Texture and consistency in oatmeal: A study on the effects of plant-based proteins

A dissertation
submitted in partial fulfilment
of the requirements for the Degree
of Master of Science in Food
Innovation

at
Lincoln University
by
Kelvin Kurniawan

Lincoln University
2024

Abstract of a Dissertation submitted in partial fulfilment of the requirements for the Degree of Master of Science in Food Innovation.

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Oatmeal is a very popular breakfast cereal all over the world. Oatmeal is known for its practicality as well as its health benefits. This fast and nutritious breakfast meal can provide high carbohydrate and dietary fiber such as β-glucan, which can reduce LDL cholesterol. However, it is also known that plant-based foods such as oatmeal has low protein content. This study investigated the rheological and textural changes on oat paste when fortified with five different plant proteins such as fava bean, mung bean, pea protein, chickpea, and green lentil in order to boost its nutritional value. The study of this particular topic is very important for food developers since having a better understanding of starch-protein interaction will allow food developers to modify the rheological properties and to improve the organoleptic quality of various food products better, so that they can be more appealing and satisfying to consumers. In this experiment, oat flour was combined with different plant proteins and distilled water, then the mixture was put into a waterbath for 30 minutes at 95 °C. The textural analysis showed that the addition of some plant proteins such as mung bean and pea protein can increase the firmness, consistency, and cohesiveness; while the addition of chickpea and green lentil can decrease those factors. When exposed to increasing shear rate, the oat-protein mixture can maintain its viscosity better than the oatmeal alone. However, the addition of plant protein to oat paste in rising temperature can make the oatmeal more vulnarable to shear rate, which resulted to a decreased in viscosity. Meanwhile, the dynamic rheology tests such as amplitude sweep test and frequency test showed the crossover point in which the mixture turn from visoelastic solid to viscoelastic liquid and the rheological stability of the mixture in an increasing angular frequency range. Furthermore, the findings from this study can be used as a reference for food developers to expand the application of plant-based proteins in oatmeal or any oat-based/starch-based food products.

Keywords: Oatmeal, oatflour, plant proteins, rheology, texture, viscosity, temperature sweep

Acknowledgements

I am eternally grateful to Dr Lokesh Kumar for his endless support in the completion of this dissertation. I am thankful for all the guidance he has provided every step of the way, and for doing so with ever-lasting patience.

I would like to thank Annu Mehta for her help in data collection and rheometer learning.

I am also appreciative to every other lab technician, lecturer, and staff member who assisted me throughout this journey.

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Introduction and Literature Review

1.1 Introduction

In recent years, consumers are increasingly aware about health and sustainability. Driven by dramatic increase in lifestyle pace, climate change, and diseases, consumers of the present generation are looking for food products that provide nutritional benefits and produced in a sustainable manner (Prabha et al., 2021). With these changes, consumers are starting to look for alternative food sources since animal-based products are environmentally harmful and considered as unsustainable food sources. Moreover, there are also several ethical dilemmas regarding the care and the consumption of these animals, and the products made from them (De Bakker and Dagevos, 2012; Hampton et al., 2021). Therefore, consuming plant-based foods has increased in popularity and become a great alternative. Oat (*Avena sativa*) is a cereal grain that widely consumed around the world. Oat grain is usually crushed into oatmeal or ground into oat flour. Then, oat flour can be used to make several food products such as oatcakes, oatmeal cookies, oat bread, muesli and also granola (Clifton & Keogh, 2016). Oatmeal is also considered a popular breakfast meal among young, adult, and elderly people due to its easy-to-chew texture, convenience, nutritional benefits, and also extended shelf life. Oat is very popular due to its high carbohydrate content and dietary fiber content. β-glucan, which is a soluble fiber that can reduce low density lipoprotein (LDL) cholesterol, which is very beneficial for health also can be found in oats. However, it is known that plant-based foods have less digestibility and incomplete amino acids composition compared to animal-based foods, including oats. In fact, oat only contain 11 – 15 % of protein, which is very insufficient (Rasane et al., 2013). It also lacks of several necessary amino acids to balance the daily nutritional needs of the expanding and ageing society (Mahgoub et al., 2020). Therefore, there has been an increasing interest in boosting oatmeal protein content by incorporating various proteins to it. Fortifying oat flour with plant proteins such as mung bean, chickpea, fava bean, green lentil, and pea protein is one of many ways to boost its nutritional value, especially its protein content. Plant proteins can be used to enrich oat flour due to the fact that they have a high protein content ranging from 20 – 40%, enhance its digestibility, and are also considered to have great potential to deliver desirable textural properties to food products due to the starch-protein interaction (Ge et al., 2021; Zhang et al., 2021). In fact, the interaction of protein and starch are responsible for the overall texture and structural stability of the food product (Shao et al., 2023). This means that this interaction is playing a significant role in determining the physical properties as well as sensory characteristics resulting from protein-starch interactions in the food system (Ge et al., 2023). Understanding the interaction between these two macromolecules is very essential since it will allow food developers to modify the rheological properties and to improve the organoleptic quality of various food products, so that they can be more appealing and satisfying to consumers. The protein-starch interaction involves both covalent and non-covalent interactions such as hydrogen bonds, disulfide bonds, and hydrophobic interactions, which then lead to crosslink and a gel network formation between these two macromolecules (Zhang et al., 2021). There are lots of studies conducted to investigate the rheological and textural properties changes due to the interaction of common starch sources (wheat, corn, rice, potato, sorghum, tapioca, etc.) with various animal proteins. However, the studies on oat starch and their interactions are relatively rare. This study aims to investigate the changes in rheological and textural properties of oatmeal with the addition of various plant proteins. Rheological properties of the oatmeal added with various plant proteins are going to be measured for its flow behaviour and viscosity/shear stress by using rheometer. Calculation using Herschel–Bulkley or power law also needs to be done in order to understand the rheological equation resulted from the changes occurred during the test. As an addition, temperature sweep test is also conducted with this test in order to understand the change of flow behaviour when the mixture is heated up. Amplitude-sweep and frequency-sweep tests are also done to provide the information about the mixture's deformation resistance under large forces and allow the identification of viscoelastic solids, liquids, or gels (Stachnik, 2022). Lastly, the hardness of the mixture, which defined as the peak force observed during the compression cycle is going to be measured by back extrusion test in a texture analyser.

1.2 Literature Review

1.2.1 Oat flour

Oat flour can be made by grinding oatmeal and sifting out the fine material. Most commonly, oat flour is eaten as porridge for infant foods or as ready-to-eat cereals, and can also be used as thickener in many commercial food products. When combined with heat and water, oat flour become a viscous slurry. This can happen due to the starch content in the oat flour, and this process is called starch gelatinization. Starch gelatinization is the process where starch and water are subjected to heat. When starch is heated in water, water will be absorbed in the amorphous space of starch, then granules will swell and water is gradually absorbed in an irreversible manner. This process resulted in the leaching of amylose from the starch granule structure into the surrounding water, which will thicken the liquid and gives the system a viscous and transparent texture (Ratnayake & Jackson, 2006). The viscosity resulted from starch gelatinization in oat-based breakfast cereals is very important because consumers tend to have different preferences regarding the viscosity of the cereal they consume. Some consumers prefer thinner slurries while others prefer more viscous slurries. This is why the understanding of oat flour and starch rheology and texture is very important for food developers in order to develop breakfast cereal products according to consumers' preference.

1.2.2 Oat flour and starch rheology

Rheology is a study conducted in order to characterize the viscous, viscoelastic, and elastic properties of different materials by studying how external forces such as shear stress, shear strain, shear rate and difference in temperature can influence them. The viscoelastic behaviour of starch is usually measured by oscillatory tests. Parameters such as storage modulus (G'), loss modulus (G''), and loss factor (tan δ) are often done to describe the rheological properties of starch suspension. Storage modulus (G") represents the elastic component and loss modulus (G'') represents viscous component, while loss factor (tan δ) is measured as the ratio between G" and G' which is used to describe the material (Yoo et al., 2012). The author also added that if tan δ close to zero it means that most of the overall complex modulus is due to an elastic contribution. It means that the product is more of a solid than a liquid. However, if tan δ is 90 degrees (>1), the material is a perfect viscous body in which there exists a phase difference at a given shear strain. As is widely known, oat flour contains 60% of starch, which means that starch is a key macromolecule responsible for the thickness, body, and texture of oat-based products. Based on studies, it can be concluded that the starch granular properties are the major factors responsible for starch rheological behaviour, followed by the degree of amylose leaching during the gelatinization process, especially in high concentration system (Bao & Bergman, 2004). Furthermore, the molecular weight and structure of β-glucan can also affect the viscosity of the starch paste; the higher the content of oat β-glucan (native flour), the higher the viscosity levels (Lazaridou & Biliaderis, 2007). The ratio of amylose and amylopectin in oat starch is about 25% and 75% respectively, which means that oat starch is considered a high-amylopectin starch (Berggren, 2017). Oat starch also offers untypical properties such as small size of granules, well developed granule surface and high lipid content (Berski et al., 2011). According to Hoover & Vasanthan (1992), oat starches have different physicochemical properties compared to other cereal starches. Their study showed that oat starches showed higher swelling factor, decreased amylose leaching, co-leaching of a branched starch component and amylose during pasting process, higher peak viscosity and set back, low gel rigidity, greater susceptibility towards acid hydrolysis, greater resistance to α-amylase action and high free-thaw stability. Due to this unique pasting property, the gelatinization of oat starch can occur in short processing time during commercial production since it requires less time to attain peak viscosity and less pasting temperature. However, it is important to note that the variation in amylose and amylopectin proportion among oat cultivars will also influence the pasting and rheological properties of oat starch in food system (Punia et al., 2020). Other than that, temperature also plays an important role in changing the rheological properties of starch. The gelatinization process of starch by heating can be put into four transition stages such as: starch suspension into sol, sol transition to gel, network destruction and network strengthening (Bao & Bergman, 2004). The author also stated that when the temperature rises, the storage modulus (G') and tan δ will increase slightly. This indicates that the amylose content has dissolved and the mixture has turned into a 'sol'. Then, when the temperature coincides with the onset temperature, G' and G" will increase to a maximum while the tan δ will decrease; this indicates that the amylose has constructed a three-dimensional gel network because of the strong interactions between the swollen starch particles. When the heating continues, G' will decrease and tan δ will increase; this indicates that the structure has been destroyed because of the melting crystalline regions that still remains inside the swollen starch granule. Other than that, the collapse of the gel structure can also be caused by the interaction between particles and network has been lost. However, after an inflection point, G' and G" values are still increasing simultaneously while the tan δ value is increasing even higher. The leaching of low molecular weight amylopectin content that interacts with the amylose matrix will strengthen the network and will increase the G' value as well. However, tan δ gets larger in this phase due to the fact that the dispersed phase turned softer due to the continuing dissolution of amylopectin (Bao & Bergman, 2004). In terms of gelatinization temperature, oat starch requires the lowest temperature (55 °C) to reach 50 percent gelatinization compared to any other cereal starches (Mavromichalis, 2022).

1.2. 3 Rheological properties of binary mixture of starch/protein

In food industry, the interaction between protein-starch is known to have effect to the rheological properties of the overall mixture by either decreasing or increasing the gel strength/rigidity. Recent studies have found that the presence of protein in starch suspension can inhibit the migration of water and the recrystallization of starch, which leads to a retardation of the retrogradation of the gelatinized starch (Zhao et al., 2022). This means that the addition of protein can decrease gel strength by reducing the availability of water needed for starch to swell and leach amylose when the proportion of starch in the gels are higher than proportion of protein (Joshi et al., 2014). Furthermore, if the starch has a higher gelatinization temperature and the protein gels first, diffusion and network formation by the starch amylose is hindered and the starch instead acts mainly as a filler material, resulting in decreased gel strength as well (Johansson et al., 2022). In contrast, the rigidity/gel strength of high-amylopectin starch gel is going to be increased when protein is added since the protein will act as a filler in this case (Onwulata et al., 2013). For example, recent studies have showed that the addition of some types of plant proteins such as mung bean and chickpea to starch paste can potentially reduce the gel strength by increasing the pasting temperature while decreasing the peak viscosity and peak viscosity temperature. This will also create a shear thinning behaviour characterized by decreased viscosity with increasing shear rate (Tan et al., 2006). Furthermore, chickpea addition will also increase water absorption and may resulted in paste with lower strength and inextensible texture (Mohammed et al., 2012). Meanwhile, the addition of fava bean can result in lower pasting viscosities, less firm gels and a more compact and less fibrous gel structure, with the starch appearing to aggregate into clusters when protein content in the fava bean starch-protein samples is higher (Nilsson et al., 2023). In contrast, recent studies have also found that the addition of other plant proteins such as pea protein and green lentils to a starch paste can promote a more compact structure during processing in high moisture. Amylopectin content in starch could also help to promote the formation of anisotropic structure and improve the fibrous degree of the extrudates when combined with pea protein (Chen et al., 2021). The addition of green lentils to starch is also claimed to be able to change the rheological behaviour of the mixture by increasing the hardness of the mixture and giving higher resistance to flow deformability of the paste (Atudorei et al., 2022). Some examples of rheological analysis of various starches with added plant proteins are summarized in Table 1. Below.

Table 1. The rheological analysis of various plant protein-starch mixtures

Flour/Starch Source	**Plant Protein Added**	**Rheological Analysis**	**Effect**	**Reference**
Carrageenan starch	Pea protein	Dynamic rheological analysis	Increased in elastic modulus and texture parameters is obtained at rapid cooling.	Nunes et al., 2006

Wheat starch	Mung bean	Thixotropic analysis (Hysteresis test)	Mixture exhibits thixotropic flow behaviour characterized by a viscosity that decreases with increasing shear rate, but does not return to its initial viscosity. The mixture has shear-thinning or pseudoplastic behaviour.	Tan et al., 2006
Fava bean starch	Fava bean	Flow behaviour, temperature sweep, oscillatory tests, and texture analysis	Pasting temperature increased and viscosity decreased as protein replaced starch. Gels became softer as protein replaced starch. Water binding and textural/rheological properties improved with starch content.	Nilsson et al., 2023
Rice starch	Green lentil	Rapid visco analyzer (RVA)	Decreasing trend in degree of gelatinization and higher resistance to flow deformability of the mixture.	Atudorei et al., 2022
Wheat flour	Chickpea	Consistograph	Water absorption, tolerance to mixing, consistency, dough extensibility, index of swelling, and loss factor (tan δ) for the temperature sweep test decreased with the increased level of chickpea addition.	Atudorei et al., 2022
Corn starch	Soy protein	Dynamic rheological analysis	Reduced water availability and raised the endothermic temperatures of cornstarch mixture	Li et al., 2007

			in the composites. Lowering G’ and increasing starch mass percentage.	

In terms of flow behaviour (steady state), most of the recent studies have found that incorporation of protein to starch paste can reduce its viscosity when shear rate is increased. However, since oat starch has higher amylopectin ratio, there is a high possibility that the final gel strength and viscosity will be much higher if compared to the control oat. This also means that the oat paste with added plant proteins will have an increased hardness when being measured by back extrusion test to investigate changes in the textural properties. The temperature sweep test of the oat paste with plant protein mixture is expected to have a reduced the gelatinization enthalpy, indicating that protein hindered the melting of crystals inside starch granules (Sun et al., 2023). In terms of dynamic rheological analysis, recent studies have shown that the addition of plant protein like mung bean to starch can potentially decrease in the storage modulus (G’) and loss modulus (G”) and an increase in the loss factor (tan δ), which means that the final mixture is expected to be less firm and have more viscoelastic liquid behaviour (Tarahi et al., 2022).

1.3 Plant Proteins

1.3.1 Pea protein

Pea *(Pisum sativum L.)* is known to be the most popular legume crops in the world by contributing to 26% of the total pulse production (Shen et al., 2022). Pea protein contains 20-25% of protein with lysine, threonine, and tryptophan as the major proteins, which makes it a good source of protein (Shen et al., 2022). The incorporation of pea protein to starch can potentially increase the pasting temperature, reduce viscosity, and increase the thermal stability of the mixture. Some reports also shown that the pea-starch mixture can lead to a greater increase in storage modulus (G’) and lower elongation-at-break values. However, these effects can be influence by other factors such as the type of starch, amylose to amylopectin ratio, rigidity, granular size, and etc (Farshi et al., 2024).

1.3.2 Mung bean

Mung bean *(Vigna radiata)* also known as the green gram is a member of legume family that contains high amount of minerals, vitamins and essential amino acids. It is reported that mung beans have about 21 – 31% protein content, and claimed to have twofold higher protein content than cereal maize and conventional root crops. Phenylalanine, tyrosine, leucine, lysine, and valine are the major essential amino acids that can be found in this legume (Yi-Shen et al., 2018). Due to its high protein content, mung bean can also be combined with oat flour in order to boost its protein content. The incorporation of mung bean to starch mixture is known to exhibited highest zero-shear viscosity and the largest hysteresis loop area at higher temperatures due to the forthcoming gelatinization of starch. This gelatinization reaction can give the mixture overly high viscosity for flow behaviour of the mixture (Tan et al., 2007).

1.3.3 Fava bean

Fava bean *(Vicia faba L)* is one of the oldest winter crops in Middle East. However, fava bean is also grown worldwide and has become a staple dietary protein source in several regions around the world (Maalouf et al., 2021). Even though it is not as popular as other grains, fava bean contains 23 – 36% of protein content and high in lysine, which is an essential amino acid in human and monogastric diets. Due to this fact, fava bean is considered as the most protein-rich major pulse crop in the world (Khazaei & Vandenberg, 2020). The combination of fava bean and oat can result in excellent amino acid composition (Ramos-Diaz et al., 2022). The fava-starch mixture is known to have a stronger and firmer gel network. The incorporation of this plant protein can also result in high final viscosity during pasting (Nilsson et al., 2023).

