	23.58		
Total	7	156.73				

Model Summary
S = 4.85632 R-Sq = 9.71% R-Sq(adj) = 0.00

Analysis of Variance for SDS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Time	1	43.21	43.21	43.21	2.28	0.182
Error	6	113.74	113.74	18.96		
Total	7	156.95				

Model Summary

S = 4.35394 R-Sq = 27.53% R-Sq(adj) = 15.45%

Analysis of Variance for RS/WF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Time	1	250.32	250.32	250.32	5.66	0.055
Error	6	265.37	265.37	44.23		
Total	7	515.70				

Model Summary

S = 6.65047 R-Sq = 48.54% R-Sq(adj) = 39.96%

Comparisons for Starch Type Ratio Results

Tukey Pairwise Comparisons: Time

Grouping Information Using Tukey Method and 95.0% Confidence for RDS/DWF

Time	N	Mean	Grouping
Time(10 min)	4	42.9	A
Time(2 min)	4	40.2	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Time

Grouping Information Using Tukey Method and 95.0% Confidence for SDS/DWF

Time	N	Mean	Grouping
Time10 min)	4	29.1	A
Time(2 min)	4	24.5	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Time

Grouping Information Using Tukey Method and 95.0% Confidence for RS/ DWF

Time	N	Mean	Grouping
Time(2 min)	4	20.2	A
Time(10 min)	4	9.0	A

Means that do not share a letter are significantly different.

Table C. 14 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DWF, SDS/DWF, RS/DWF) versus time in psyllium enriched samples steamed at 100 ˚C.

General Linear Model: Starch Type Ratio (RDS/DM, SDS/DM, RS/DM) versus Time

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Time	Fixed	2	Time (2 min); Time (10 min)

Analysis of Variance for RDS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Time	1	0.51	0.51	0.51	0.01	0.915
Error	6	250.31	250.31	41.72		
Total	7	250.82				

Model Summary
S = 6.45896 R-Sq = 0.20% R-Sq(adj) = 0.00%

Analysis of Variance for SDS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Time	1	46.50	46.50	46.50	0.84	0.394
Error	6	330.66	330.66	55.11		
Total	7	377.16				

Model Summary
S = 7.42359 R-Sq = 12.33% R-Sq(adj) = 0.00%

Analysis of Variance for RS/WF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Time	1	6.51	6.51	6.51	0.07	0.807
Error	6	596.53	596.53	99.42		
Total	7	603.05				

Model Summary
S = 9.97108 R-Sq = 1.08% R-Sq(adj) = 0.00%

Comparisons for Starch Type Ratio Results
Tukey Pairwise Comparisons: Time
Grouping Information Using Tukey Method and 95.0% Confidence for RDS/DWF

Time	N	Mean	Grouping
Time(10 min)	4	27.7	A
Time(2 min)	4	27.2	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Time
Grouping Information Using Tukey Method and 95.0% Confidence for SDS/DWF

Time	N	Mean	Grouping
Time(2 min)	4	37.5	A
Time(10 min)	4	32.5	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Time
Grouping Information Using Tukey Method and 95.0% Confidence for RS/ DWF

Time	N	Mean	Grouping
Time(2 min)	4	20.0	A
Time(10 min)	4	18.2	A

Means that do not share a letter are significantly different.

Table C. 15 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/TS, SDS/TS, RS/TS) versus fiber in control and psyllium enriched samples roasted at100˚C, 2 min

General Linear Model: Starch Type Ratio Results (RDS/TS, SDS/TS, RS/TS) versus Fiber

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Fiber	Fixed	2	Control; Fiber

Analysis of Variance for RDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	991.80	991.80	991.80	29.96	0.002
Error	6	198.65	198.65	33.11		
Total	7	1190.45				

Model Summary

S = 5.75398 R-Sq = 83.31% R-Sq(adj) = 80.53%

Analysis of Variance for SDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	710.71	710.71	710.71	24.93	0.002
Error	6	171.03	171.03	28.51		
Total	7	881.74				

Model Summary
S = 5.33903 R-Sq = 80.60% R-Sq(adj) = 77.37%

Analysis of Variance for RS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	23.36	23.36	23.36	0.80	0.407
Error	6	176.19	176.19	29.37		
Total	7	199.56				

Model Summary

S = 5.41900 R-Sq = 11.71% R-Sq(adj) = 0.00%

Comparisons for Starch Type Ratios
Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for RDS/TS

Fiber	N	Mean	Grouping
Control	4	39.3	A
Fiber	4	17.1	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for SDS/TS

Fiber	N	Mean	Grouping
Fiber	4	56.1	A
Control	4	37.2	B

Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for RS/TS

Fiber	N	Mean	Grouping
Fiber	4	26.9	A
Control	4	23.4	A

Table C. 16 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/TS, SDS/TS, RS/TS) versus fiber in control and psyllium enriched samples roasted at 250˚C, 2 min

General Linear Model: Starch Type Ratio Results (RDS/TS, SDS/TS, RS/TS) versus Fiber

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Fiber	Fixed	2	Control; Fiber

Analysis of Variance for RDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	690.14	690.14	690.14	17.10	0.006
Error	6	242.11	242.11	40.35		
Total	7	932.25				

Model Summary
S = 6.35227 R-Sq = 74.03% R-Sq(adj) = 69.70%

Analysis of Variance for SDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	790.6	790.6	790.6	4.98	0.067
Error	6	952.1	952.1	158.7		
Total	7	1742.8				

Model Summary

S = 12.5972 R-Sq = 45.37% R-Sq(adj) = 36.26%

Analysis of Variance for RS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	3.4	3.4	3.4	0.02	0.882
Error	6	851.0	851.0	141.8		
Total	7	854.4				

Model Summary

S = 11.9095 R-Sq = 0.40% R-Sq(adj) = 0.00%

Comparisons for Starch Type Ratios

Tukey Pairwise Comparisons: Fiber

Grouping Information Using Tukey Method and 95.0% Confidence for RDS/TS

Fiber	N	Mean	Grouping
Control	4	44.6	A
Fiber	4	26.0	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Fiber

Grouping Information Using Tukey Method and 95.0% Confidence for SDS/TS

Fiber	N	Mean	Grouping
Fiber	4	46.2	A
Control	4	26.3	A

Tukey Pairwise Comparisons: Fiber

Grouping Information Using Tukey Method and 95.0% Confidence for RS/TS

Fiber	N	Mean	Grouping
Control	4	29.1	A
Fiber	4	27.8	A

Table C. 17 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/TS, SDS/TS, RS/TS) versus temperature in control samples roasted for 2 min

General Linear Model: Starch Type Ratio Results (RDS/TS, SDS/TS, RS/TS) versus Temperature

Method

Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values

Temperature	Fixed	2	Temperature (100˚C); Temperature (250˚C)

Analysis of Variance for RDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temperature	1	55.10	55.10	55.10	0.80	0.406
Error	6	414.77	414.77	69.13		
Total	7	469.87				

Model Summary

S = 8.31434 R-Sq = 11.73% R-Sq(adj) = 0.00%

Analysis of Variance for SDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temperature	1	237.45	237.45	237.45	2.69	0.152
Error	6	529.14	529.14	88.19		
Total	7	766.59				

Model Summary

S = 9.39095 R-Sq = 30.97% R-Sq(adj) = 19.47%

Analysis of Variance for RS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temperature	1	63.79	63.79	63.79	1.86	0.221
Error	6	205.30	205.30	34.22		
Total	7	269.09				

Model Summary

S = 5.84950 R-Sq = 23.70% R-Sq(adj) = 10.99%

Comparisons for Starch Type Ratios

Tukey Pairwise Comparisons: Temperature

Grouping Information Using Tukey Method and 95.0% Confidence for RDS/TS

Temperature	N	Mean	Grouping
Temperature(250˚C)	4	44.6	A
Temperature(100˚C)	4	39.3	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Fiber

Grouping Information Using Tukey Method and 95.0% Confidence for SDS/TS

Temperature	N	Mean	Grouping
Temperature(100˚C)	4	37.2	A
Temperature(250˚C)	4	26.3	A

Tukey Pairwise Comparisons: Fiber

Grouping Information Using Tukey Method and 95.0% Confidence for RS/TS

Temperature	N	Mean	Grouping
Temperature(250˚C)	4	29.1	A
Temperature(100˚C)	4	23.4	A

Table C. 18 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/TS, SDS/TS, RS/TS) versus temperature in psyllium enriched samples roasted for 2 min

General Linear Model: Starch Type Ratio Results (RDS/TS, SDS/TS, RS/TS) versus Temperature

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Temperature	Fixed	2	Temperature (100˚C); Temperature (250˚C)