1.3.4 Green lentil

Green lentil *(Lens culinaris L)* is one of the oldest legumes that harvested and consumed by humans around the world. Lentils contain around 26% of protein. Lentils are rich in some non-essential amino acids such as arginine, aspartic and glutamic acids; however, lentils are deficit in some essential amino acids such as threonine, methionine, phenylalanine, and etc. (Khazaei et al., 2019). The incorporation of green lentil to starch mixture can potentially reducing the viscosity, lowering the firmness and setback but increasing surface stickiness (Wang et al., 2014).

1.3.5 Chickpea

Chickpeas *(Cicer arietinum L)* are one of the most important pulse crops in the world since they are rich in proteins, minerals, vitamins, and fibers that beneficial for health (Singh et al., 2021). Chickpea contains 19-27% of protein with arginine, aspartic acid and glutamic acid as the major amino acids. However, chickpea is deficit in some amino acids such as arginine, aspartic acid, methionine and cysteine (Begum et al., 2023). Incorporating chickpea to food has been proven to increase the nutritional value and to reduce acrylamide, which is an antinutritional substance present in several foods (Rachwa-Rosiak et al., 2015). The mixture of chickpea and starch can increase the firmness of the mixture due to the amylose content that has the ability to form junction zones, then quickly re-associate and reestablish intermolecular hydrogen bonds (Zhang et al., 2016). Additionally, Zhang et al. (2016) also claims that the addition of chickpea to starch mixture can also result in a sudden increase G' and G" values if compared to the starch-only mixture.

1.4 Aims and objectives

The aim of this study was to analyse changes in rheological and textural properties of oat paste fortified with five different plant proteins such as pea protein, mung bean, fava bean, green lentil, and chickpea.

- **Aim 1:**

Analyse the differences in basic textural parameters such as firmness, consistency, cohesiveness and index of viscosity of each oat sample.

- **Aim 2:**

Visualise and analyse the differences in flow behaviour/viscosity of each of the oat paste sample using power law model and Herschel Bulkley model.

- **Aim 3:**

Determine the deformation resistance and identify the viscoelastic properties of each of oat paste sample using dynamic rheology tests such as amplitude sweep test and frequency sweep test.

Chapter 2
Materials and Methods

2.1 Materials

Oat flour was purchased from GoodFor (Christchurch, New Zealand) and the Pure Pea protein isolate was acquired from Reactiv Supplements (Auckland, New Zealand). Then, mung bean, chickpea, fava bean, and green lentil protein were obtained from Green Boy Group (Los Angeles, California, United States). Pea protein contains 20.9 g of protein per serving, mung bean and chickpea contain 25 g of protein per serving, fava bean contains 27 g of protein per serving, and lastly green lentil contains 26 g of protein per serving.

2.2 Preparation of oat paste

Every test in this experiment used the same fresh samples that will be made in the very beginning of the day. The control oat paste will be made by mixing oat flour and water in a 1:10 ratio. The protein-oat paste (pea, mung bean, chickpea, fava bean, and green lentil) samples were prepared in a 1:4 protein-oat ratio. After that, the paste mixtures were cooked for 30 minutes in a water bath at 95°C, with constant stirring every 1 minute for 10 minutes, and then every 5 minutes for the remaining 20 minutes. In this experiment, in order to make 150 g of sample,10% of oat flour, 2.5% of plant protein were mixed with150 mL of distilled water. The control sample was made using the same measurement but without the addition of plant protein.

2.3 Textural properties analysis

Back extrusion test was conducted using a TA-XT2i Texture Analyzer (Stable Micro Systems Ltd, Surrey, UK) equipped with a Texture Expert software and a 5 kg load for measurement. The pastes were compressed at a constant crosshead speed of 1 mm/s to a distance of 20 mm with cylindrical plunger (p/5) for single compression cycle at room temperature (25°C). In this experiment, the firmness, consistency, cohesiveness and index of viscosity of each sample was recorded. Lastly, data were analysed using one-way ANOVA followed with Tukey’s test in order to assess the significant differences at $p \leq 0.05$.

2.4 Flow behavior/viscosity determination

All the rheological measurements were done in rheometer (MCR 302, Anton Paar, Austria). Anton Paar RheoCompass™ software was used to record and analyse data for the viscosity-shear rate and temperature sweep. Oat pastes viscosity measurements were conducted at different shear rates ranging from 0.1 to 100 s-1. A parallel plate geometry (PP50/SN) (d = 25 mm, gap= 0.00 mm) was used, and temperature was kept constant at 25 °C for this analysis. In this experiment, 35 g of sample was used and three replicates were measured for each sample. Then, all pastes viscosity were measured from 25°C to 50°C for the temperature ramp test. In this experiment, 35 g of sample was used and two replicates were measure for each sample. To predict and describe the flow curves of viscosity versus shear rate, Power Law model as can be seen in Equation 1 below and Herschel-Bulkley model as can be seen in Equation 2 below were used.

Equation 1: $\eta = \kappa\gamma^{n-1}$

Equation 2: $\tau = \tau 0 + \kappa * \gamma^{n}$

2.5 Dynamic rheology analysis

Amplitude sweep test was conducted in order to investigate the rheological stability/deformation resistance of the oat paste samples. This test was done to determine the LVER (Linear Viscoelastic Region) first through the application of increasing % strain value until “break” the macrostructure. An amplitude strain sweep test was performed at a constant angular frequency of 10 rad/s. The amplitude sweep test was performed at an increasing logarithmic rate from 10^{-2} % to 10^{3} % strain value. The storage modulus (G’), loss modulus (G’’) and loss tangent (tan δ = G’’/G’) were calculated as a function of strain at 10 rad/s. Meanwhile, in order to calculate the overall resistance to deformation, the complex modulus (G*) value was obtained by the γmax value, which is the maximum strain and σmax value, which is the maximum stress at the crossover point. Moreover, the flow point was calculated during the amplitude sweep test. After the amplitude sweep test was conducted, frequency sweep test was also conducted in the same temperature as amplitude sweep test (25°C). During the frequency sweep, the amount of deformation (sheer strain) was held constant at 0.5% while the angular frequency was increased from 1 rad/s to 100rad/s.

Chapter 3

Results and Discussion

3.1 Textural properties analysis

Table 2. Textural properties of control oat and mixture of oat with different plant proteins

Sample	Firmness (g)	Consistency (g.s)	Cohesiveness (g)	Index of Viscosity (g.s)
Control	367.37 ± 19.90^{BC}	4518.84 ± 503.00^{AB}	-614.67 ± 35.90^{AB}	-251.68 ± 116.30^{A}
Oat + Fava	486.02 ± 131.40^{AB}	5495.70 ± 2216.00^{AB}	-742.55 ± 214.00^{BC}	-369.86 ± 245.00^{A}
Oat + Pea Protein	591.96 ± 44.10^{A}	6963.15 ± 719.00^{A}	-990.24 ± 50.70^{CD}	-477.72 ± 74.40^{A}
Oat + Mung Bean	650.63 ± 57.40^{A}	7227.75 ± 962.00^{A}	-1172.45 ± 90.10^{D}	-420.88 ± 115.80^{A}
Oat + Chickpea	263.27 ± 27.00^{C}	3455.98 ± 558.00^{B}	-459.86 ± 69.00^{AB}	-178.04 ± 73.00^{A}
Oat + Green Lentil	217.52 ± 22.50^{C}	3235.64 ± 597.00^{B}	-378.19 ± 34.70^{A}	-215.38 ± 10.50^{A}

**Means showed by the same letter are not statistically different from each other (p>0.05).*

Basic textural parameters such as firmness, consistency, cohesiveness, and index viscosity are very important to assess the quality of a paste. In Table 2, it can be seen that these four parameters were measured and recorded by a texture analyser. Firmness represents the force required to attain a given deformation. According to the data above, it can be seen that there were significant differences between the samples in terms of firmness values ($P<0.05$). The mixture of oat and mung bean has the highest value while the mixture of oat and green lentil has the lowest value in terms of firmness. This means that the addition of protein to starch can either decrease or increase the firmness of the mixture. Consistency represents the viscosity of the mixture and highly correlated with firmness (Imbart et al., 2022). Based on the data, the mixture of oat and mung bean has the highest consistency, while the mixture of oat and green lentil has the lowest consistency. There were also significant differences between the samples in terms of consistency values ($P<0.05$). Cohesiveness represents the strength of internal bonds in the mixture. Greater negative value means that the mixture has larger cohesiveness value, which means that it was harder for that particular mixture to generate fragments during swallowing. Based on the data, it can be seen that the oat and mung bean mixture has the highest cohesiveness value, while the oat and green lentil mixture has the lowest cohesiveness value. Significant differences were also observed between the samples, indicated by low P-value ($P<0.05$). In terms of index of viscosity, the mixture of oat and pea protein has the highest value while the mixture of oat and chickpea has the lowest value. This means that the mixture of oat and pea protein is more resistant to gradual deformation by shear stress (Yilmaz-Ersan & Topcuoglu, 2022). However, based on the ANOVA test and tukey's test, there were no significant differences between the samples in terms of index of viscosity (P>0.05). It is known that the presence of legume proteins can impact the textural properties of food products (Ahmad et al., 2017). An increase in consistency, firmness, and cohesiveness in the mixture of oat and plant protein may happened due to the increased in elastic modulus (G") via cross-linking between protein hydrophilic group and starch (Zhu et al., 2020). If the starch has a higher gelatinization temperature and the protein gels first, diffusion and network formation by the starch amylose is hindered and the starch instead acts mainly as a filler material, resulting in decreased gel strength as well (Johansson et al., 2022). In contrast, the rigidity/gel strength of high-amylopectin starch gel is going to be increased when protein is added since the protein will act as a filler in this case (Onwulata et al., 2013). Lastly, each plant protein has different variations in the globulin subunit composition and secondary structure in the system, which makes the firmness of the gel formed by the mixture may vary as well (Ge et al., 2023).

3.2 Flow behavior/viscosity determination

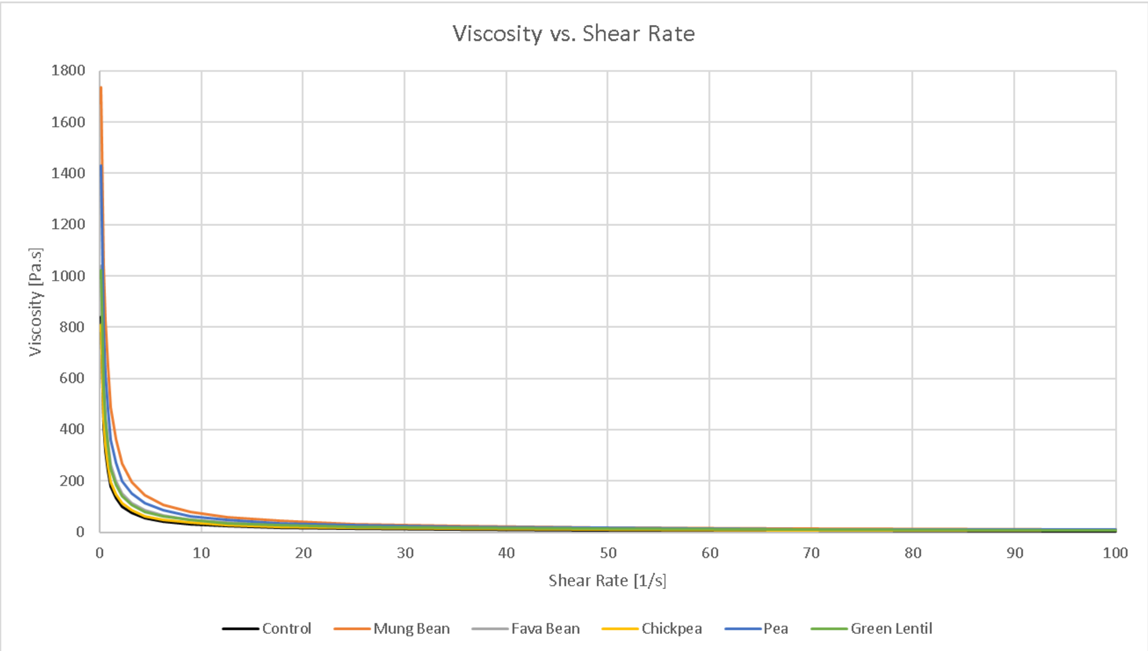

Figure 1. The relationship between viscosity and shear rate for control oat and mixture of oat with addition of different plant proteins

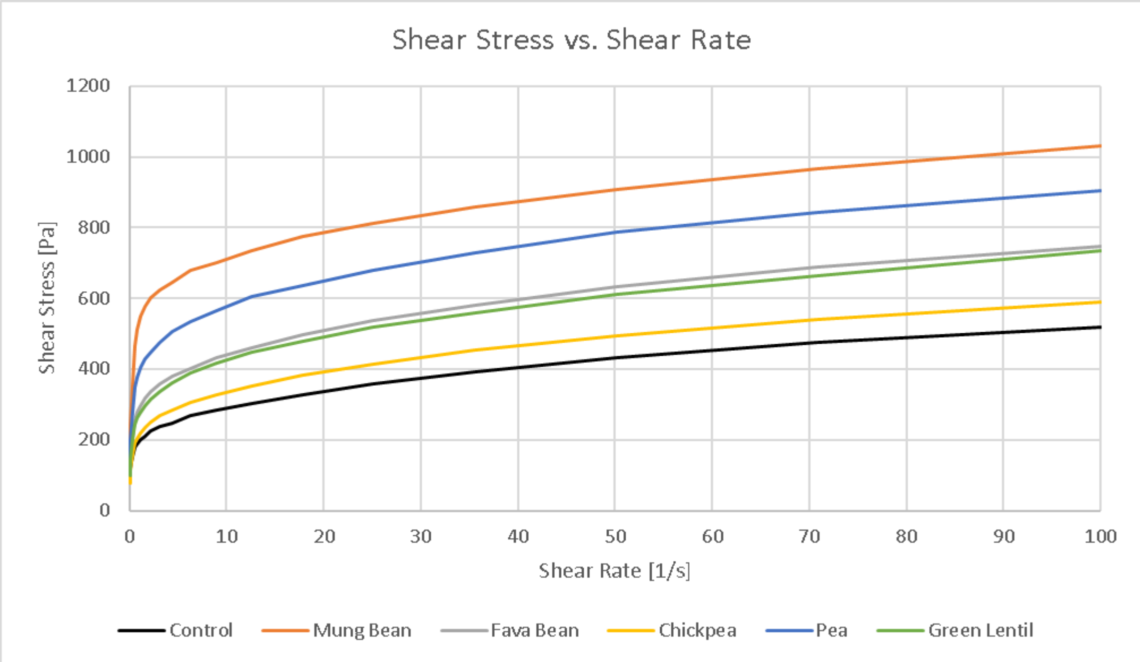

Figure 2. The relationship between shear stress and shear rate for control oat and mixture of oat with addition of different plant proteins

The viscosity of protein-starch mixture was measured with a shear rate range of 0 to 100 $s^{-1}$to determine the rheological properties. In Figure 1, the viscosity of all samples dropped significantly when the shear rate was increased from 0 s^{-1} to 20 $s^{-1}$and steadily decreased from 20 s^{-1} to 100 s^{-1}. This data tells that the faster the product is stirred, the thinner the product becomes. As the stirring goes faster, more force is exerted to the mixture, making the mixture less viscous and flow more easily than before. Figure 2 also shows that as the shear rate increases, the shear stress increases as well. This means that all oat samples exhibit non-Newtonian and shear-thinning fluid behaviour, as Hoover & Vasanthan (1994) also stated that native starches, including oat starch exhibited a non-Newtonian shear thinning behaviour. In Figure 1, it can be seen that the control oat paste experienced the greatest decrease in viscosity; Figure 2 also shows that the control oat paste has the highest shear thinning behaviour since the curve was the lowest compared to other samples' curves. In contrast, the mixture of oat and mung bean has the highest starting viscosity and the lowest shear thinning behaviour. The differences in shear thinning behaviour amongst the samples could happen due to the fact that the viscosity of the control sample is influenced only by the gelatinization of the starch itself. Gelatinization of starch resulted in the rupture of the glycosidic linkages, which then reduces the gel strength when shear rate increases. On the other hand, the mixture of oat starch with protein resulted in an increase in viscosity due to the fact that the addition of protein can help to form a stronger and a more stable gel (Xu et al., 2022). Cooking oat starch with protein at 95 °C resulted in partial denaturation of protein and changes in protein structure, which allows the gel network to develop (Widjajaseputra & Widyaastuti, 2017). Oat is also a high-amylopectin starch, which means that the rigidity/gel strength of high-amylopectin starch gel is going to be increased when protein is added since the protein will act as a filler in this case (Onwulata et al., 2013). For example, mung bean is able to retain water in gel formation during cooking, making them responsible for the high viscosity through gelation (Widjajaseputra & Widyaastuti, 2017). Another example is the addition of pea protein can help to promote the formation of a more compact structure and to improve the fibrous degree of the extrudates in high moisture (Chen et al., 2021). However, it is also important to remember that other factors such as the protein type and also the protein to starch ratio can also influence the viscosity of the starch-protein mixture.