Analysis of Variance for RDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temperature	1	159.90	159.90	159.90	36.92	0.001
Error	6	25.99	25.99	4.33		
Total	7	185.89				

Model Summary
S = 2.08120 R-Sq = 86.02% R-Sq(adj) = 83.69%

Analysis of Variance for SDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temperature	1	194.61	194.61	194.61	1.97	0.210
Error	6	594.03	594.03	99.01		
Total	7	788.64				

Model Summary
S = 9.95013 R-Sq = 24.68% R-Sq(adj) = 12.12%

Analysis of Variance for RS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temperature	1	1.7	1.7	1.7	0.01	0.915
Error	6	821.9	821.9	137.0		
Total	7	823.6				

Model Summary
S = 11.7041 R-Sq = 0.21% R-Sq(adj) = 0.00%

Comparisons for Starch Type Ratios
Tukey Pairwise Comparisons: Temperature
Grouping Information Using Tukey Method and 95.0% Confidence for RDS/TS

Temperature	N	Mean	Grouping
Temperature(250˚C)	4	26.0	A
Temperature(100˚C)	4	17.1	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Temperature
Grouping Information Using Tukey Method and 95.0% Confidence for SDS/TS

Temperature	N	Mean	Grouping
Temperature(100˚C)	4	56.1	A
Temperature(250˚C)	4	46.2	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Temperature
Grouping Information Using Tukey Method and 95.0% Confidence for RS/TS

Temperature	N	Mean	Grouping
Temperature(250˚C)	4	27.8	A
Temperature(100˚C)	4	26.9	A

Means that do not share a letter are significantly different.

Table C. 19 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DM, SDS/DM, RS/DM) versus fiber in control and psyllium enriched samples roasted at 100 ˚C, 2 min

General Linear Model:Starch Type Ratio Results(RDS/DM, SDS/DM, RS/DM) versus Fiber

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Fiber	Fixed	2	Control; Fiber

Analysis of Variance for RDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	808.62	808.62	808.62	26.13	0.002
Error	6	185.68	185.68	30.95		
Total	7	994.29				

Model Summary
S = 5.56291 R-Sq = 81.33% R-Sq(adj) = 78.21%

Analysis of Variance for SDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	89.14	89.14	89.14	1.09	0.336
Error	6	489.83	489.83	81.64		
Total	7	578.97				

Model Summary
S = 9.03538 R-Sq = 15.40% R-Sq(adj) = 1.30%

Analysis of Variance for RS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	4.05	4.05	4.05	0.22	0.655
Error	6	109.91	109.91	18.32		
Total	7	113.96				

Model Summary
S = 4.27993 R-Sq = 3.56% R-Sq(adj) = 0.00%

Comparisons for Starch Type Ratio Results
Tukey Pairwise Comparisons:Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for RDS/DM

Grouping Information Using Tukey Method and 95.0% Confidence for RDS/DM

Fiber	N	Mean	Grouping
Control	4	31.0	A
Fiber	4	10.8	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons:Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for SDS/DM

Fiber	N	Mean	Grouping
Fiber	4	35.9	A
Control	4	29.3	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons:Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for RS/DM

Fiber	N	Mean	Grouping
Control	4	18.3	A
Fiber	4	16.9	A

Means that do not share a letter are significantly different.

Table C. 20 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DM, SDS/DM, RS/DM) versus fiber in control and psyllium enriched samples roasted at 250 ˚C, 2 min

General Linear Model:Starch Type Ratio Results(RDS/DM, SDS/DM, RS/DM) versus Fiber

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Fiber	Fixed	2	Control; Fiber

Analysis of Variance for RDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	764.40	764.40	764.40	20.47	0.004
Error	6	224.01	224.01	37.34		
Total	7	988.41				

Model Summary
S = 6.11024 R-Sq = 77.34% R-Sq(adj) = 73.56%

Analysis of Variance for SDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	129.62	129.62	129.62	1.33	0.293
Error	6	585.16	585.16	97.53		
Total	7	714.78				

Model Summary

S = 9.87555 R-Sq = 18.13% R-Sq(adj) = 4.49%

Analysis of Variance for RS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	51.85	51.85	51.85	0.65	0.450
Error	6	475.71	475.71	79.28		
Total	7	527.55				

Model Summary

S = 8.90420 R-Sq = 9.83% R-Sq(adj) = 0.00%

Comparisons for Starch Type Ratio Results

Tukey Pairwise Comparisons:Fiber

Grouping Information Using Tukey Method and 95.0% Confidence for RDS/DM

Grouping Information Using Tukey Method and 95.0% Confidence for RDS/DM

Fiber	N	Mean	Grouping
Control	4	36.5	A
Fiber	4	17.0	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons:Fiber

Grouping Information Using Tukey Method and 95.0% Confidence for SDS/DM

Fiber	N	Mean	Grouping
Fiber	4	29.9	A
Control	4	21.9	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons:Fiber

Grouping Information Using Tukey Method and 95.0% Confidence for RS/DM

Fiber	N	Mean	Grouping
Control	4	23.5	A
Fiber	4	18.4	A

Means that do not share a letter are significantly different.

Table C. 21 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DM, SDS/DM, RS/DM) versus temperature in control roasted for 2 min

General Linear Model: Starch Type Ratio Results (RDS/DM, SDS/DM, RS/DM) versus Temperature

Method

Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Temperature	Fixed	2	Temperature (100˚C); Temperature (250˚C)

Analysis of Variance for RDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temperature	1	62.17	62.17	62.17	1.05	0.344
Error	6	353.86	353.86	58.98		
Total	7	416.03				

Model Summary

S = 7.67958 R-Sq = 14.94% R-Sq(adj) = 0.77%

Analysis of Variance for SDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temperature	1	108.92	108.92	108.92	1.64	0.248
Error	6	398.72	398.72	66.45		
Total	7	507.64				

Model Summary

S = 8.15188 R-Sq = 21.46% R-Sq(adj) = 8.37%

Analysis of Variance for RS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temperature	1	53.74	53.74	53.74	4.21	0.086
Error	6	76.53	76.53	12.75		
Total	7	130.26				

Model Summary

S = 3.57139 R-Sq = 41.25% R-Sq(adj) = 31.46%

Comparisons for Starch Type Ratios

Tukey Pairwise Comparisons: Temperature

Grouping Information Using Tukey Method and 95.0% Confidence for RDS/DM

Temperature	N	Mean	Grouping
Temperature(250˚C)	4	36.5	A
Temperature(100˚C)	4	31.0	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Fiber

Grouping Information Using Tukey Method and 95.0% Confidence for SDS/DM

Temperature	N	Mean	Grouping
Temperature(100˚C)	4	29.3	A
Temperature(250˚C)	4	21.9	A

Tukey Pairwise Comparisons: Fiber

Grouping Information Using Tukey Method and 95.0% Confidence for RS/DM

Temperature	N	Mean	Grouping
Temperature(250˚C)	4	23.5	A
Temperature(100˚C)	4	18.3	A

Table C. 22 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DM, SDS/DM, RS/DM) versus temperature in psyllium enriched samples roasted for 2 min

General Linear Model: Starch Type Ratio Results (RDS/DM, SDS/DM, RS/DM) versus Temperature

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Temperature	Fixed	2	Temperature (100˚C); Temperature (250˚C)

Analysis of Variance for RDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temperature	1	75.224	75.224	75.224	8.08	0.029
Error	6	55.830	55.830	9.305		
Total	7	131.055				

Model Summary
S = 7.67958 R-Sq = 14.94% R-Sq(adj) = 0.77%

Analysis of Variance for SDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temp	1	72.1	72.1	72.1	0.64	0.454
Error	6	676.3	676.3	112.7		
Total	7	748.4				

Model Summary
S = 10.6166 R-Sq = 9.64% R-Sq(adj) = 0.00%

Analysis of Variance for RS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temperature	1	4.60	4.60	4.60	0.05	0.824
Error	6	509.09	509.09	84.85		
Total	7	513.68				

Model Summary
S = 9.21129 R-Sq = 0.89% R-Sq(adj) = 0.00%

Comparisons for Starch Type Ratios
Tukey Pairwise Comparisons: Temperature
Grouping Information Using Tukey Method and 95.0% Confidence for RDS/DM

Temperature	N	Mean	Grouping
Temperature(250˚C)	4	17.0	A
Temperature(100˚C)	4	10.8	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for SDS/DM

Temperature	N	Mean	Grouping
Temperature(100˚C)	4	35.9	A
Temperature(250˚C)	4	29.9	A

Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for RS/DM

Temperature	N	Mean	Grouping
Temperature(250˚C)	4	18.4	A
Temperature(100˚C)	4	16.9	A