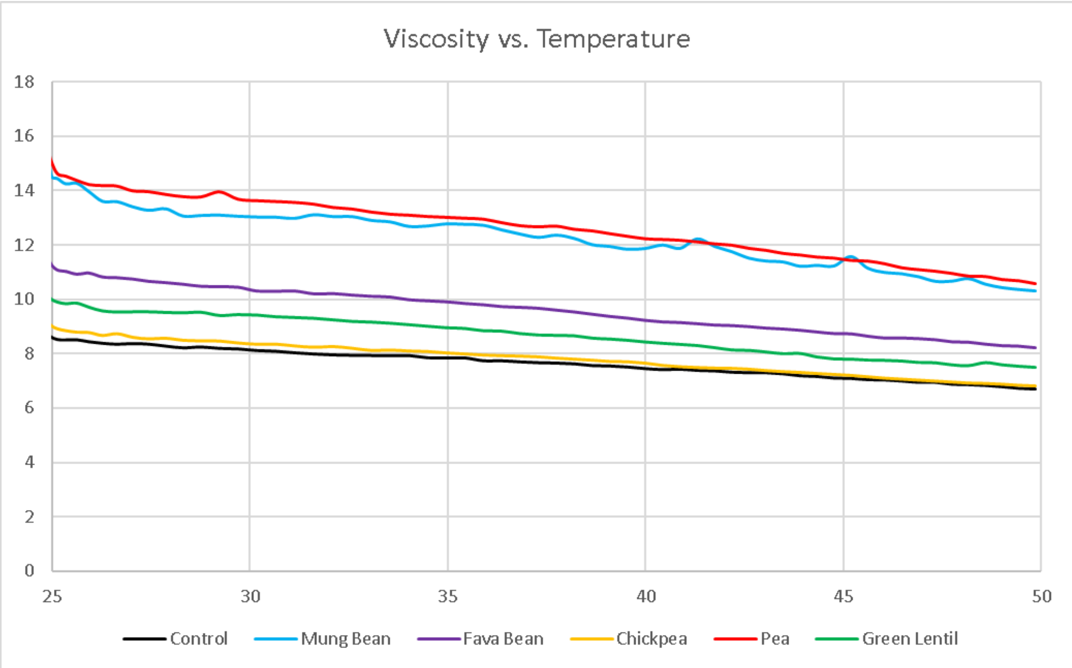

Figure 3. The relationship between viscosity and temperature for control oat and mixture of oat with addition of different plant proteins

Temperature ramp analysis was also done to observe and analyse the change of flow behaviour of the oat paste samples when they are heated. In this experiment, the test was performed by measuring the viscosity of the sample as the temperature raises from 25 °C (room temperature) to 50 °C. In Figure 3, it can be seen that the viscosity of all oat paste samples declines as the temperature increases, making them less viscous and flow easier at higher temperature. This can be caused by the significant decrease in amylopectin concentrations at temperature above 30°C (Liu et al., 2011). Other than that, extensive heat treatment can also promote the melting and gelatinisation of starch, which will decrease the viscosity of the mixture due to the inability of the starch granules to absorb water and swell (van Rooyen et al., 2022). Based on the data in Figure 3, it can be seen that the control oat paste is the most stable sample in terms of maintaining the mixture viscosity as the temperature rises. This data means that the control sample is more resistant to heat and can maintain the structure of the mixture in increasing temperature compared to the other samples. Tao et al. (2019) stated that the reassociation of amylose and amylopectin during the retrogradation process after being heated and cooled down to room temperature will cause the mixture to develop a firmer and denser structure. Therefore, the temperature of 25°C was not enough to disrupt the structure and more heat energy is required to do it. On the other hand, the mixtures of oat with plant protein have much lesser viscosity when they heated up compared to the control. This also means that the mixture of oat and plant protein is less stable in higher temperatures. Plant proteins such as fava bean, green lentil, and chickpea can maintain their viscosity stability better compared to pea protein and mung bean at high temperature. Figure 3 shows that the curves of fava bean, green lentil, and chickpea did not drop much when being heated up, while the curves of pea protein and mung bean dropped significantly when being heated up. This may happen due to the fact that the presence of protein in the mixture can prevent the retrogradation of starch. During the cooling, the hydrophobic interactions between the protein chains will interfere with the hydrogen bonds formation between the starch and water in the mixture (Zhang et al., 2019). Due to this reason, the protein-starch system produced with the presence of protein will produce a much softer gel network compared to the starch-only mixture. When the temperature rise from 25°C to 50°C, the protein-starch system will have more significant decrease in terms of viscosity. Even though the protein-starch system was more resistant to shear rates in the flow behaviour test compared to the starch-only system, but the protein-starch system showed more sensitivity and less resistant to higher temperatures if compared to the starch-only system.

Table 3. Herschel-Bulkley model of control oat and mixture of oat with different plant proteins

Model	Herschel-Bulkley					
Equation	$\tau = \tau 0 + \kappa * \gamma^n$					
Plot	Control 1	Mung Bean 1	Fava 1	Chickpea 1	Pea 1	Lentil 1
$\tau 0$	83.30	244.93	103.05	78.37	183.43	98.81
κ	97.57	270.20	175.18	128.31	213.00	160.15
n	0.32	0.23	0.28	0.30	0.26	0.30
R^2	0.99	0.98	1.00	1.00	0.98	0.99

**τ0= yield stress*
**κ= consistency index*
**τ= shear stress*
**γ= shear rate*
**n= flow behaviour index*

Table 4. Power Law model of control oat and mixture of oat with different plant proteins

Model	Power Law					
Equation	$\eta = \kappa\gamma^{n-1}$					
Plot	Control 1	Mung Bean 1	Fava 1	Chickpea 1	Pea 1	Lentil 1
K	219.00	548.71	310.31	233.68	418.80	299.43
n	0.36	0.45	0.42	0.41	0.41	0.41
R^2	0.98	0.97	0.97	0.97	0.98	0.97

**η= viscosity*
**κ= flow consistency index*
**γ= shear rate*
**n= flow behaviour index*

Herschel-Bulkley (HB) model and power law (PL) model were used in this experiment in order to accurately characterize the rheological behaviours of non-Newtonian fluids. PL model only got two parameters such as consistency index (κ) and flow index (n), while the HB model got three parameters such as consistency index (κ), flow index (n) and also yield stress (τ0), making HB model a more complete and better model in defining the behaviour of fluids (Magnon & Cayeux, 2021). The flow index (n) can be used to measure the degree of shear thinning or shear thickening. When n<1, the fluid is called pseudoplastic, which means that the fluid has shear-thinning behaviour when stress is applied. When n>1, the fluid called dilatant, which means that the fluid has shear-thickening behaviour when stress is applied. When n=1, it means that the fluid is a Newtonian fluid (Berker, 2002). Based on the data from Table 3 and Table 4, it can be clearly seen that all of the oat pastes sample exhibited shear-thinning behaviour since all the n values were below 1 (n<1) in both models, with mung bean and pea protein have the highest degree of shear thinning compared to other samples. On the other hand, the control n value was the highest among other samples, which means that the control oat paste is the most resistant to shear rates since it has the lowest degree of shear thinning. κ measures the average viscosity of the non-Newtonian fluid (Pang et al., 2020). Based on the values in Table 3 and Table 4, it can be clearly seen that oat-mung bean mixture and oat-pea protein mixture have the highest viscosity compared to the other samples, while the control oat paste has the lowest viscosity. In HB model, τ0 represents the initial resistance of fluid to flow by determining the value at low shear rates in order to estimate the fluid behaviour more accurately (Rehm et al., 2012). The HB model in Table 3 shows that mung bean and pea protein have the highest τ0 values compared to other samples, which means that the mixture of oat with these two plant proteins have made the overall mixture more resistant to flow. As discovered by Tan et al. (2007), the mixture of mung bean and starch showed an initial Newtonian plateau, which is the region where viscosity approximately constant and has relatively high yield stress. On the other hand, the HB model shows that the oat-chickpea paste has the lowest τ0 value followed by the control. This means that the addition of chickpea to oat paste can slightly make the oat paste easier to flow. Tan et al. (2006) found that the addition of chickpea to starch paste can potentially reduce the gel strength by increasing the pasting temperature while decreasing the peak viscosity and peak viscosity temperature.

3.3 Dynamic rheology analysis

3.3.1 Amplitude sweep test

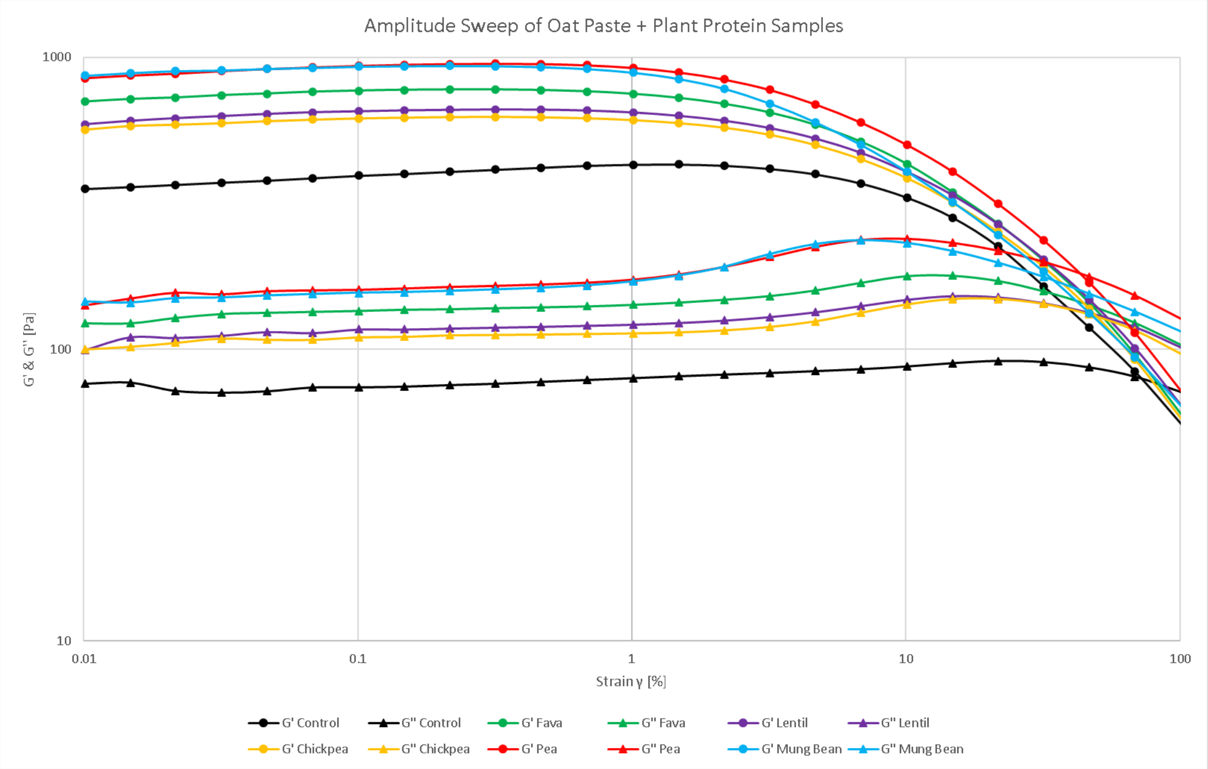

Figure 4. The amplitude sweep test of control oat and mixture of oat with addition of different plant proteins

In this experiment, amplitude sweep test, which is an oscillatory assay was done in order to measure and characterize the rheological stability of the oat pastes sample by using increasing oscillatory strain at a constant frequency (Stojkov et al., 2021). The test was performed within the Linear Viscoelastic Region (LVER) in order to avoid sample damage and to ensure that all measurement were performed within this range. In this LVER range, G' (storage modulus), G" (loss modulus) and tan δ (tangent of the phase angle) do not vary with the application of deformation (Zerbinati et al., 2022). Zerbinati et al. (2022) also added that when the stress is increased, the G'-G" crossover point will reach the point at which the transformation occurs, this means that the material starts to behave more like viscoelastic liquid rather than viscoelastic solid. Based on the data of all oat samples in Figure 4, it can be clearly seen that pea and mung bean proteins have the highest initial G' and G" values, indicating that these two mixtures behave most like viscoelastic solids compared to other oat samples. Moreover, fava bean, green lentil and chickpea also followed with much higher initial G’ and G” values compared to the control oat. The data shows that G’>G” in the LVER range, which means that all oat samples behave more like viscoelastic solid than viscoelastic liquid. It can also be observed that the viscoelastic behaviour of all oat samples became non-linear at around 0.5% strain value, which also means that 0.5% is the limiting value of the LVER. The data also shows the crossover point between 10^1 % and 10^2% in all oat samples in which G”>G’. The transition process/crossover is also known as flow point (G’=G”). This means that the magnitude strain exerted at the flow point was higher for oat paste with plant protein samples compared to the control oat paste. Dabbaghi et al. (2021) also confirms that the greater elastic nature of the oat pastes with plant protein samples allows a substantial elongation of the structural network under continually increasing straining force before the structure was distorted to a state of viscoelastic liquid. This means that as the strain increased, all oat samples experienced macro crack that ruptured the entire sample. At this point, all samples have turned into irreversible viscoelastic liquid. It can also be seen that all oat pastes with added plant protein have much higher G’ and G” compared to the control oat. Barbosa et al. (2023) found that the addition of protein to starch mixture can delay the beginning of gelatinization and led to an increase in both G’ and G” and decrease in tan δ. Due to this fact, the oat mixture with plant protein resulted in a more structured and stronger gel.

3.3.2 Frequency sweep test

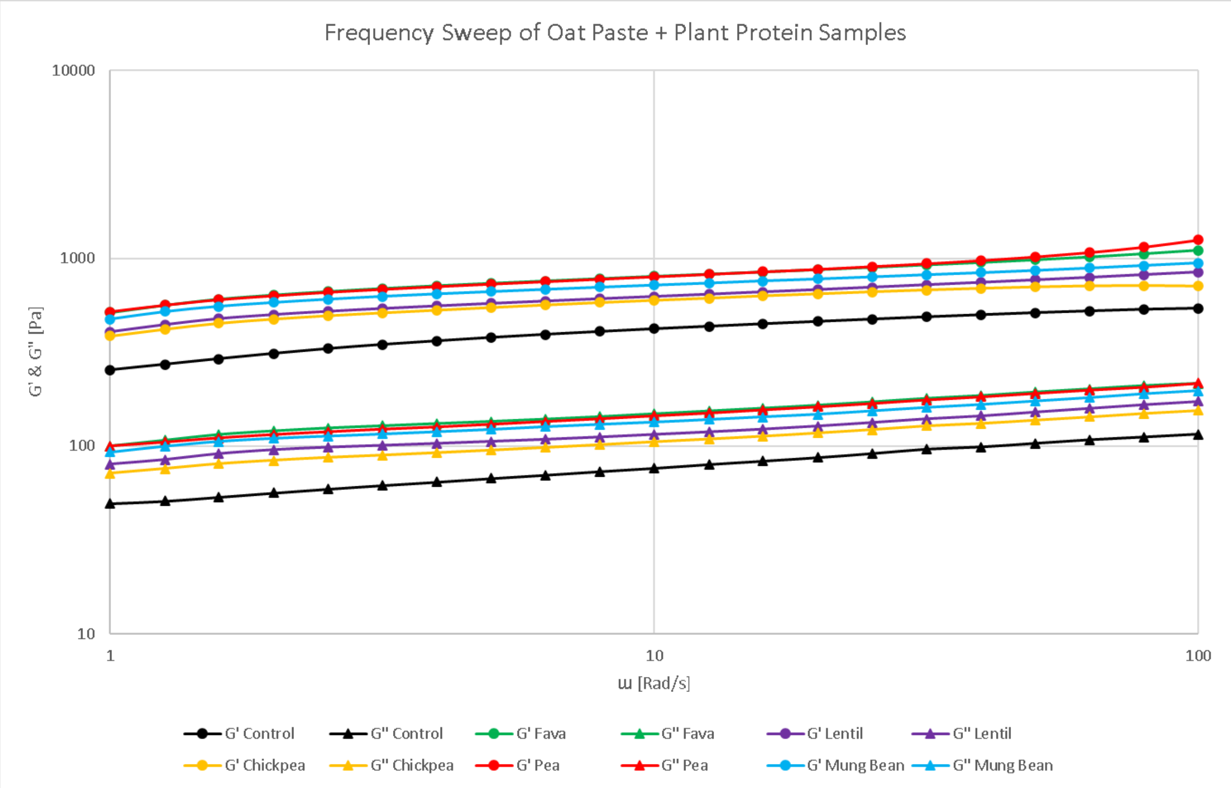

Figure 5. The frequency sweep test of control oat and mixture of oat with addition of different plant proteins

After amplitude test was done, frequency sweep test was also conducted in order to determine the relationship between testing frequency and the storage modulus (G') and loss modulus (G") of a material. This test also gives an insight into the viscoelastic properties and state of the mixture by comparing both modulus values over a given frequency range (Stojkov et al., 2021). The test was performed at the same temperature with the amplitude sweep test (25 °C) and within the LVER at shear strain 0.5%, obtained by the preliminary amplitude sweep test that was done before in order to avoid sample damage. Figure 5 shows that G' and G" increase proportionally as the angular frequency increases from 1 rad/s to 100 rad/s. G' and G" run parallel without any crossover point, which means that the elastic nature of all oat samples prevailed on the viscous nature under the tested conditions. According to Singh & Kaur (2017), the mixture of oat paste is expected to have greater G' values than G" at all frequency, showing the strong elastic behaviour of the samples. They also added that G' is also expected to be independent of frequency and much higher than G" (G'>>G"). From this frequency test, it is also safe to conclude that the values obtained from this particular test have indicated that all oat samples were more elastic than viscous.

Chapter 4
Overall Conclusion

From this experiment, the addition of five different plant proteins – mung bean, pea protein, chickpea, green lentil, and fava bean can influence the rheological and textural properties of oatmeal. The differences between the control oatmeal and the oatmeal-plant protein samples can be resulted from the interaction of protein and starch in the mixture. It is important to remember that each plant protein has different amino acid composition, which can contribute to the rheological properties of the mixture. The ratio of amylose and amylopectin in the starch itself can also give different viscosity result when combined with plant proteins. Heating can also influence the gelation process, which resulted in different outcomes from the control oatmeal. However, from the overall data obtained from this experiment, it can be concluded that some plant protein such as mung bean and pea protein can give higher viscosity, firmer structure, increase the degree of shear-thinning, increase the resistant to flow, while some plant proteins such as chickpea and green lentil can reduce the viscosity, less firmness, decrease the degree of shear-thinning, and makes the oatmeal to flow better. However, there are several things that can be improve from this research in order to make the results even more reliable such as using fresher ingredients, analysing the oat amylose and amylopectin ratio, doing more replicates, and etc. Further research can still be done in order to understand more and investigate further the exact formulation and development of commercial oatmeal products that incorporate these plant proteins in order to control its rheological properties and boost its nutritional values.