Table C.23. ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DWF, SDS/DWF, RS/DWF) versus fiber in control and psyllium enriched samples roasted at 100 C, 2 min

General Linear Model: Starch Type Ratio Results (RDS/DWF, SDS/DWF, RS/DWF) versus Temperature; Fiber

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Fiber	Fixed	2	Control; Fiber

Analysis of Variance for RDS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	701.39	701.39	701.39	21.83	0.003
Error	6	192.75	192.75	32.12		
Total	7	894.14				

Model Summary
S = 5.66789 R-Sq = 78.44% R-Sq(adj) = 74.85%

Analysis of Variance for SDS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	253.1	253.1	253.1	2.49	0.165
Error	6	609.3	609.3	101.6		
Total	7	862.4				

Model Summary
S = 10.0775 R-Sq = 29.35% R-Sq(adj) = 17.57%

Analysis of Variance for RS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	1.07	1.07	1.07	0.05	0.832
Error	6	130.23	130.23	21.71		

Total 7 131.30

Model Summary
S = 4.65894 R-Sq = 0.81% R-Sq(adj) = 0.00%

Comparisons for Starch Type Ratio Results
Tukey Pairwise Comparisons:Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for RDS/DWF

Fiber	N	Mean	Grouping
Control	4	31.0	A
Fiber	4	12.2	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons:Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for SDS/DWF

Fiber	N	Mean	Grouping
Fiber	4	40.5	A
Control	4	29.3	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for RS/DWF

Fiber	N	Mean	Grouping
Fiber	4	19.1	A
Control	4	18.3	A

Means that do not share a letter are significantly different.

Table C. 24 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DWF, SDS/DWF, RS/DWF) versus fiber in control and psyllium enriched samples roasted at 250 ˚C, 2 min

General Linear Model: Starch Type Ratio Results (RDS/DWF, SDS/DWF, RS/DWF) versus Temperature; Fiber

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Fiber	Fixed	2	Control; Fiber

Analysis of Variance for RDS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	617.33	617.33	617.33	16.01	0.007
Error	6	231.34	231.34	38.56		
Total	7	848.68				

Model Summary
S = 6.20947 R-Sq = 72.74% R-Sq(adj) = 68.20%

Analysis of Variance for SDS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	266.4	266.4	266.4	2.49	0.166
Error	6	643.2	643.2	107.2		
Total	7	909.6				

Model Summary
S = 10.3534 R-Sq = 29.29% R-Sq(adj) = 17.51%

Analysis of Variance for RS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Fiber	1	17.29	17.29	17.29	0.18	0.688
Error	6	582.88	582.88	97.15		
Total	7	600.17				

Model Summary
S = 9.85634 R-Sq = 2.88% R-Sq(adj) = 0.00%

Comparisons for Starch Type Ratio Results
Tukey Pairwise Comparisons:Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for RDS/DWF

Fiber	N	Mean	Grouping
Control	4	36.5	A
Fiber	4	19.0	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons:Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for SDS/DWF

Fiber	N	Mean	Grouping
Fiber	4	33.4	A
Control	4	21.9	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for RS/DWF

Fiber	N	Mean	Grouping
Control	4	23.5	A
Fiber	4	20.6	A

Means that do not share a letter are significantly different.

Table C. 25 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DWF, SDS/DWF, RS/DWF) versus temperature in control samples roasted for 2 min

General Linear Model: Starch Type Ratio Results (RDS/DWF, SDS/DWF, RS/DWF) versus Temperature

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Temperature	Fixed	2	Temperature (100˚C); Temperature (250˚C)

Analysis of Variance for RDS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temperature	1	62.17	62.17	62.17	1.05	0.344
Error	6	353.86	353.86	58.98		
Total	7	416.03				

Model Summary
S = 7.67958 R-Sq = 14.94% R-Sq(adj) = 0.77%

Analysis of Variance for SDS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temperature	1	108.92	108.92	108.92	1.64	0.248
Error	6	398.72	398.72	66.45		
Total	7	507.64				

Model Summary
S = 8.15188 R-Sq = 21.46% R-Sq(adj) = 8.37%

Analysis of Variance for RS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temperature	1	53.74	53.74	53.74	4.21	0.086
Error	6	76.53	76.53	12.75		
Total	7	130.26				

Model Summary
S = 3.57139 R-Sq = 41.25% R-Sq(adj) = 31.46%

Comparisons for Starch Type Ratios
Tukey Pairwise Comparisons: Temperature
Grouping Information Using Tukey Method and 95.0% Confidence for RDS/DWF