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Appendix A

Raw Data

A.1 Textural properties analysis

Table 1. Texture analyser result for control oat

Test ID	Batch		Firmness	Consistency	Cohesivenes:	Index of Viscosity
			g	g.sec	g	g.sec
			Force 1	Area F-T 1:2	Force 2	Area F-T 2:3
control 11	control 1		345.29	4301.3	-573.68	-301.93
control 12	control 1		383.94	5094.29	-640.76	-334.39
control 13	control 1		372.87	4160.93	-629.58	-118.73

Table 2. Texture analyser result for fava bean

Test ID	Batch		Firmness	Consistency	Cohesiveness	Index of Viscosity
			g	g.sec	g	g.sec
			Force 1	Area F-T 1:2	Force 2	Area F-T 2:3
Oat and Fava beans1	Oat and Fava beans		430.79	3718.08	-601.79	-119.88
Oat and Fava beans2	Oat and Fava beans		635.97	7978.62	-989.35	-610.53
Oat and Fava beans3	Oat and Fava beans		391.29	4790.39	-636.5	-379.16

Table 3. Texture analyser result for pea protein

Test ID	Batch		Firmness	Consistency	Cohesiveness	Index of Viscosity
			g	g.sec	g	g.sec
			Force 1	Area F-T 1:2	Force 2	Area F-T 2:3
Oat and Pea protein1	Oat and Pea protein		642.36	7577.69	-1047.91	-562.94
Oat and Pea protein2	Oat and Pea protein		572.83	7139	-952.83	-444.7
Oat and Pea protein3	Oat and Pea protein		560.69	6172.77	-969.97	-425.53

Table 4. Texture analyser result for mung bean

Test ID	Batch		Firmness	Consistency	Cohesiveness	Index of Viscosity
			g	g.sec	g	g.sec
			Force 1	Area F-T 1:2	Force 2	Area F-T 2:3
Oat and mung bean1	Oat and mung bean		706.67	8018.23	-1259.26	-412.4
Oat and mung bean2	Oat and mung bean		591.99	6157.04	-1079.43	-309.58
Oat and mung bean3	Oat and mung bean		653.22	7507.97	-1178.66	-540.67

Table 5. Texture analyser result for chickpea

Test ID	Batch		Firmness	Consistency	Cohesiveness	Index of Viscosity
			g	g.sec	g	g.sec
			Force 1	Area F-T 1:2	Force 2	Area F-T 2:3
Oat and Chickpea1	Oat and Chickpea		250.43	3265.76	-415.89	-129.64
Oat and Chickpea2	Oat and Chickpea		294.29	4083.86	-539.4	-142.45
Oat and Chickpea3	Oat and Chickpea		245.1	3018.32	-424.3	-262.03

Table 6. Texture analyser result for green lentil

Test ID	Batch		Firmness	Consistency	Cohesiveness	Index of Viscosity
			g	g.sec	g	g.sec
			Force 1	Area F-T 1:2	Force 2	Area F-T 2:3
Oat and Green lentil1	Oat and Green lentil		201.55	2706.76	-355.83	-212.95
Oat and Green lentil2	Oat and Green lentil		243.29	3883.38	-418.12	-206.31
Oat and Green lentil3	Oat and Green lentil		207.73	3116.77	-360.63	-226.88

A.2 Flow behaviour/viscosity determination

Table 7. Flow behaviour test for control oat

Control 1					Control 2					Control 3				
Point No.	Shear Rate	Shear Stress	Viscosity	Torque	Point No.	Shear Rate	Shear Stress	Viscosity	Torque	Point No.	Shear Rate	Shear Stress	Viscosity	Torque
	[1/s]	[Pa]	[Pa·s]	[mN·m]		[1/s]	[Pa]	[Pa·s]	[mN·m]		[1/s]	[Pa]	[Pa·s]	[mN·m]
1	0.1	82.318	823.19	0.87712	1	0.1	90.464	904.66	0.96392	1	0.1	77.107	771.09	0.8216
2	0.141	110.62	783.14	1.1787	2	0.141	129.01	913.31	1.3746	2	0.141	117.22	829.83	1.249
3	0.2	127.62	639.62	1.3598	3	0.2	149.13	747.45	1.5891	3	0.2	139.7	700.17	1.4886
4	0.282	140.26	497.67	1.4945	4	0.282	164.37	583.2	1.7514	4	0.282	155.04	550.11	1.652
5	0.398	150.23	377.38	1.6007	5	0.398	177.38	445.58	1.8901	5	0.398	168.33	422.83	1.7936
6	0.562	159.55	283.74	1.7001	6	0.562	190.27	338.37	2.0274	6	0.562	182.86	325.19	1.9484
7	0.794	167.26	210.58	1.7822	7	0.794	200.4	252.31	2.1354	7	0.794	194.81	245.26	2.0757
8	1.12	177.67	158.36	1.8932	8	1.12	218.22	194.51	2.3252	8	1.12	203.93	181.76	2.1729
9	1.58	190.86	120.44	2.0337	9	1.58	228.55	144.21	2.4353	9	1.58	212.86	134.31	2.2681
10	2.24	207.79	92.824	2.2141	10	2.24	240.81	107.57	2.5659	10	2.24	224.12	100.12	2.3881
11	3.16	220.58	69.756	2.3503	11	3.16	259.09	81.936	2.7606	11	3.16	237.72	75.181	2.533
12	4.47	228.01	51.047	2.4295	12	4.47	263.2	58.927	2.8044	12	4.47	252.67	56.569	2.6922
13	6.31	248.24	39.344	2.6451	13	6.31	286.59	45.423	3.0537	13	6.31	271.51	43.035	2.893
14	8.91	262.35	29.44	2.7954	14	8.91	297.17	33.342	3.1664	14	8.91	294.04	32.994	3.133
15	12.6	279.91	22.237	2.9826	15	12.6	308.53	24.51	3.2874	15	12.6	320.01	25.422	3.4098
16	17.8	309.57	17.41	3.2986	16	17.8	333.07	18.732	3.5489	16	17.8	341.07	19.182	3.6342
17	25.1	339.72	13.525	3.6198	17	25.1	358.57	14.276	3.8207	17	25.1	373.65	14.877	3.9814
18	35.5	376.05	10.6	4.0069	18	35.5	388.3	10.945	4.1375	18	35.5	410.63	11.574	4.3754
19	50.1	417.18	8.3248	4.4451	19	50.1	422.51	8.4305	4.5019	19	50.1	456.13	9.1022	4.8602
20	70.8	460.87	6.5102	4.9107	20	70.8	460.07	6.4991	4.9021	20	70.8	500.8	7.0745	5.3361
21	100	498.93	4.9895	5.3163	21	100	505.81	5.0585	5.3895	21	100	550.01	5.5005	5.8605

Table 8. Flow behaviour test for mung bean

Mung Bean 1					Mung Bean 2					Mung Bean 3				
Point No.	Shear Rat	Shear Stre	Viscosity	Torque	Point No.	Shear Rat	Shear Stre	Viscosity	Torque	Point No.	Shear Rat	Shear Stre	Viscosity	Torque
	[1/s]	[Pa]	[Pa·s]	[mN·m]		[1/s]	[Pa]	[Pa·s]	[mN·m]		[1/s]	[Pa]	[Pa·s]	[mN·m]
1	0.1	179.76	1797.6	1.9154	1	0.1	158.96	1589.6	1.6938	1	0.1	162.37	1623.7	1.7301
2	0.141	253.85	1797.2	2.7049	2	0.141	233.2	1650.9	2.4848	2	0.141	247.87	1754.8	2.6411
3	0.2	311.14	1559.4	3.3153	3	0.2	286.98	1438.3	3.0579	3	0.2	309.1	1549.2	3.2936
4	0.282	369.6	1311.4	3.9382	4	0.282	338.23	1200.1	3.6039	4	0.282	367.36	1303.5	3.9144
5	0.398	429.46	1078.8	4.576	5	0.398	385.41	968.14	4.1067	5	0.398	424.82	1067.1	4.5265
6	0.562	491.15	873.42	5.2333	6	0.562	425.01	755.81	4.5286	6	0.562	480.7	854.85	5.122
7	0.794	550.12	692.59	5.8617	7	0.794	456.92	575.25	4.8686	7	0.794	533.19	671.27	5.6813
8	1.12	596.64	531.78	6.3574	8	1.12	477.57	425.66	5.0886	8	1.12	570.21	508.22	6.0758
9	1.58	627.55	395.97	6.6867	9	1.58	495.6	312.71	5.2807	9	1.58	607.2	383.14	6.4699
10	2.24	645.63	288.4	6.8793	10	2.24	516.42	230.69	5.5026	10	2.24	639.94	285.87	6.8188
11	3.16	661	209.04	7.0432	11	3.16	546.33	172.78	5.8213	11	3.16	661.95	209.34	7.0532
12	4.47	681.68	152.62	7.2635	12	4.47	573.3	128.36	6.1087	12	4.47	684.61	153.28	7.2947
13	6.31	706.34	111.96	7.5263	13	6.31	601.87	95.398	6.4131	13	6.31	726.61	115.17	7.7423
14	8.91	724.19	81.262	7.7164	14	8.91	628.4	70.514	6.6958	14	8.91	753.65	84.569	8.0303
15	12.6	751.12	59.667	8.0034	15	12.6	659.24	52.368	7.0244	15	12.6	790.99	62.835	8.4283
16	17.8	783.51	44.062	8.3486	16	17.8	699.78	39.355	7.4564	16	17.8	836.31	47.034	8.9111
17	25.1	810.83	32.282	8.6396	17	25.1	733.1	29.186	7.8114	17	25.1	889.81	35.426	9.4812
18	35.5	841.79	23.726	8.9696	18	35.5	779.64	21.974	8.3073	18	35.5	954.65	26.907	10.172
19	50.1	894.2	17.843	9.5279	19	50.1	831.3	16.586	8.8578	19	50.1	998.93	19.932	10.644
20	70.8	939.58	13.272	10.012	20	70.8	880.62	12.439	9.3833	20	70.8	1076.2	15.202	11.467
21	100	999.88	9.9983	10.654	21	100	950.03	9.5002	10.123	21	100	1138.8	11.388	12.134

Table 9. Flow behaviour test for fava bean

Fava 1					Fava 2					Fava 3				
Point No.	Shear Rat	Shear Stre	Viscosity	Torque	Point No.	Shear Rat	Shear Stre	Viscosity	Torque	Point No.	Shear Rat	Shear Stre	Viscosity	Torque
	[1/s]	[Pa]	[Pa·s]	[mN·m]		[1/s]	[Pa]	[Pa·s]	[mN·m]		[1/s]	[Pa]	[Pa·s]	[mN·m]
1	0.1	108.62	1086.2	1.1574	1	0.1	99.762	997.64	1.063	1	0.1	100.78	1007.8	1.0738
2	0.141	153.15	1084.2	1.6318	2	0.141	144.06	1019.9	1.535	2	0.141	143.88	1018.6	1.5331
3	0.2	184.34	923.92	1.9642	3	0.2	174.27	873.46	1.857	3	0.2	177.24	888.31	1.8885
4	0.282	211.77	751.41	2.2565	4	0.282	200.86	712.68	2.1402	4	0.282	208.3	739.1	2.2195
5	0.398	236.89	595.04	2.5241	5	0.398	225.95	567.58	2.4076	5	0.398	237.38	596.29	2.5294
6	0.562	259.02	460.62	2.7599	6	0.562	247.76	440.6	2.6399	6	0.562	263.84	469.19	2.8113
7	0.794	280.28	352.87	2.9865	7	0.794	265.35	334.07	2.8274	7	0.794	287.84	362.38	3.067
8	1.12	299.15	266.63	3.1875	8	1.12	284.38	253.47	3.0302	8	1.12	309.3	275.68	3.2957
9	1.58	315.9	199.33	3.366	9	1.58	304.75	192.3	3.2472	9	1.58	330.63	208.62	3.523
10	2.24	335.51	149.88	3.575	10	2.24	324.69	145.04	3.4597	10	2.24	350.52	156.58	3.7349
11	3.16	358.97	113.52	3.8249	11	3.16	345.22	109.18	3.6785	11	3.16	367.75	116.3	3.9185
12	4.47	382.21	85.574	4.0726	12	4.47	368.45	82.493	3.926	12	4.47	388.73	87.034	4.1421
13	6.31	403.51	63.957	4.2995	13	6.31	392.19	62.162	4.1789	13	6.31	411.23	65.18	4.3818
14	8.91	431.14	48.379	4.5939	14	8.91	421.12	47.254	4.4872	14	8.91	440.81	49.462	4.6969
15	12.6	461.04	36.624	4.9125	15	12.6	451.38	35.858	4.8096	15	12.6	468.83	37.243	4.9955
16	17.8	496.74	27.936	5.293	16	17.8	488.9	27.495	5.2094	16	17.8	507.15	28.521	5.4038
17	25.1	535.55	21.322	5.7064	17	25.1	530.09	21.105	5.6483	17	25.1	543.21	21.627	5.7881
18	35.5	581.2	16.382	6.1928	18	35.5	577.59	16.28	6.1544	18	35.5	585.79	16.511	6.2418
19	50.1	633.27	12.637	6.7477	19	50.1	631.04	12.592	6.724	19	50.1	638.27	12.736	6.801
20	70.8	689.86	9.7452	7.3507	20	70.8	685.15	9.6784	7.3005	20	70.8	693.29	9.7938	7.3872
21	100	747.57	7.4759	7.9655	21	100	745.75	7.458	7.9462	21	100	748.76	7.4879	7.9783

Table 10. Flow behaviour test for chickpea

Chickpea 1					Chickpea 2					Chickpea 3				
Point No.	Shear Rat	Shear Stre	Viscosity	Torque	Point No.	Shear Rat	Shear Stre	Viscosity	Torque	Point No.	Shear Rat	Shear Stre	Viscosity	Torque
	[1/s]	[Pa]	[Pa·s]	[mN·m]		[1/s]	[Pa]	[Pa·s]	[mN·m]		[1/s]	[Pa]	[Pa·s]	[mN·m]
1	0.1	85.011	850.13	0.90581	1	0.1	76.479	764.81	0.81491	1	0.1	73.637	736.39	0.78462
2	0.141	120.91	855.98	1.2883	2	0.141	114.5	810.62	1.2201	2	0.141	108.2	766.03	1.1529
3	0.2	145.66	730.02	1.552	3	0.2	137.74	690.32	1.4676	3	0.2	130.97	656.42	1.3955
4	0.282	167.51	594.35	1.7848	4	0.282	155.73	552.55	1.6593	4	0.282	150.12	532.67	1.5996
5	0.398	187.21	470.27	1.9948	5	0.398	170.39	428.02	1.8156	5	0.398	167.4	420.49	1.7837
6	0.562	205.06	364.67	2.185	6	0.562	183.71	326.71	1.9575	6	0.562	182.74	324.97	1.9471
7	0.794	221.65	279.05	2.3617	7	0.794	196.22	247.03	2.0907	7	0.794	196.16	246.96	2.0901
8	1.12	238.09	212.21	2.537	8	1.12	207.8	185.21	2.2142	8	1.12	210.72	187.81	2.2453
9	1.58	256.28	161.71	2.7307	9	1.58	220.29	139	2.3472	9	1.58	224.46	141.64	2.3917
10	2.24	275.96	123.28	2.9405	10	2.24	234.83	104.9	2.5021	10	2.24	239.39	106.94	2.5508
11	3.16	293.27	92.748	3.1249	11	3.16	252.29	79.787	2.6882	11	3.16	256.79	81.211	2.7362
12	4.47	305.64	68.429	3.2567	12	4.47	269.08	60.243	2.8671	12	4.47	274.31	61.416	2.9229
13	6.31	335.35	53.153	3.5733	13	6.31	285.4	45.236	3.0411	13	6.31	296.44	46.986	3.1587
14	8.91	354.1	39.734	3.773	14	8.91	309.55	34.734	3.2983	14	8.91	321.21	36.044	3.4226
15	12.6	377.26	29.971	4.0198	15	12.6	332.74	26.432	3.5454	15	12.6	346.99	27.564	3.6973
16	17.8	406.49	22.86	4.3312	16	17.8	360.83	20.293	3.8448	16	17.8	376.81	21.191	4.015
17	25.1	440.96	17.556	4.6985	17	25.1	389.37	15.502	4.1489	17	25.1	409.32	16.296	4.3614
18	35.5	482.96	13.613	5.1461	18	35.5	425.19	11.985	4.5306	18	35.5	450.53	12.699	4.8005
19	50.1	525.27	10.481	5.5969	19	50.1	461.95	9.2176	4.9222	19	50.1	494.26	9.8624	5.2665
20	70.8	574.59	8.1172	6.1224	20	70.8	503.26	7.1092	5.3624	20	70.8	543.05	7.6715	5.7863
21	100	626.92	6.2692	6.68	21	100	544.33	5.4434	5.8	21	100	596.71	5.9674	6.3581

Table 11. Flow behaviour test for pea protein

Pea 1					Pea 2					Pea 3				
Point No.	Shear Rat	Shear Stre	Viscosity	Torque	Point No.	Shear Rat	Shear Stre	Viscosity	Torque	Point No.	Shear Rat	Shear Stre	Viscosity	Torque
	[1/s]	[Pa]	[Pa·s]	[mN·m]		[1/s]	[Pa]	[Pa·s]	[mN·m]		[1/s]	[Pa]	[Pa·s]	[mN·m]
1	0.1	144.96	1449.6	1.5446	1	0.1	145.58	1455.8	1.5512	1	0.1	138.16	1381.6	1.4722
2	0.141	198.4	1404.6	2.114	2	0.141	204.68	1449	2.1809	2	0.141	195.74	1385.7	2.0857
3	0.2	241.04	1208.1	2.5684	3	0.2	248.32	1244.6	2.6459	3	0.2	236.74	1186.5	2.5225
4	0.282	280.67	995.86	2.9906	4	0.282	288.4	1023.3	3.073	4	0.282	273.83	971.62	2.9178
5	0.398	316.95	796.17	3.3772	5	0.398	323.76	813.27	3.4498	5	0.398	307.97	773.59	3.2815
6	0.562	350.68	623.63	3.7366	6	0.562	355.41	632.04	3.787	6	0.562	337.72	600.59	3.5985
7	0.794	382.14	481.11	4.0718	7	0.794	384.86	484.53	4.1008	7	0.794	365.77	460.5	3.8974
8	1.12	410.49	365.87	4.3739	8	1.12	414.45	369.4	4.4161	8	1.12	390.37	347.93	4.1595
9	1.58	432.14	272.68	4.6046	9	1.58	438.87	276.92	4.6763	9	1.58	413.55	260.95	4.4065
10	2.24	446.82	199.6	4.7611	10	2.24	463.76	207.17	4.9415	10	2.24	436.68	195.07	4.653
11	3.16	467.26	147.77	4.9788	11	3.16	488.03	154.34	5.2001	11	3.16	473.24	149.66	5.0425
12	4.47	511.4	114.5	5.4491	12	4.47	519.45	116.3	5.5349	12	4.47	490.89	109.91	5.2305
13	6.31	521.88	82.72	5.5608	13	6.31	555.7	88.081	5.9212	13	6.31	528.09	83.706	5.627
14	8.91	544.82	61.136	5.8052	14	8.91	594.46	66.705	6.3342	14	8.91	559.23	62.754	5.9588
15	12.6	582.34	46.261	6.205	15	12.6	634.68	50.418	6.7627	15	12.6	597.98	47.502	6.3716
16	17.8	606.14	34.088	6.4586	16	17.8	680.38	38.263	7.2496	16	17.8	618.67	34.79	6.5921
17	25.1	651.62	25.944	6.9432	17	25.1	738.04	29.383	7.864	17	25.1	651.87	25.953	6.9459
18	35.5	693.68	19.551	7.3914	18	35.5	801.62	22.594	8.5415	18	35.5	685.93	19.332	7.3088
19	50.1	759.22	15.149	8.0897	19	50.1	865.15	17.263	9.2184	19	50.1	735.01	14.665	7.8318
20	70.8	800.15	11.303	8.5259	20	70.8	936.34	13.226	9.977	20	70.8	795.08	11.231	8.4718
21	100	847.59	8.4763	9.0314	21	100	1010.4	10.104	10.766	21	100	852.05	8.5203	9.0788

Table 12. Flow behaviour test for green lentil

Lentil 1					Lentil 2					Lentil 3				
Point No.	Shear Rat	Shear Stre	Viscosity	Torque	Point No.	Shear Rat	Shear Stre	Viscosity	Torque	Point No.	Shear Rat	Shear Stre	Viscosity	Torque
	[1/s]	[Pa]	[Pa·s]	[mN·m]		[1/s]	[Pa]	[Pa·s]	[mN·m]		[1/s]	[Pa]	[Pa·s]	[mN·m]
1	0.1	99.808	998.08	1.0635	1	0.1	103.48	1034.8	1.1026	1	0.1	93.128	931.31	0.99231
2	0.141	146.77	1039.1	1.5639	2	0.141	150.52	1065.6	1.6038	2	0.141	136.57	966.82	1.4551
3	0.2	179.02	897.22	1.9075	3	0.2	185.25	928.48	1.9739	3	0.2	164.96	826.78	1.7577
4	0.282	205.41	728.84	2.1887	4	0.282	216.36	767.7	2.3054	4	0.282	187.54	665.45	1.9983
5	0.398	226.85	569.84	2.4172	5	0.398	244.03	612.98	2.6002	5	0.398	206.59	518.93	2.2012
6	0.562	244.49	434.79	2.6051	6	0.562	267.26	475.29	2.8478	6	0.562	222.59	395.84	2.3718
7	0.794	259.85	327.15	2.7688	7	0.794	289.81	364.87	3.088	7	0.794	240.03	302.2	2.5576
8	1.12	276.18	246.15	2.9427	8	1.12	304.92	271.78	3.249	8	1.12	255.38	227.62	2.7211
9	1.58	295.14	186.24	3.1448	9	1.58	321.79	203.04	3.4288	9	1.58	271.13	171.08	2.889
10	2.24	313.99	140.26	3.3457	10	2.24	337.27	150.66	3.5938	10	2.24	294.57	131.59	3.1387
11	3.16	338.58	107.08	3.6077	11	3.16	357.6	113.09	3.8103	11	3.16	313.13	99.029	3.3365
12	4.47	363.02	81.276	3.8681	12	4.47	373.84	83.699	3.9834	12	4.47	343.92	77.001	3.6646
13	6.31	391.89	62.116	4.1757	13	6.31	413.23	65.5	4.4031	13	6.31	365.74	57.97	3.8971
14	8.91	421.57	47.304	4.4919	14	8.91	430.25	48.278	4.5844	14	8.91	397.46	44.6	4.2351
15	12.6	454.61	36.114	4.844	15	12.6	467.05	37.101	4.9766	15	12.6	423.84	33.669	4.5161
16	17.8	491.93	27.665	5.2417	16	17.8	490.68	27.596	5.2284	16	17.8	455.68	25.626	4.8554
17	25.1	532.41	21.197	5.673	17	25.1	530.07	21.105	5.6481	17	25.1	490.93	19.546	5.231
18	35.5	578.54	16.307	6.1645	18	35.5	567.86	16.005	6.0508	18	35.5	532.07	14.996	5.6694
19	50.1	628.5	12.541	6.6969	19	50.1	618.51	12.342	6.5904	19	50.1	582.88	11.631	6.2108
20	70.8	686.99	9.7046	7.32	20	70.8	667.99	9.4355	7.1177	20	70.8	638.19	9.0156	6.8001
21	100	749.61	7.4966	7.9873	21	100	722.75	7.2282	7.7012	21	100	727.16	7.2728	7.7481

A.3 Temperature ramp analysis

Table 13. Temperature ramp test for control oat

Control 1						Control 2					
Point No.	Time	Temperat	Shear Stre	Viscosity	Torque	Point No.	Time	Temperat	Shear Stre	Viscosity	Torque
	[min]	[°C]	[Pa]	[Pa·s]	[mN·m]		[min]	[°C]	[Pa]	[Pa·s]	[mN·m]
1	0.083	24.95	438.65	8.7743	4.6739	1	0.083	24.89	457.94	9.16	4.8794
2	0.167	24.95	430.97	8.6212	4.5922	2	0.167	24.9	438.18	8.7653	4.669
3	0.25	25.01	423.71	8.4759	4.5148	3	0.25	24.96	435.89	8.7195	4.6445
4	0.333	25.16	420.14	8.4041	4.4767	4	0.333	25.11	430.9	8.6193	4.5914
5	0.417	25.38	417.92	8.3596	4.4531	5	0.417	25.32	431.52	8.6315	4.598
6	0.5	25.65	415.13	8.3035	4.4233	6	0.5	25.6	435.04	8.7017	4.6355
7	0.583	25.96	416.77	8.3361	4.4408	7	0.583	25.91	426.19	8.5245	4.5412
8	0.667	26.3	413.22	8.2648	4.403	8	0.667	26.25	424.41	8.4886	4.5222
9	0.75	26.66	410.17	8.2038	4.3705	9	0.75	26.62	423.89	8.4781	4.5167
10	0.833	27.05	413.42	8.2686	4.4051	10	0.833	27.02	422.93	8.4587	4.5065
11	0.917	27.46	408.62	8.1724	4.3539	11	0.917	27.43	425.62	8.5126	4.5351
12	1	27.89	406.05	8.1211	4.3266	12	1	27.86	421.04	8.4207	4.4863
13	1.083	28.33	405.84	8.1168	4.3243	13	1.083	28.3	415.28	8.3058	4.425
14	1.167	28.78	405.41	8.1083	4.3198	14	1.167	28.75	418.48	8.3697	4.459
15	1.25	29.25	403.43	8.0686	4.2987	15	1.25	29.22	415.36	8.3073	4.4258
16	1.333	29.71	400.74	8.0148	4.27	16	1.333	29.69	415.97	8.3194	4.4323
17	1.417	30.19	395.35	7.907	4.2126	17	1.417	30.16	415.73	8.3147	4.4297
18	1.5	30.67	391.64	7.8329	4.173	18	1.5	30.64	416.63	8.3325	4.4393
19	1.583	31.15	387.76	7.7552	4.1317	19	1.583	31.12	415.2	8.3041	4.4241
20	1.667	31.63	384.96	7.6992	4.1018	20	1.667	31.6	413.35	8.2668	4.4043
21	1.75	32.12	385.69	7.7137	4.1096	21	1.75	32.09	409.39	8.1877	4.3621
22	1.833	32.6	383.12	7.6623	4.0822	22	1.833	32.57	410.59	8.2121	4.375
23	1.917	33.08	383.42	7.6684	4.0855	23	1.917	33.05	409.52	8.1904	4.3636
24	2	33.56	384.02	7.6805	4.0918	24	2	33.53	408.5	8.17	4.3527
25	2.083	34.04	384.02	7.6805	4.0919	25	2.083	34	408.55	8.1712	4.3532
26	2.167	34.51	379.97	7.5994	4.0487	26	2.167	34.48	404.77	8.0955	4.313
27	2.25	34.98	381.06	7.6213	4.0603	27	2.25	34.95	402.49	8.0499	4.2887
28	2.333	35.45	381.47	7.6295	4.0647	28	2.333	35.42	402.51	8.0503	4.2889
29	2.417	35.92	376.48	7.5295	4.0115	29	2.417	35.89	397.05	7.9411	4.2307
30	2.5	36.38	376.56	7.5311	4.0123	30	2.5	36.35	396.81	7.9364	4.2282
31	2.583	36.85	374.85	7.497	3.9941	31	2.583	36.81	394.7	7.894	4.2057
32	2.667	37.31	372.64	7.4528	3.9706	32	2.667	37.27	393.89	7.8778	4.197
33	2.75	37.77	373.1	7.462	3.9755	33	2.75	37.73	392.1	7.8418	4.1779
34	2.833	38.22	369.43	7.3886	3.9364	34	2.833	38.18	392.79	7.856	4.1853
35	2.917	38.67	367.16	7.3433	3.9122	35	2.917	38.63	388.95	7.7791	4.1444
36	3	39.12	366.02	7.3204	3.9	36	3	39.08	388.42	7.7683	4.1387
37	3.083	39.57	364.91	7.2983	3.8883	37	3.083	39.53	385.67	7.7136	4.1095
38	3.167	40.01	360.94	7.2188	3.8459	38	3.167	39.97	384.05	7.6811	4.0922
39	3.25	40.45	360.45	7.209	3.8407	39	3.25	40.41	380.8	7.616	4.0575
40	3.333	40.89	360.62	7.2124	3.8425	40	3.333	40.85	381.98	7.6398	4.0701
41	3.417	41.33	360.57	7.2113	3.8419	41	3.417	41.29	377.85	7.5569	4.0261
42	3.5	41.77	359.14	7.1828	3.8268	42	3.5	41.73	377.32	7.5465	4.0205
43	3.583	42.2	357.01	7.1402	3.804	43	3.583	42.16	374.72	7.4944	3.9927
44	3.667	42.63	355.37	7.1075	3.7866	44	3.667	42.6	374.51	7.4902	3.9905
45	3.75	43.07	356.33	7.1265	3.7968	45	3.75	43.03	373.52	7.4705	3.98
46	3.833	43.5	355.78	7.1157	3.791	46	3.833	43.46	370.21	7.4041	3.9447
47	3.917	43.93	352.65	7.0531	3.7576	47	3.917	43.89	366.03	7.3208	3.9002
48	4	44.35	349.1	6.9819	3.7197	48	4	44.32	367.03	7.3406	3.9108
49	4.083	44.78	346.57	6.9314	3.6928	49	4.083	44.74	363.94	7.2787	3.8779
50	4.167	45.21	345.32	6.9064	3.6794	50	4.167	45.17	363.91	7.2783	3.8776
51	4.25	45.64	342.87	6.8573	3.6534	51	4.25	45.6	361.67	7.2335	3.8537
52	4.333	46.07	342.69	6.8539	3.6515	52	4.333	46.02	360.78	7.2155	3.8442
53	4.417	46.49	341.13	6.8225	3.6348	53	4.417	46.45	358.43	7.1687	3.8192
54	4.5	46.91	338.59	6.7718	3.6078	54	4.5	46.87	356.38	7.1276	3.7973
55	4.583	47.34	339.16	6.7833	3.6139	55	4.583	47.3	355.52	7.1104	3.7882
56	4.667	47.76	336.77	6.7353	3.5884	56	4.667	47.72	351.21	7.0242	3.7422
57	4.75	48.18	335.41	6.7081	3.5739	57	4.75	48.14	350.72	7.0143	3.737
58	4.833	48.61	334.78	6.6957	3.5672	58	4.833	48.57	348.61	6.9722	3.7145
59	4.917	49.03	331.7	6.634	3.5344	59	4.917	48.99	346.99	6.9399	3.6973
60	5	49.45	329.13	6.5827	3.507	60	5	49.41	343.87	6.8775	3.6641
61	5.083	49.87	327.24	6.5449	3.4869	61	5.083	49.83	342.81	6.8561	3.6527

Table 14. Temperature ramp test for mung bean

Mung Bean 1						Mung Bean 2					
Point No.	Time	Temperat	Shear Stre	Viscosity	Torque	Point No.	Time	Temperat	Shear Stre	Viscosity	Torque
	[min]	[°C]	[Pa]	[Pa·s]	[mN·m]		[min]	[°C]	[Pa]	[Pa·s]	[mN·m]
1	0.083	24.85	837.26	16.748	8.9213	1	0.083	24.98	829.9	16.6	8.8429
2	0.167	24.87	785.28	15.708	8.3674	2	0.167	24.98	731.59	14.634	7.7953
3	0.25	24.94	753.93	15.081	8.0333	3	0.25	25.04	699.38	13.99	7.4522
4	0.333	25.1	730.79	14.618	7.7868	4	0.333	25.18	713.88	14.28	7.6066
5	0.417	25.33	728.71	14.576	7.7646	5	0.417	25.4	696.36	13.929	7.4199
6	0.5	25.62	716.9	14.339	7.6388	6	0.5	25.67	710.66	14.215	7.5723
7	0.583	25.94	709.65	14.194	7.5616	7	0.583	25.98	686.64	13.734	7.3164
8	0.667	26.29	691.5	13.831	7.3682	8	0.667	26.32	669.27	13.386	7.1313
9	0.75	26.66	680.25	13.605	7.2482	9	0.75	26.69	679.42	13.588	7.2394
10	0.833	27.06	677.19	13.544	7.2157	10	0.833	27.08	663.68	13.274	7.0717
11	0.917	27.48	672.69	13.454	7.1677	11	0.917	27.49	654.89	13.098	6.9781
12	1	27.91	664.55	13.291	7.081	12	1	27.91	668.66	13.373	7.1247
13	1.083	28.36	658.82	13.177	7.02	13	1.083	28.35	647.34	12.947	6.8976
14	1.167	28.82	651.54	13.031	6.9424	14	1.167	28.81	657.09	13.142	7.0015
15	1.25	29.28	644.71	12.894	6.8695	15	1.25	29.27	665.04	13.301	7.0862
16	1.333	29.76	653.68	13.074	6.9652	16	1.333	29.73	651.92	13.039	6.9464
17	1.417	30.23	653.41	13.068	6.9623	17	1.417	30.21	649.61	12.992	6.9217
18	1.5	30.72	644.58	12.892	6.8682	18	1.5	30.69	657.62	13.152	7.0071
19	1.583	31.2	642.83	12.857	6.8495	19	1.583	31.17	655.32	13.106	6.9826
20	1.667	31.69	642.94	12.859	6.8507	20	1.667	31.65	668.39	13.368	7.1219
21	1.75	32.17	635.89	12.718	6.7756	21	1.75	32.13	668.61	13.372	7.1243
22	1.833	32.66	639.59	12.792	6.815	22	1.833	32.61	664.65	13.293	7.082
23	1.917	33.14	635.45	12.709	6.7709	23	1.917	33.09	655.26	13.105	6.982
24	2	33.62	634.48	12.69	6.7605	24	2	33.57	650.47	13.009	6.931
25	2.083	34.1	629.58	12.592	6.7083	25	2.083	34.05	638.72	12.774	6.8058
26	2.167	34.57	631.6	12.632	6.7299	26	2.167	34.52	638.25	12.765	6.8007
27	2.25	35.05	627.22	12.545	6.6832	27	2.25	34.99	650.36	13.007	6.9298
28	2.333	35.51	626.43	12.529	6.6748	28	2.333	35.46	649.59	12.992	6.9215
29	2.417	35.98	622.48	12.45	6.6327	29	2.417	35.93	649.84	12.997	6.9243
30	2.5	36.44	613.66	12.273	6.5387	30	2.5	36.39	641.82	12.836	6.8388
31	2.583	36.9	621.12	12.422	6.6182	31	2.583	36.85	618.93	12.378	6.5949
32	2.667	37.36	609.72	12.194	6.4967	32	2.667	37.31	618.25	12.365	6.5876
33	2.75	37.82	607.68	12.153	6.475	33	2.75	37.77	628.31	12.566	6.6948
34	2.833	38.27	606.1	12.122	6.4582	34	2.833	38.22	617.66	12.353	6.5813
35	2.917	38.71	598.85	11.977	6.381	35	2.917	38.67	601.93	12.038	6.4138
36	3	39.16	601.74	12.035	6.4117	36	3	39.12	592.41	11.848	6.3123
37	3.083	39.61	597.64	11.953	6.3681	37	3.083	39.57	586.08	11.722	6.2449
38	3.167	40.05	592	11.84	6.3079	38	3.167	40.01	594.71	11.894	6.3369
39	3.25	40.49	589.45	11.789	6.2808	39	3.25	40.45	609.81	12.196	6.4977
40	3.333	40.93	586.71	11.734	6.2516	40	3.333	40.89	600.55	12.011	6.399
41	3.417	41.37	590.16	11.803	6.2883	41	3.417	41.33	631.77	12.636	6.7317
42	3.5	41.8	582.08	11.642	6.2022	42	3.5	41.77	612.02	12.24	6.5213
43	3.583	42.24	574.27	11.486	6.119	43	3.583	42.2	600.53	12.011	6.3988
44	3.667	42.67	566.97	11.339	6.0413	44	3.667	42.63	583.92	11.678	6.2218
45	3.75	43.1	564.68	11.293	6.0168	45	3.75	43.06	575.65	11.513	6.1337
46	3.833	43.53	564.24	11.285	6.0122	46	3.833	43.49	572.51	11.45	6.1003
47	3.917	43.96	557.59	11.152	5.9412	47	3.917	43.92	563.27	11.266	6.0019
48	4	44.38	556.61	11.132	5.9309	48	4	44.35	567.67	11.353	6.0487
49	4.083	44.81	554.1	11.082	5.9041	49	4.083	44.78	567.86	11.357	6.0507
50	4.167	45.24	551.38	11.028	5.8751	50	4.167	45.2	605.34	12.107	6.4501
51	4.25	45.66	541.44	10.829	5.7692	51	4.25	45.63	572.12	11.442	6.0961
52	4.333	46.08	541.83	10.837	5.7734	52	4.333	46.06	556.4	11.128	5.9286
53	4.417	46.51	540.03	10.801	5.7541	53	4.417	46.48	553.38	11.068	5.8964
54	4.5	46.93	537.62	10.753	5.7286	54	4.5	46.91	544.93	10.899	5.8064
55	4.583	47.36	530.05	10.601	5.6478	55	4.583	47.33	535.28	10.706	5.7036
56	4.667	47.78	525.85	10.517	5.6031	56	4.667	47.76	540	10.8	5.7538
57	4.75	48.2	521.45	10.429	5.5562	57	4.75	48.18	553.89	11.078	5.9019
58	4.833	48.62	517.64	10.353	5.5157	58	4.833	48.6	537.1	10.742	5.7229
59	4.917	49.04	510.92	10.218	5.444	59	4.917	49.02	531.13	10.623	5.6593
60	5	49.47	504.62	10.092	5.3769	60	5	49.44	530.62	10.612	5.6539
61	5.083	49.89	503.87	10.077	5.3689	61	5.083	49.86	525.93	10.519	5.604