Temperature	N	Mean	Grouping
Temperature(250˚C)	4	36.5	A
Temperature(100˚C)	4	31.0	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for SDS/DWF

Temperature	N	Mean	Grouping
Temperature(100˚C)	4	29.3	A
Temperature(250˚C)	4	21.9	A

Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for RS/DWF

Temperature	N	Mean	Grouping
Temperature(250˚C)	4	23.5	A
Temperature(100˚C)	4	18.3	A

Table C. 26 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DWF, SDS/DWF, RS/DWF) versus temperature in psyllium enriched samples roasted for 2 min

General Linear Model: Starch Type Ratio Results (RDS/DWF, SDS/DWF, RS/DWF) versus Temperature

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Temperature	Fixed	2	Temperature (100˚C); Temperature (250˚C)

Analysis of Variance for RDS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temperature	1	90.68	90.68	90.68	7.75	0.032
Error	6	70.24	70.24	11.71		
Total	7	160.91				

Model Summary
S = 3.42148 R-Sq = 56.35% R-Sq(adj) = 49.08%

Analysis of Variance for SDS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temperature	1	100.5	100.5	100.5	0.71	0.433
Error	6	853.8	853.8	142.3		
Total	7	954.2				

Model Summary
S = 11.9288 R-Sq = 10.53% R-Sq(adj) = 0.00%

Analysis of Variance for RS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Temperature	1	4.6	4.6	4.6	0.04	0.842
Error	6	636.6	636.6	106.1		

Total	7	641.2

Model Summary
S = 10.3004 R-Sq = 0.71% R-Sq(adj) = 0.00%

Comparisons for Starch Type Ratios
Tukey Pairwise Comparisons: Temperature
Grouping Information Using Tukey Method and 95.0% Confidence for RDS/DWF

Temperature	N	Mean	Grouping
Temperature(250˚C)	4	19.0	A
Temperature(100˚C)	4	12.2	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for SDS/DWF

Temperature	N	Mean	Grouping
Temperature(100˚C)	4	40.5	A
Temperature(250˚C)	4	33.4	A

Tukey Pairwise Comparisons: Fiber
Grouping Information Using Tukey Method and 95.0% Confidence for RS/DWF

Temperature	N	Mean	Grouping
Temperature(250˚C)	4	20.6	A
Temperature(100˚C)	4	19.1	A

Table C. 27 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/TS, SDS/TS, RS/TS) of roasted and steamed control samples (100˚C, 2 min)

General Linear Model: Glucose Release Rate Results (RDS/TS, SDS/TS , RS/TS) versus Process

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Process	Fixed	2	Roasted; Steamed

Analysis of Variance for RDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Process	1	141.80	141.80	141.80	2.35	0.176
Error	6	361.47	361.47	60.24		
Total	7	503.27				

Model Summary
S = 7.76175 R-Sq = 28.18% R-Sq(adj) = 16.20%

Analysis of Variance for SDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Process	1	132.32	132.32	132.32	4.53	0.077
Error	6	175.18	175.18	29.20		
Total	7	307.50				

Model Summary

S = 5.40344 R-Sq = 43.03% R-Sq(adj) = 33.54%

Analysis of Variance for RS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Process	1	0.16	0.16	0.16	0.01	0.944
Error	6	181.19	181.19	30.20		
Total	7	181.36				

Model Summary

S = 5.49534 R-Sq = 0.09% R-Sq(adj) = 0.00%

Tukey Pairwise Comparisons: Process
Grouping Information Using Tukey Method and 95.0% Confidence for RDS/TS

Process	N	Mean	Grouping
Steamed	4	47.7	A
Roasted	4	39.3	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Process
Grouping Information Using Tukey Method and 95.0% Confidence for SDS/TS

Process	N	Mean	Grouping
Roasted	4	37.2	A
Steamed	4	29.1	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Process
Grouping Information Using Tukey Method and 95.0% Confidence for RS/TS

Process	N	Mean	Grouping
Roasted	4	23.4	A
Steamed	4	23.2	A

Means that do not share a letter are significantly different.