Table 15. Temperature ramp test for fava bean

Fava 1						Fava 2					
Point No.	Time	Temperat	Shear Stre	Viscosity	Torque	Point No.	Time	Temperat	Shear Stre	Viscosity	Torque
	[min]	[°C]	[Pa]	[Pa·s]	[mN·m]		[min]	[°C]	[Pa]	[Pa·s]	[mN·m]
1	0.083	24.84	601.73	12.036	6.4116	1	0.083	24.81	586.04	11.723	6.2445
2	0.167	24.86	579.15	11.585	6.171	2	0.167	24.83	570.28	11.408	6.0765
3	0.25	24.92	568.29	11.368	6.0553	3	0.25	24.9	559.19	11.186	5.9583
4	0.333	25.07	559.46	11.191	5.9612	4	0.333	25.06	548.85	10.979	5.8482
5	0.417	25.29	553.65	11.074	5.8993	5	0.417	25.29	549.72	10.996	5.8574
6	0.5	25.56	548.04	10.962	5.8396	6	0.5	25.58	545.06	10.902	5.8078
7	0.583	25.87	554.38	11.088	5.907	7	0.583	25.9	543.02	10.861	5.786
8	0.667	26.22	545.32	10.907	5.8105	8	0.667	26.25	537.57	10.752	5.7279
9	0.75	26.59	543.86	10.877	5.795	9	0.75	26.62	536.26	10.725	5.714
10	0.833	26.99	543.24	10.865	5.7884	10	0.833	27.02	532.06	10.641	5.6693
11	0.917	27.4	533.82	10.677	5.688	11	0.917	27.44	532.93	10.659	5.6785
12	1	27.83	531.48	10.63	5.6631	12	1	27.87	530.6	10.612	5.6537
13	1.083	28.28	526.79	10.536	5.6132	13	1.083	28.32	529.32	10.586	5.6401
14	1.167	28.73	519.44	10.389	5.5348	14	1.167	28.78	529.24	10.585	5.6392
15	1.25	29.19	523.46	10.469	5.5776	15	1.25	29.25	523.71	10.474	5.5803
16	1.333	29.66	522.01	10.44	5.5622	16	1.333	29.72	523.04	10.461	5.5732
17	1.417	30.14	513.09	10.262	5.4672	17	1.417	30.2	517.97	10.36	5.5191
18	1.5	30.62	512.57	10.252	5.4616	18	1.5	30.68	517.35	10.347	5.5126
19	1.583	31.1	514.99	10.3	5.4874	19	1.583	31.16	516.05	10.321	5.4986
20	1.667	31.59	510.07	10.201	5.4349	20	1.667	31.65	510.73	10.215	5.442
21	1.75	32.07	512.39	10.248	5.4597	21	1.75	32.13	509.11	10.182	5.4247
22	1.833	32.56	508.84	10.177	5.4218	22	1.833	32.61	507.1	10.142	5.4033
23	1.917	33.04	507.37	10.147	5.4061	23	1.917	33.1	504.32	10.086	5.3737
24	2	33.52	509.02	10.18	5.4238	24	2	33.58	499.9	9.998	5.3266
25	2.083	34	499.43	9.9886	5.3216	25	2.083	34.06	499.45	9.989	5.3218
26	2.167	34.48	496.92	9.9386	5.2949	26	2.167	34.53	497.92	9.9584	5.3055
27	2.25	34.95	495.62	9.9124	5.281	27	2.25	35.01	495.65	9.9131	5.2813
28	2.333	35.42	490.69	9.8139	5.2285	28	2.333	35.48	494.31	9.8863	5.2671
29	2.417	35.89	488.93	9.7786	5.2097	29	2.417	35.95	491.27	9.8255	5.2347
30	2.5	36.35	485.01	9.7002	5.168	30	2.5	36.41	488.51	9.7701	5.2052
31	2.583	36.81	484.65	9.6931	5.1641	31	2.583	36.87	485.87	9.7174	5.1771
32	2.667	37.27	482.48	9.6497	5.141	32	2.667	37.33	484.82	9.6963	5.1659
33	2.75	37.73	479.67	9.5934	5.111	33	2.75	37.78	480.66	9.6132	5.1215
34	2.833	38.18	473.75	9.475	5.0479	34	2.833	38.24	479.89	9.5979	5.1134
35	2.917	38.63	469.67	9.3934	5.0045	35	2.917	38.69	475.77	9.5153	5.0694
36	3	39.08	464.73	9.2945	4.9518	36	3	39.13	472.62	9.4524	5.0359
37	3.083	39.52	460.75	9.2149	4.9094	37	3.083	39.58	470	9.4	5.008
38	3.167	39.97	457.33	9.1465	4.8729	38	3.167	40.02	465.26	9.3053	4.9575
39	3.25	40.41	454.17	9.0835	4.8393	39	3.25	40.47	462.87	9.2573	4.932
40	3.333	40.85	456.27	9.1254	4.8617	40	3.333	40.91	458.4	9.1681	4.8844
41	3.417	41.29	453.58	9.0717	4.833	41	3.417	41.34	456.74	9.1348	4.8667
42	3.5	41.72	449.49	8.9899	4.7895	42	3.5	41.78	455.76	9.1153	4.8563
43	3.583	42.16	451.09	9.0218	4.8065	43	3.583	42.22	452.29	9.0459	4.8193
44	3.667	42.59	449.99	8.9999	4.7948	44	3.667	42.65	449.56	8.9914	4.7902
45	3.75	43.02	445.93	8.9187	4.7515	45	3.75	43.08	448.16	8.9632	4.7753
46	3.833	43.45	442.29	8.8458	4.7128	46	3.833	43.51	448.47	8.9695	4.7786
47	3.917	43.88	442.95	8.859	4.7197	47	3.917	43.94	443.05	8.861	4.7208
48	4	44.31	438.46	8.7691	4.6719	48	4	44.37	441.22	8.8244	4.7013
49	4.083	44.74	436.4	8.728	4.65	49	4.083	44.8	437.6	8.752	4.6627
50	4.167	45.17	437.55	8.751	4.6622	50	4.167	45.22	435.18	8.7036	4.6369
51	4.25	45.59	430.67	8.6134	4.5889	51	4.25	45.65	433.36	8.6672	4.6176
52	4.333	46.02	427	8.5401	4.5498	52	4.333	46.07	430.37	8.6074	4.5857
53	4.417	46.44	428.21	8.5642	4.5627	53	4.417	46.5	429.24	8.5849	4.5737
54	4.5	46.86	427	8.54	4.5498	54	4.5	46.92	428.19	8.5638	4.5625
55	4.583	47.28	425.76	8.5153	4.5366	55	4.583	47.34	425.32	8.5064	4.5319
56	4.667	47.71	419.34	8.3868	4.4682	56	4.667	47.77	424.12	8.4824	4.5191
57	4.75	48.13	423.24	8.4647	4.5097	57	4.75	48.19	418.53	8.3707	4.4596
58	4.833	48.55	419.72	8.3945	4.4723	58	4.833	48.61	414.9	8.2981	4.4209
59	4.917	48.97	413.73	8.2746	4.4084	59	4.917	49.03	415.45	8.309	4.4267
60	5	49.4	414.57	8.2915	4.4174	60	5	49.46	412.58	8.2516	4.3961
61	5.083	49.82	409.79	8.1959	4.3665	61	5.083	49.88	411.58	8.2315	4.3855

Table 16. Temperature ramp test for chickpea

Chickpea 1						Chickpea 2					
Point No.	Time	Temperat	Shear Stre	Viscosity	Torque	Point No.	Time	Temperat	Shear Stre	Viscosity	Torque
	[min]	[°C]	[Pa]	[Pa·s]	[mN·m]		[min]	[°C]	[Pa]	[Pa·s]	[mN·m]
1	0.083	24.68	472.31	9.4475	5.0326	1	0.083	24.84	486.46	9.7307	5.1834
2	0.167	24.71	448.29	8.9675	4.7766	2	0.167	24.86	468.31	9.3681	4.99
3	0.25	24.79	441.78	8.8373	4.7073	3	0.25	24.93	460.83	9.2184	4.9103
4	0.333	24.96	440.25	8.8064	4.691	4	0.333	25.09	451.34	9.0284	4.8092
5	0.417	25.19	439.8	8.7972	4.6862	5	0.417	25.32	444.85	8.8981	4.74
6	0.5	25.48	437.1	8.7429	4.6574	6	0.5	25.6	442.14	8.8437	4.7111
7	0.583	25.81	439.11	8.7828	4.6789	7	0.583	25.92	438.87	8.7779	4.6763
8	0.667	26.17	433.39	8.6681	4.6179	8	0.667	26.27	433.76	8.6755	4.6218
9	0.75	26.55	438.27	8.7654	4.6699	9	0.75	26.64	435.53	8.7108	4.6407
10	0.833	26.96	428.82	8.5766	4.5693	10	0.833	27.04	431.71	8.6344	4.6
11	0.917	27.38	426.64	8.533	4.546	11	0.917	27.46	428.17	8.5636	4.5623
12	1	27.82	430.52	8.6103	4.5873	12	1	27.89	426.4	8.528	4.5434
13	1.083	28.28	426.59	8.5319	4.5455	13	1.083	28.34	422.95	8.4591	4.5067
14	1.167	28.74	427.54	8.5509	4.5556	14	1.167	28.79	419.78	8.3956	4.4729
15	1.25	29.21	427	8.5401	4.5498	15	1.25	29.26	419.53	8.3905	4.4702
16	1.333	29.69	422.86	8.4572	4.5057	16	1.333	29.73	416.86	8.3373	4.4418
17	1.417	30.17	419.53	8.3907	4.4702	17	1.417	30.21	415.34	8.3069	4.4256
18	1.5	30.66	421.51	8.4301	4.4913	18	1.5	30.69	413.71	8.2743	4.4082
19	1.583	31.15	417.54	8.3507	4.449	19	1.583	31.18	411.21	8.2241	4.3815
20	1.667	31.63	415.93	8.3186	4.4319	20	1.667	31.66	408.04	8.1609	4.3478
21	1.75	32.12	415.63	8.3127	4.4287	21	1.75	32.15	410.83	8.2167	4.3776
22	1.833	32.61	413.2	8.2639	4.4028	22	1.833	32.63	407.04	8.1408	4.3372
23	1.917	33.09	409.11	8.1823	4.3592	23	1.917	33.11	403.17	8.0635	4.2959
24	2	33.57	408.63	8.1726	4.3541	24	2	33.59	404.77	8.0955	4.313
25	2.083	34.05	408.34	8.167	4.351	25	2.083	34.07	401.98	8.0396	4.2832
26	2.167	34.52	405.35	8.107	4.3191	26	2.167	34.54	402.65	8.0529	4.2903
27	2.25	35	403.58	8.0715	4.3002	27	2.25	35.01	399.43	7.9887	4.2561
28	2.333	35.47	402	8.04	4.2834	28	2.333	35.48	397.32	7.9465	4.2336
29	2.417	35.93	399.38	7.9875	4.2555	29	2.417	35.95	395.94	7.9188	4.2188
30	2.5	36.4	398.94	7.9788	4.2508	30	2.5	36.41	394.04	7.8807	4.1986
31	2.583	36.86	398.26	7.9651	4.2435	31	2.583	36.88	392.98	7.8597	4.1873
32	2.667	37.32	396.86	7.9373	4.2287	32	2.667	37.34	391.87	7.8373	4.1754
33	2.75	37.77	395.98	7.9197	4.2193	33	2.75	37.79	387.9	7.758	4.1332
34	2.833	38.22	393.27	7.8654	4.1904	34	2.833	38.24	386.83	7.7367	4.1218
35	2.917	38.67	391.75	7.8351	4.1743	35	2.917	38.69	384.41	7.6883	4.096
36	3	39.12	389.56	7.7912	4.1509	36	3	39.14	382.15	7.6429	4.0719
37	3.083	39.57	388.48	7.7696	4.1394	37	3.083	39.58	381.83	7.6366	4.0685
38	3.167	40.01	385.58	7.7117	4.1085	38	3.167	40.02	379.85	7.5969	4.0474
39	3.25	40.45	380.35	7.607	4.0527	39	3.25	40.46	376.76	7.5352	4.0145
40	3.333	40.89	378.28	7.5655	4.0306	40	3.333	40.9	373.96	7.4792	3.9847
41	3.417	41.33	377.2	7.5441	4.0192	41	3.417	41.34	371.89	7.4379	3.9626
42	3.5	41.76	376.12	7.5223	4.0076	42	3.5	41.77	370.93	7.4187	3.9524
43	3.583	42.2	374.91	7.4982	3.9948	43	3.583	42.21	371.09	7.4217	3.954
44	3.667	42.63	373.99	7.4797	3.9849	44	3.667	42.64	369.08	7.3815	3.9326
45	3.75	43.06	370.39	7.4078	3.9466	45	3.75	43.08	367.54	7.3508	3.9162
46	3.833	43.49	368.83	7.3766	3.93	46	3.833	43.51	365.42	7.3084	3.8937
47	3.917	43.92	367.18	7.3436	3.9124	47	3.917	43.94	363.89	7.2779	3.8774
48	4	44.35	364.72	7.2943	3.8862	48	4	44.37	362.48	7.2497	3.8624
49	4.083	44.78	363.57	7.2714	3.874	49	4.083	44.8	360.47	7.2095	3.841
50	4.167	45.2	362.12	7.2424	3.8585	50	4.167	45.22	358.27	7.1655	3.8175
51	4.25	45.63	359.18	7.1835	3.8271	51	4.25	45.65	355.96	7.1193	3.7929
52	4.333	46.05	356.73	7.1346	3.8011	52	4.333	46.07	353.37	7.0675	3.7653
53	4.417	46.48	354.99	7.0998	3.7825	53	4.417	46.5	351.74	7.0348	3.7479
54	4.5	46.9	352.84	7.0568	3.7596	54	4.5	46.92	350.25	7.005	3.732
55	4.583	47.32	350.76	7.0152	3.7375	55	4.583	47.34	348.75	6.975	3.716
56	4.667	47.75	349.03	6.9807	3.7191	56	4.667	47.76	346.9	6.9379	3.6963
57	4.75	48.17	348	6.96	3.708	57	4.75	48.19	344.42	6.8884	3.6699
58	4.833	48.59	347.76	6.9552	3.7055	58	4.833	48.61	342.94	6.8587	3.6541
59	4.917	49.01	346.94	6.9387	3.6967	59	4.917	49.03	340.98	6.8196	3.6332
60	5	49.43	345.34	6.9068	3.6797	60	5	49.46	338.8	6.776	3.61
61	5.083	49.86	343.94	6.8789	3.6648	61	5.083	49.88	337.38	6.7476	3.5949

Table 17. Temperature ramp test for pea protein

Pea 1						Pea 2					
Point No.	Time	Temperat	Shear Stre	Viscosity	Torque	Point No.	Time	Temperat	Shear Stre	Viscosity	Torque
	[min]	[°C]	[Pa]	[Pa·s]	[mN·m]		[min]	[°C]	[Pa]	[Pa·s]	[mN·m]
1	0.083	24.71	809.57	16.194	8.6263	1	0.083	24.86	792.79	15.858	8.4475
2	0.167	24.74	777.95	15.562	8.2892	2	0.167	24.88	763.34	15.269	8.1337
3	0.25	24.81	760.15	15.206	8.0997	3	0.25	24.94	746.64	14.935	7.9556
4	0.333	24.96	727.94	14.561	7.7564	4	0.333	25.09	734.65	14.695	7.828
5	0.417	25.19	722.85	14.459	7.7022	5	0.417	25.31	730.78	14.617	7.7867
6	0.5	25.48	713.75	14.276	7.6052	6	0.5	25.59	724.42	14.49	7.7189
7	0.583	25.8	701.28	14.026	7.4723	7	0.583	25.9	721.47	14.43	7.6874
8	0.667	26.15	707.24	14.146	7.5358	8	0.667	26.25	711.75	14.236	7.5839
9	0.75	26.54	706.51	14.13	7.5281	9	0.75	26.62	710.75	14.215	7.5732
10	0.833	26.94	694.46	13.89	7.3997	10	0.833	27.01	705.26	14.106	7.5148
11	0.917	27.36	691.26	13.825	7.3656	11	0.917	27.43	705.3	14.106	7.5152
12	1	27.8	689.99	13.8	7.3521	12	1	27.86	696.42	13.929	7.4205
13	1.083	28.25	683.71	13.674	7.2852	13	1.083	28.3	694.52	13.89	7.4003
14	1.167	28.71	684.26	13.685	7.2909	14	1.167	28.76	693.02	13.86	7.3843
15	1.25	29.18	699.81	13.996	7.4567	15	1.25	29.22	696.01	13.92	7.4162
16	1.333	29.65	678.29	13.566	7.2274	16	1.333	29.69	690.45	13.809	7.3569
17	1.417	30.13	683.19	13.664	7.2796	17	1.417	30.17	680.08	13.602	7.2465
18	1.5	30.62	675.63	13.513	7.1991	18	1.5	30.65	684.47	13.69	7.2932
19	1.583	31.1	670.69	13.414	7.1464	19	1.583	31.14	686.09	13.722	7.3105
20	1.667	31.59	664.32	13.286	7.0785	20	1.667	31.62	686.04	13.721	7.3099
21	1.75	32.07	662.61	13.252	7.0603	21	1.75	32.1	675.6	13.512	7.1987
22	1.833	32.56	661.21	13.224	7.0454	22	1.833	32.59	671.34	13.427	7.1533
23	1.917	33.04	658.45	13.169	7.016	23	1.917	33.07	662.69	13.254	7.0612
24	2	33.52	654.41	13.088	6.9729	24	2	33.55	658.98	13.18	7.0216
25	2.083	34	649.68	12.994	6.9225	25	2.083	34.02	659.95	13.199	7.0319
26	2.167	34.48	650.22	13.005	6.9283	26	2.167	34.5	654.63	13.093	6.9752
27	2.25	34.95	646.66	12.933	6.8904	27	2.25	34.97	655	13.1	6.9792
28	2.333	35.42	646.76	12.935	6.8914	28	2.333	35.44	651.7	13.034	6.9441
29	2.417	35.89	644.46	12.889	6.8669	29	2.417	35.91	650.52	13.01	6.9315
30	2.5	36.36	636.1	12.722	6.7778	30	2.5	36.37	645.93	12.919	6.8826
31	2.583	36.82	632.43	12.649	6.7387	31	2.583	36.83	638.53	12.771	6.8038
32	2.667	37.28	631.59	12.632	6.7297	32	2.667	37.29	635.21	12.704	6.7683
33	2.75	37.73	632.82	12.656	6.7429	33	2.75	37.75	636.26	12.725	6.7795
34	2.833	38.18	625.24	12.505	6.6621	34	2.833	38.2	632.3	12.646	6.7373
35	2.917	38.63	621.11	12.422	6.6181	35	2.917	38.65	630.7	12.614	6.7202
36	3	39.08	615.91	12.318	6.5627	36	3	39.1	625.46	12.509	6.6645
37	3.083	39.52	614.77	12.295	6.5506	37	3.083	39.55	616.65	12.333	6.5706
38	3.167	39.97	608.74	12.175	6.4863	38	3.167	39.99	613.86	12.277	6.5408
39	3.25	40.41	608.02	12.16	6.4786	39	3.25	40.43	611.9	12.238	6.52
40	3.333	40.85	604.58	12.092	6.442	40	3.333	40.87	612.42	12.248	6.5255
41	3.417	41.29	601.23	12.025	6.4063	41	3.417	41.31	609.72	12.194	6.4967
42	3.5	41.72	596.71	11.934	6.3581	42	3.5	41.74	606.72	12.135	6.4648
43	3.583	42.16	598.96	11.979	6.3821	43	3.583	42.17	599.74	11.995	6.3904
44	3.667	42.59	594.01	11.88	6.3294	44	3.667	42.61	593.12	11.862	6.3198
45	3.75	43.03	591	11.82	6.2973	45	3.75	43.04	588.76	11.775	6.2735
46	3.833	43.46	582.91	11.658	6.2111	46	3.833	43.47	585.62	11.712	6.24
47	3.917	43.89	581.51	11.63	6.1962	47	3.917	43.9	580.96	11.619	6.1903
48	4	44.31	576.06	11.521	6.1381	48	4	44.33	578.82	11.576	6.1675
49	4.083	44.74	576.55	11.531	6.1434	49	4.083	44.76	574.44	11.489	6.1208
50	4.167	45.17	571.65	11.433	6.0911	50	4.167	45.18	570.95	11.419	6.0836
51	4.25	45.59	567.37	11.348	6.0455	51	4.25	45.61	572.52	11.45	6.1004
52	4.333	46.02	568.27	11.365	6.0551	52	4.333	46.03	561.88	11.238	5.987
53	4.417	46.44	560.23	11.205	5.9694	53	4.417	46.46	555.14	11.103	5.9152
54	4.5	46.87	555.98	11.12	5.9242	54	4.5	46.89	552.51	11.05	5.8872
55	4.583	47.29	553.84	11.077	5.9013	55	4.583	47.31	548.68	10.974	5.8463
56	4.667	47.71	551.67	11.033	5.8782	56	4.667	47.73	542.91	10.858	5.7849
57	4.75	48.13	543.01	10.86	5.786	57	4.75	48.15	541.4	10.828	5.7687
58	4.833	48.55	545.8	10.916	5.8156	58	4.833	48.58	536.91	10.738	5.7209
59	4.917	48.98	539.23	10.785	5.7456	59	4.917	49	532.48	10.65	5.6738
60	5	49.4	535.1	10.702	5.7016	60	5	49.42	532.19	10.644	5.6706
61	5.083	49.82	530.44	10.609	5.652	61	5.083	49.84	525.96	10.519	5.6042

Table 18. Temperature ramp test for green lentil

Lentil 1						Lentil 2					
Point No.	Time	Temperat	Shear Stre	Viscosity	Torque	Point No.	Time	Temperat	Shear Stre	Viscosity	Torque
	[min]	[°C]	[Pa]	[Pa·s]	[mN·m]		[min]	[°C]	[Pa]	[Pa·s]	[mN·m]
1	0.083	24.65	531.2	10.626	5.6601	1	0.083	24.9	514.32	10.288	5.4802
2	0.167	24.69	512.1	10.244	5.4566	2	0.167	24.91	500.3	10.008	5.3308
3	0.25	24.76	503.52	10.072	5.3652	3	0.25	24.97	495.64	9.9149	5.2812
4	0.333	24.91	498.37	9.969	5.3102	4	0.333	25.12	491	9.8218	5.2318
5	0.417	25.14	494.98	9.9009	5.2742	5	0.417	25.33	488.67	9.7746	5.2069
6	0.5	25.43	501.19	10.025	5.3403	6	0.5	25.61	484.56	9.6922	5.1632
7	0.583	25.75	491.14	9.8234	5.2332	7	0.583	25.92	479.45	9.5897	5.1087
8	0.667	26.11	483.91	9.6787	5.1563	8	0.667	26.26	473.15	9.4634	5.0416
9	0.75	26.49	481.8	9.6362	5.1337	9	0.75	26.63	471.35	9.4272	5.0223
10	0.833	26.9	482.25	9.6452	5.1385	10	0.833	27.02	471.47	9.4296	5.0237
11	0.917	27.32	481.23	9.6249	5.1277	11	0.917	27.43	472.67	9.4535	5.0364
12	1	27.76	482.7	9.6542	5.1434	12	1	27.86	468.82	9.3764	4.9954
13	1.083	28.22	483.31	9.6663	5.1498	13	1.083	28.3	466.76	9.3353	4.9735
14	1.167	28.7	485.15	9.703	5.1694	14	1.167	28.75	467.1	9.3421	4.9771
15	1.25	29.17	478.16	9.5633	5.095	15	1.25	29.22	462.4	9.248	4.927
16	1.333	29.64	479.93	9.5986	5.1138	16	1.333	29.69	463.69	9.274	4.9408
17	1.417	30.12	479.66	9.5932	5.1109	17	1.417	30.16	462.22	9.2444	4.9251
18	1.5	30.61	476.43	9.5285	5.0765	18	1.5	30.64	459.49	9.1898	4.896
19	1.583	31.09	476.57	9.5315	5.078	19	1.583	31.12	456.47	9.1294	4.8638
20	1.667	31.59	473.35	9.467	5.0437	20	1.667	31.6	456.74	9.1349	4.8667
21	1.75	32.08	468.87	9.3774	4.9959	21	1.75	32.09	455.49	9.1099	4.8534
22	1.833	32.56	464.74	9.2948	4.9519	22	1.833	32.57	453.99	9.0798	4.8374
23	1.917	33.04	461.25	9.2251	4.9148	23	1.917	33.05	454.78	9.0957	4.8458
24	2	33.52	461.34	9.2267	4.9157	24	2	33.53	450.87	9.0175	4.8042
25	2.083	34	457.56	9.1513	4.8755	25	2.083	34.01	449.12	8.9825	4.7855
26	2.167	34.47	454.23	9.0846	4.84	26	2.167	34.48	446.76	8.9352	4.7603
27	2.25	34.94	449.26	8.9852	4.787	27	2.25	34.95	446.3	8.9261	4.7555
28	2.333	35.41	450.36	9.0073	4.7987	28	2.333	35.42	442.41	8.8481	4.714
29	2.417	35.88	443.66	8.8733	4.7274	29	2.417	35.89	440.72	8.8145	4.6961
30	2.5	36.35	444.27	8.8854	4.7339	30	2.5	36.35	438.5	8.7699	4.6723
31	2.583	36.82	438.65	8.773	4.6739	31	2.583	36.82	435.32	8.7064	4.6385
32	2.667	37.28	436.97	8.7395	4.6561	32	2.667	37.27	431.85	8.6371	4.6015
33	2.75	37.73	437.15	8.7431	4.6579	33	2.75	37.73	430.18	8.6037	4.5837
34	2.833	38.18	438.11	8.7622	4.6682	34	2.833	38.18	427.54	8.5508	4.5555
35	2.917	38.63	433.39	8.6679	4.618	35	2.917	38.63	423.97	8.4794	4.5175
36	3	39.08	431.4	8.6279	4.5967	36	3	39.08	422.33	8.4466	4.5
37	3.083	39.52	428.09	8.5618	4.5615	37	3.083	39.53	421.22	8.4244	4.4882
38	3.167	39.96	425.17	8.5034	4.5303	38	3.167	39.97	417.96	8.3593	4.4535
39	3.25	40.4	422.4	8.448	4.5008	39	3.25	40.41	416.01	8.3202	4.4327
40	3.333	40.84	422.52	8.4503	4.5021	40	3.333	40.85	411.77	8.2354	4.3875
41	3.417	41.27	420.24	8.4049	4.4778	41	3.417	41.29	409.79	8.1957	4.3664
42	3.5	41.71	416.33	8.3267	4.4362	42	3.5	41.73	405.98	8.1196	4.3258
43	3.583	42.14	411.4	8.2279	4.3836	43	3.583	42.16	402.44	8.0488	4.2881
44	3.667	42.58	411.5	8.23	4.3846	44	3.667	42.59	400.78	8.0156	4.2704
45	3.75	43.01	408.25	8.1649	4.35	45	3.75	43.03	398.22	7.9644	4.2431
46	3.833	43.44	405.83	8.1167	4.3242	46	3.833	43.46	394.4	7.8879	4.2024
47	3.917	43.87	407.55	8.151	4.3426	47	3.917	43.89	393.38	7.8676	4.1916
48	4	44.29	401.83	8.0365	4.2816	48	4	44.32	386.22	7.7245	4.1153
49	4.083	44.72	398.57	7.9713	4.2468	49	4.083	44.75	382.44	7.6489	4.075
50	4.167	45.15	400.45	8.009	4.2669	50	4.167	45.17	379.63	7.5927	4.0451
51	4.25	45.57	398.51	7.9702	4.2462	51	4.25	45.6	378.23	7.5647	4.0302
52	4.333	46	396.34	7.9267	4.2231	52	4.333	46.03	379.15	7.583	4.04
53	4.417	46.42	395.93	7.9185	4.2187	53	4.417	46.45	377.2	7.544	4.0192
54	4.5	46.84	392.2	7.844	4.179	54	4.5	46.88	375.98	7.5195	4.0061
55	4.583	47.27	393.51	7.8704	4.193	55	4.583	47.3	373.2	7.4641	3.9766
56	4.667	47.69	390.03	7.8007	4.1559	56	4.667	47.72	369.15	7.3831	3.9334
57	4.75	48.11	387.94	7.7587	4.1336	57	4.75	48.15	368.31	7.3663	3.9245
58	4.833	48.54	398.99	7.9798	4.2514	58	4.833	48.57	368.23	7.3647	3.9236
59	4.917	48.96	393.84	7.8767	4.1964	59	4.917	48.99	365.43	7.3087	3.8938
60	5	49.38	392	7.8401	4.1769	60	5	49.41	362.06	7.2411	3.8578
61	5.083	49.81	388.56	7.7712	4.1402	61	5.083	49.83	361.26	7.2253	3.8494

A.4 Dynamic rheology analysis

Table 19. Amplitude sweep test for control oat

Point No.	Shear Strain	Shear Stress	Storage Modulus	Loss Modulus	Loss Factor	Torque	Point No.	Shear Strain	Shear Stress	Storage Modulus	Loss Modulus	Loss Factor
	[%]	[Pa]	[Pa]	[Pa]	[1]	[µN·m]		[%]	[Pa]	[Pa]	[Pa]	[1]
1	0.0101	0.036489	355.11	75.138	0.212	0.16774	1	0.0101	0.036341	353.12	77.431	0.219
2	0.0148	0.053515	355.26	73.534	0.207	0.246	2	0.0148	0.05497	363.91	80.325	0.221
3	0.0216	0.079094	358.78	69.009	0.192	0.36359	3	0.0217	0.08235	372.8	75.241	0.202
4	0.0318	0.12004	371.15	70.122	0.189	0.55181	4	0.0318	0.12089	373.51	72.108	0.193
5	0.0466	0.17785	374.71	70.357	0.188	0.81756	5	0.0466	0.18127	381.6	73.413	0.192
6	0.0685	0.26527	380.28	73.9	0.194	1.2194	6	0.0685	0.27232	390.7	74.287	0.19
7	0.101	0.39685	387.83	74.055	0.191	1.8242	7	0.101	0.40711	398.19	74.259	0.186
8	0.148	0.58886	392.28	73.883	0.188	2.7069	8	0.148	0.60768	404.98	75.27	0.186
9	0.217	0.87827	398.69	74.598	0.187	4.0373	9	0.217	0.90786	412.25	76.339	0.185
10	0.318	1.307	404.31	75.249	0.186	6.0083	10	0.318	1.3566	419.78	77.285	0.184
11	0.466	1.9454	409.99	76.246	0.186	8.9427	11	0.467	2.0291	427.79	78.594	0.184
12	0.685	2.8915	415.08	77.614	0.187	13.292	12	0.685	3.031	435.46	79.521	0.183
13	1.01	4.2653	417.03	78.668	0.189	19.607	13	1.01	4.5026	440.67	80.71	0.183
14	1.48	6.2678	417.33	79.703	0.191	28.812	14	1.48	6.626	441.6	82.078	0.186
15	2.17	9.136	414.09	80.92	0.195	41.997	15	2.17	9.635	437.16	83.005	0.19
16	3.18	13.123	404.66	82.139	0.203	60.327	16	3.18	13.786	425.6	83.841	0.197
17	4.66	18.494	387.59	83.386	0.215	85.017	17	4.67	19.448	408.13	85.027	0.208
18	6.85	25.399	361.08	84.931	0.235	116.76	18	6.85	26.578	378.49	86.049	0.227
19	10.1	33.637	323.05	87.455	0.271	154.62	19	10.1	35.116	338.34	87.228	0.258
20	14.8	42.861	275.96	90.904	0.329	197.03	20	14.8	44.577	288.95	88.411	0.306
21	21.7	51.739	219.91	93.479	0.425	237.84	21	21.7	53.282	229.42	88.971	0.388
22	31.8	58.384	158.67	92.577	0.583	268.38	22	31.8	60.834	169.87	88.212	0.519
23	46.7	67.561	114.56	88.605	0.773	310.57	23	46.6	69.402	122.21	84.845	0.694
24	68.5	78.232	79.709	81.856	1.027	359.62	24	68.5	81.156	87.931	79.472	0.904
25	101	87.991	50.705	71.373	1.408	404.48	25	101	93.851	60.027	71.53	1.192