Table C. 28 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DM, SDS/DM, RS/DM) of roasted and steamed control samples (100˚C, 2 min)

General Linear Model: Glucose Release Rate Results (RDS/DM, SDS/DM , RS/DM) versus Process

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Process	Fixed	2	Roasted; Steamed

Analysis of Variance for RDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Process	1	170.52	170.52	170.52	4.05	0.091
Error	6	252.66	252.66	42.11		
Total	7	423.18				

Model Summary
S = 6.48916 R-Sq = 40.30% R-Sq(adj) = 30.34%

Analysis of Variance for SDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Process	1	45.37	45.37	45.37	2.10	0.197
Error	6	129.49	129.49	21.58		
Total	7	174.85				

Model Summary
S = 4.64554 R-Sq = 25.94% R-Sq(adj) = 13.60%

Analysis of Variance for RS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Process	1	6.77	6.77	6.77	0.17	0.692
Error	6	233.98	233.98	39.00		
Total	7	240.74				

Model Summary
S = 6.24468 R-Sq = 2.81% R-Sq(adj) = 0.00%

Tukey Pairwise Comparisons: Process
Grouping Information Using Tukey Method and 95.0% Confidence for RDS/DM

Process	N	Mean	Grouping
Steamed	4	40.2	A
Roasted	4	31.0	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Process
Grouping Information Using Tukey Method and 95.0% Confidence for SDS/DM

Process	N	Mean	Grouping
Roasted	4	29.3	A

Steamed 4 24.5 A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Process
Grouping Information Using Tukey Method and 95.0% Confidence for RS/DM

Process	N	Mean	Grouping
Roasted	4	20.2	A
Steamed	4	18.3	A

Means that do not share a letter are significantly different.

Table C. 29 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DWF, SDS/DWF, RS/DWF) of roasted and steamed control samples (100˚C, 2 min)

General Linear Model: Starch Type Ratio Results(RDS/DWF, SDS/DWF, RS/DWF) versus Process

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Process	Fixed	2	Roasted; Steamed

Analysis of Variance for RDS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Process	1	170.52	170.52	170.52	4.05	0.091
Error	6	252.66	252.66	42.11		
Total	7	423.18				

Model Summary
S = 6.48916 R-Sq = 40.30% R-Sq(adj) = 30.34%

Analysis of Variance for SDS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Process	1	45.37	45.37	45.37	2.10	0.197
Error	6	129.49	129.49	21.58		
Total	7	174.85				

Model Summary
S = 4.64554 R-Sq = 25.94% R-Sq(adj) = 13.60

Analysis of Variance for RS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Process	1	6.77	6.77	6.77	0.17	0.692

Error	6	233.98	233.98	39.00
Total	7	240.74		

Model Summary

S = 6.24468 R-Sq = 2.81% R-Sq(adj) = 0.00%

Comparisions for Starch Type Ratio Results

Tukey Pairwise Comparisons: Process

Grouping Information Using Tukey Method and 95.0% Confidence for RDS/DWF

Process	N	Mean	Grouping
Steaming	4	40.2	A
Roasting	4	31.0	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Process

Grouping Information Using Tukey Method and 95.0% Confidence for SDS/DWF

Process	N	Mean	Grouping
Roasting	4	29.3	A
Steaming	4	24.5	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Process

Grouping Information Using Tukey Method and 95.0% Confidence for RS/DWF

Process	N	Mean	Grouping
Steaming	4	20.2	A
Roasting	4	18.3	A

Means that do not share a letter are significantly different.

Table C. 30 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/TS, SDS/TS, RS/TS) of roasted and steamed psyllium enriched samples (100˚C, 2 min)

General Linear Model:Starch Type Ratio Results(RDS/TS, SDS/TS, RS/TS) versus Process

Method

Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Process	Fixed	2	Roasted; Steamed

Analysis of Variance for RDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P

Process	1	439.38	439.38	439.38	99.61	0.000
Error	6	26.46	26.46	4.41		
Total	7	465.84				

Model Summary

S = 2.10019 R-Sq = 94.23% R-Sq(adj) = 93.37%

Analysis of Variance for SDS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Process	1	242,47	242,47	242,47	3,30	0,119
Error	6	441,21	441,21	73,53		
Total	7	683,68				

Model Summary

S = 8,57523 R-Sq = 35,47% R-Sq(adj) = 24,71%

Analysis of Variance for RS/TS

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Process	1	29,05	29,05	29,05	0,46	0,523
Error	6	379,16	379,16	63,19		
Total	7	408,21				

Model Summary

S = 7,94937 R-Sq = 7,12% R-Sq(adj) = 0,00%

Comparisions for Starch Type Ratio Results

Tukey Pairwise Comparisons: Process

Grouping Information Using Tukey Method and 95,0% Confidence for RDS/TS

Process	N	Mean	Grouping
Steamed	4	31.9	A
Roasted	4	17.1	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Process

Grouping Information Using Tukey Method and 95,0% Confidence for SDS/TS

Process	N	Mean	Grouping
Roasted	4	56.1	A
Steamed	4	45.1	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Process

Grouping Information Using Tukey Method and 95,0% Confidence for RS/TS

Process	N	Mean	Grouping
Roasted	4	26.9	A
Steamed	4	23.1	A

Means that do not share a letter are significantly different.

Table C. 31 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DM, SDS/DM, RS/DM) of roasted and steamed psyllium enriched samples (100˚C, 2 min)

General Linear Model:Starch Type Ratio Results(RDS/DM, SDS/DM, RS/DM) versus Process

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Process	Fixed	2	Roasting; Steaming

Analysis of Variance for RDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Process	1	363.27	363.27	363.27	20.74	0.004
Error	6	105.10	105.10	17.52		
Total	7	468.37				

Model Summary
S = 4.18533 R-Sq = 77.56% R-Sq(adj) = 73.82%

Analysis of Variance for SDS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Process	1	11.84	11.84	11.84	0.13	0.728
Error	6	533.46	533.46	88.91		
Total	7	545.29				

Model Summary
S =9.42919 R-Sq = 2.17% R-Sq(adj) = 0.00%

Analysis of Variance for RS/DM

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Process	1	1.83	1.83	1.83	0.03	0.862
Error	6	335.46	335.46	55.91		
Total	7	337.29				

Model Summary
S =7.47735 R-Sq = 0.54% R-Sq(adj) = 0.00%

Comparisions for Starch Type Ratio Results
Tukey Pairwise Comparisons: Process
Grouping Information Using Tukey Method and 95,0% Confidence for RDS/DM

Process	N	Mean	Grouping
Steaming	4	24.3	A
Roasting	4	10.8	B

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Process

Grouping Information Using Tukey Method and 95,0% Confidence for SDS/DM

Process	N	Mean	Grouping
Roasting	4	35.9	A
Steaming	4	33.5	A

Means that do not share a letter are significantly different.

Tukey Pairwise Comparisons: Process
Grouping Information Using Tukey Method and 95,0% Confidence for RS/DM

Process	N	Mean	Grouping
Steaming	4	17.9	A
Roasting	4	16.9	A

Means that do not share a letter are significantly different.

Table C. 32 ANOVA and Tukey's Comparison Test with 95% confidence level for comparing starch type ratio results (RDS/DWF, SDS/DWF, RS/DWF) of roasted and steamed psyllium enriched samples (100˚C, 2 min)

General Linear Model: Starch Type Ratio Results(RDS/DWF, SDS/DWF, RS/DWF) versus Process

Method
Factor Coding (-1,0,+1)

Factor Information

Factor	Type	Levels	Values
Process	Fixed	2	Roasting; Steaming

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Process	1	448.96	448.96	448.96	20.40	0.004
Error	6	132.03	132.03	22.00		
Total	7	580.99				

Model Summary
S = 4.69090 R-Sq = 77.28% R-Sq(adj) = 73.49%

Analysis of Variance for SDS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Process	1	18.4	18.4	18.4	0.16	0.700
Error	6	676.1	676.1	112.7		
Total	7	694.5				

Model Summary
S = 10.6153 R-Sq = 2.65% R-Sq(adj) = 0.00%

Analysis of Variance for RS/DWF

Source	DF	Seq SS	Adj SS	Adj MS	F	P

Process	1	1.71	1.71	1.71	0.02	0.881
Error	6	421.24	421.24	70.21		
Total	7	422.95				

Model Summary

S = 8.37898 R-Sq = 0.40% R-Sq(adj) = 0.00%

Comparisions for Starch Type Ratio Results

Tukey Pairwise Comparisons: Process

Grouping Information Using Tukey Method and 95,0% Confidence for RDS/DWF

Process	N	Mean	Grouping
Steaming	4	27.2	A
Roasting	4	12.2	B

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence for SDS/DWF

Process	N	Mean	Grouping
Roasting	4	40.5	A
Steaming	4	37.5	A

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence for RS/DWF

Process	N	Mean	Grouping
Steaming	4	20.0	A
Roasting	4	19.1	A

Means that do not share a letter are significantly different.