Table 20. Amplitude sweep test for fava bean

Point No.	Shear Strain	Shear Stress	Storage Modulus	Loss Modulus	Loss Factor	Torque	Point No.	Shear Strain	Shear Stress	Storage Modulus	Loss Modulus	Loss Factor	Torque
	[%]	[Pa]	[Pa]	[Pa]	[1]	[µN·m]		[%]	[Pa]	[Pa]	[Pa]	[1]	[µN·m]
1	0.0101	0.069903	684.77	121.72	0.178	0.32133	1	0.01	0.073806	723.89	123.82	0.171	0.33928
2	0.0148	0.10463	698.15	124.09	0.178	0.48096	2	0.0147	0.11056	739.8	121.41	0.164	0.50821
3	0.0217	0.15471	703.58	124.11	0.176	0.71116	3	0.0217	0.16495	750.32	132.04	0.176	0.75824
4	0.0318	0.23051	713.96	127.69	0.179	1.0596	4	0.0318	0.2478	767.59	136.54	0.178	1.1391
5	0.0467	0.34262	722.92	129.39	0.179	1.575	5	0.0467	0.36831	777.42	137.43	0.177	1.6931
6	0.0685	0.51122	734.97	131.25	0.179	2.35	6	0.0685	0.54744	787.57	137.55	0.175	2.5165
7	0.101	0.75585	740.52	131.31	0.177	3.4745	7	0.101	0.81155	795.36	139.48	0.175	3.7306
8	0.148	1.1141	743.62	132.16	0.178	5.1215	8	0.148	1.2014	802.06	141.16	0.176	5.5228
9	0.217	1.6372	744.31	133.09	0.179	7.526	9	0.217	1.7704	805.34	141.28	0.175	8.1384
10	0.318	2.3998	743.06	134.06	0.18	11.032	10	0.318	2.6039	806.78	142.61	0.177	11.97
11	0.466	3.5075	739.7	134.78	0.182	16.123	11	0.467	3.8075	803.41	143.72	0.179	17.502
12	0.685	5.0932	731.33	135.79	0.186	23.413	12	0.685	5.536	795.41	144.84	0.182	25.448
13	1.01	7.3262	715.92	137.18	0.192	33.677	13	1.01	7.9901	781.29	146.96	0.188	36.73
14	1.48	10.417	692.38	138.75	0.2	47.887	14	1.48	11.403	758.19	150.36	0.198	52.417
15	2.17	14.621	660.36	140.93	0.213	67.21	15	2.17	16.022	723.55	154.8	0.214	73.649
16	3.18	20.166	618.04	143.51	0.232	92.699	16	3.18	22.047	674.77	160.95	0.239	101.35
17	4.67	27.126	562.33	148.02	0.263	124.7	17	4.67	29.581	610.85	170.15	0.279	135.98
18	6.85	35.298	491.1	156.73	0.319	162.26	18	6.85	38.717	535.57	181.31	0.339	177.98
19	10.1	44.198	406.69	167.3	0.411	203.17	19	10.1	49.472	454.42	189.2	0.416	227.41
20	14.8	53.239	318.86	169.02	0.53	244.73	20	14.8	61.352	370.8	188.33	0.508	282.03
21	21.7	63.988	246.59	162.85	0.66	294.14	21	21.7	74.231	291.74	180.04	0.617	341.23
22	31.8	75.117	182.34	150.37	0.825	345.3	22	31.8	87.517	219.82	165.84	0.754	402.31
23	46.7	87.741	131.17	134.79	1.028	403.33	23	46.6	100.92	157.13	148.7	0.946	463.93
24	68.5	100.49	88.576	117.02	1.321	461.94	24	68.5	113.43	103.48	129.36	1.25	521.41
25	101	113.78	55.893	98.451	1.761	523.04	25	101	126.5	63.986	108.38	1.694	581.48

Table 21. Amplitude sweep test for green lentil

Point No.	Shear Strain	Shear Stress	Storage Modulus	Loss Modulus	Loss Factor	Torque	Point No.	Shear Strain	Shear Stress	Storage Modulus	Loss Modulus	Loss Factor	Torque
	[%]	[Pa]	[Pa]	[Pa]	[1]	[µN·m]		[%]	[Pa]	[Pa]	[Pa]	[1]	[µN·m]
1	0.01	0.058264	571.17	100.15	0.175	0.26783	1	0.01	0.061741	606.52	98.71	0.163	0.28382
2	0.0147	0.087961	586.26	109.4	0.187	0.40434	2	0.0148	0.093379	623.3	110.7	0.178	0.42925
3	0.0217	0.13183	600.15	102.88	0.171	0.60601	3	0.0217	0.13979	635.04	116.04	0.183	0.6426
4	0.0318	0.19745	611.74	108.04	0.177	0.90766	4	0.0318	0.20776	643.55	114.71	0.178	0.95505
5	0.0466	0.29385	620.1	110.79	0.179	1.3508	5	0.0467	0.31119	656.44	118.56	0.181	1.4305
6	0.0685	0.43755	629.22	111.31	0.177	2.0114	6	0.0685	0.46221	665.01	116.22	0.175	2.1247
7	0.101	0.64925	635.96	113.36	0.178	2.9845	7	0.101	0.68187	667.62	120.7	0.181	3.1345
8	0.148	0.96141	641.66	113.98	0.178	4.4195	8	0.148	1.0066	671.73	119.99	0.179	4.6273
9	0.217	1.4226	646.79	115.26	0.178	6.5394	9	0.217	1.4782	671.96	120.53	0.179	6.7951
10	0.318	2.1064	652.37	116.8	0.179	9.6827	10	0.318	2.1657	670.64	120.7	0.18	9.9553
11	0.466	3.1003	653.97	118.31	0.181	14.252	11	0.467	3.1603	666.6	120.76	0.181	14.528
12	0.685	4.5334	651.14	119.83	0.184	20.839	12	0.685	4.5983	660.52	121.23	0.184	21.138
13	1.01	6.5543	640.83	120.88	0.189	30.129	13	1.01	6.6547	650.75	122.27	0.188	30.591
14	1.48	9.3688	623.18	122.36	0.196	43.067	14	1.48	9.5451	635.04	124.01	0.195	43.878
15	2.17	13.258	599.32	125.34	0.209	60.945	15	2.17	13.509	611.08	125.71	0.206	62.097
16	3.18	18.418	564.76	129.85	0.23	84.664	16	3.18	18.82	578.07	128.29	0.222	86.511
17	4.67	24.99	518.16	135.96	0.262	114.88	17	4.66	25.663	534.03	132.09	0.247	117.97
18	6.85	32.971	459.56	143.74	0.313	151.56	18	6.85	34.195	480.04	137.68	0.287	157.19
19	10.1	42.343	393.5	150.51	0.382	194.65	19	10.1	44.177	414.78	145.47	0.351	203.08
20	14.8	53.138	325.94	153.33	0.47	244.27	20	14.8	55.754	346.4	151.14	0.436	256.3
21	21.7	64.428	256.75	150.37	0.586	296.17	21	21.7	68.435	277.59	151.11	0.544	314.59
22	31.8	76.722	194.68	142.72	0.733	352.68	22	31.8	81.54	211.43	145.31	0.687	374.83
23	46.7	90.516	142.75	131.42	0.921	416.09	23	46.6	95.033	152.33	135.27	0.888	436.86
24	68.5	104.71	98.35	117.09	1.191	481.32	24	68.5	109.27	103.29	121.65	1.178	502.31
25	101	118.54	63.055	99.673	1.581	544.91	25	101	122.82	65.051	103.45	1.59	564.57

Table 22. Amplitude sweep test for chickpea

Point No.	Shear Strain	Shear Stress	Storage Modulus	Loss Modulus	Loss Factor	Torque	Point No.	Shear Strain	Shear Stress	Storage Modulus	Loss Modulus	Loss Factor	Torque
	[%]	[Pa]	[Pa]	[Pa]	[1]	[µN·m]		[%]	[Pa]	[Pa]	[Pa]	[1]	[µN·m]
1	0.0101	0.056866	557.3	97.796	0.175	0.26141	1	0.01	0.058467	572.77	102.27	0.179	0.26876
2	0.0147	0.086601	577.87	103.89	0.18	0.39809	2	0.0147	0.087584	585.33	100.33	0.171	0.40261
3	0.0217	0.12825	583.32	102.97	0.177	0.58953	3	0.0217	0.1302	591.57	107.44	0.182	0.59851
4	0.0318	0.18854	583.96	104.36	0.179	0.8667	4	0.0318	0.19546	604.41	113.42	0.188	0.89849
5	0.0467	0.28226	595.73	105.6	0.177	1.2975	5	0.0466	0.29015	612.15	110.2	0.18	1.3338
6	0.0685	0.41883	602.55	105.36	0.175	1.9253	6	0.0685	0.43102	619.82	110.14	0.178	1.9813
7	0.101	0.61977	607.37	106.75	0.176	2.849	7	0.101	0.6409	627.57	113.02	0.18	2.9461
8	0.148	0.91429	610.51	106.87	0.175	4.2029	8	0.148	0.94667	631.53	113.77	0.18	4.3517
9	0.217	1.3468	612.46	108.47	0.177	6.1912	9	0.217	1.3993	635.93	114.96	0.181	6.4323
10	0.318	1.9754	612.1	108.11	0.177	9.0809	10	0.318	2.062	638.34	115.93	0.182	9.4785
11	0.466	2.8854	608.95	108.46	0.178	13.264	11	0.467	3.0236	637.6	116.38	0.183	13.899
12	0.685	4.197	603.21	108.74	0.18	19.293	12	0.685	4.4072	632.93	117	0.185	20.259
13	1.01	6.0818	595.19	109.22	0.183	27.957	13	1.01	6.3739	623.2	117.61	0.189	29.3
14	1.48	8.7385	582.04	110.1	0.189	40.17	14	1.48	9.1374	607.96	118.51	0.195	42.004
15	2.17	12.419	562.63	111.29	0.198	57.087	15	2.17	12.948	585.63	120.91	0.206	59.521
16	3.18	17.367	534.6	113.13	0.212	79.834	16	3.18	17.977	551.54	125.49	0.228	82.639
17	4.67	23.85	498	115.62	0.232	109.63	17	4.67	24.305	503.59	133.56	0.265	111.73
18	6.85	31.942	450.94	119.44	0.265	146.83	18	6.85	31.993	443.41	147.28	0.332	147.07
19	10.1	41.376	391.79	126.43	0.323	190.2	19	10.1	41.251	378.66	158.33	0.418	189.62
20	14.8	51.785	323.71	135.78	0.419	238.05	20	14.8	51.803	311.94	161.25	0.517	238.13
21	21.7	63.249	256.31	140.1	0.547	290.75	21	21.7	63.309	246.56	157.14	0.637	291.02
22	31.8	75.958	195.23	137.86	0.706	349.17	22	31.8	75.731	186.79	147.94	0.792	348.12
23	46.7	89.611	141.84	129.54	0.913	411.93	23	46.7	87.818	132.54	133.68	1.009	403.69
24	68.5	102.42	94.918	115.6	1.218	470.79	24	68.5	100.44	89.022	116.59	1.31	461.71
25	101	113.34	58.888	96.18	1.633	521.03	25	101	112.53	56.208	96.837	1.723	517.29

Table 23. Amplitude sweep test for pea protein

Point No.	Shear Strain	Shear Stress	Storage Modulus	Loss Modulus	Loss Factor	Torque	Point No.	Shear Strain	Shear Stress	Storage Modulus	Loss Modulus	Loss Factor	Torque
	[%]	[Pa]	[Pa]	[Pa]	[1]	[µN·m]		[%]	[Pa]	[Pa]	[Pa]	[1]	[µN·m]
1	0.01	0.08539	837.97	140.72	0.168	0.39253	1	0.0101	0.087572	859.67	141.92	0.165	0.40256
2	0.0148	0.12816	856.23	147.77	0.173	0.58915	2	0.0148	0.13128	876.54	150.55	0.172	0.60348
3	0.0217	0.18945	861.35	153.17	0.178	0.87089	3	0.0217	0.19735	897.47	159.09	0.177	0.90718
4	0.0318	0.28521	883.96	154.46	0.175	1.3111	4	0.0318	0.29326	909.87	154.05	0.169	1.3481
5	0.0467	0.42235	892.03	154.5	0.173	1.9415	5	0.0466	0.44139	932.29	161.7	0.173	2.029
6	0.0685	0.62788	903.62	155.63	0.172	2.8863	6	0.0685	0.65633	944.6	162.58	0.172	3.0171
7	0.101	0.92921	911.12	156.89	0.172	4.2714	7	0.1	0.97677	958.15	162.94	0.17	4.4901
8	0.148	1.3735	917.52	158.04	0.172	6.3137	8	0.148	1.4506	969.38	165.06	0.17	6.6684
9	0.217	2.0247	921.38	159.33	0.173	9.3071	9	0.217	2.1447	976.18	167.68	0.172	9.859
10	0.318	2.9728	921.51	160.24	0.174	13.666	10	0.318	3.162	980.31	169.68	0.173	14.535
11	0.467	4.3438	917.07	161.26	0.176	19.968	11	0.467	4.6459	980.9	172.19	0.176	21.357
12	0.685	6.3001	905.64	162.42	0.179	28.961	12	0.685	6.7719	973.21	175.86	0.181	31.13
13	1.01	9.0899	889.01	166.24	0.187	41.785	13	1.01	9.7378	951.96	180.29	0.189	44.764
14	1.48	12.943	860.2	172.85	0.201	59.499	14	1.48	13.8	916.35	188.11	0.205	63.436
15	2.17	18.133	817.1	183.36	0.224	83.354	15	2.17	19.168	862.38	199.89	0.232	88.113
16	3.18	24.969	760.03	198.86	0.262	114.78	16	3.18	25.954	787.83	214.94	0.273	119.31
17	4.67	33.607	687.15	216.36	0.315	154.49	17	4.67	34.165	694.4	232.71	0.335	157.05
18	6.85	44.153	602.35	230.12	0.382	202.96	18	6.85	43.956	593.51	244.61	0.412	202.06
19	10.1	56.27	509.37	232.36	0.456	258.66	19	10.1	55.336	492.4	246.33	0.5	254.37
20	14.8	69.745	415.72	225.15	0.542	320.61	20	14.8	68.163	395.63	238.68	0.603	313.33
21	21.7	83.025	319.99	211.25	0.66	381.66	21	21.7	82.699	308.7	224.89	0.729	380.16
22	31.8	97.671	238.35	194	0.814	448.98	22	31.8	98.808	233.39	205.38	0.88	454.21
23	46.6	113.1	170.07	172.8	1.016	519.92	23	46.7	115.46	167.59	182.12	1.087	530.75
24	68.5	128.26	113.67	148.89	1.31	589.61	24	68.5	132.56	113.53	156.8	1.381	609.35
25	101	143.22	70.832	123.66	1.746	658.37	25	101	149.69	72.42	130.15	1.797	688.12

Table 24. Amplitude sweep test for mung bean

Point No.	Shear Strain	Shear Stress	Storage Modulus	Loss Modulus	Loss Factor	Torque	Point No.	Shear Strain	Shear Stress	Storage Modulus	Loss Modulus	Loss Factor
	[%]	[Pa]	[Pa]	[Pa]	[1]	[µN·m]		[%]	[Pa]	[Pa]	[Pa]	[1]
1	0.01	0.088678	870.33	145.65	0.167	0.40764	1	0.01	0.08755	858.95	145.37	0.169
2	0.0148	0.13381	895.65	144.15	0.161	0.61511	2	0.0147	0.13005	869.89	144.38	0.166
3	0.0217	0.19859	904.83	150.12	0.166	0.91291	3	0.0217	0.19506	888.29	148.65	0.167
4	0.0318	0.2932	910.35	149.81	0.165	1.3478	4	0.0318	0.28759	892.29	150.41	0.169
5	0.0467	0.43585	921.78	152.33	0.165	2.0035	5	0.0467	0.42733	903.12	152.78	0.169
6	0.0685	0.64621	930.73	156.24	0.168	2.9705	6	0.0685	0.63117	909.03	152.44	0.168
7	0.101	0.95673	938.87	157.2	0.167	4.3979	7	0.101	0.93547	917.79	154.68	0.169
8	0.148	1.412	944.02	158.1	0.167	6.4909	8	0.148	1.378	921.08	155.33	0.169
9	0.217	2.0792	946.9	159.59	0.169	9.5579	9	0.217	2.0234	921.2	156.74	0.17
10	0.318	3.053	946.97	161.32	0.17	14.034	10	0.318	2.9628	918.59	158.78	0.173
11	0.467	4.4597	941.86	163.68	0.174	20.5	11	0.467	4.3109	910.02	160.55	0.176
12	0.685	6.458	928.11	167.74	0.181	29.687	12	0.685	6.2312	895.33	162.91	0.182
13	1.01	9.2255	901.46	173.11	0.192	42.409	13	1.01	8.9119	870.69	167.82	0.193
14	1.48	12.927	857.3	181.32	0.212	59.423	14	1.48	12.513	829.79	175.79	0.212
15	2.17	17.676	792.86	194.22	0.245	81.252	15	2.17	17.133	768.51	188.34	0.245
16	3.18	23.407	704.05	216.07	0.307	107.6	16	3.18	22.779	686.25	206.71	0.301
17	4.67	30.333	605.88	236.03	0.39	139.44	17	4.67	29.578	594.11	221.45	0.373
18	6.85	38.254	502.01	245.16	0.488	175.85	18	6.85	37.627	500.57	226.72	0.453
19	10.1	47.045	402.53	238.91	0.594	216.26	19	10.1	46.734	408.36	222.39	0.545
20	14.8	56.943	315.3	222.67	0.706	261.76	20	14.8	56.971	323.85	210.38	0.65
21	21.7	67.947	240.53	201.53	0.838	312.34	21	21.7	68.585	250.8	193.46	0.771
22	31.8	80.482	179.25	178.87	0.998	369.96	22	31.8	81.8	189.42	174.26	0.92
23	46.6	94.869	129.74	156.6	1.207	436.1	23	46.6	95.394	136.33	152.42	1.118
24	68.5	112.22	91.526	135.96	1.485	515.87	24	68.5	112.3	96.346	132.73	1.378
25	101	132.11	62.218	115.79	1.861	607.31	25	101	131.56	65.362	113.41	1.735

Table 25. Frequency sweep test for control oat

Point No.	Angular Frequency	Storage Modulus	Loss Modulus	Loss Factor	Shear Strain	Shear Stress	Torque	Point No.	Angular Frequency	Storage Modulus	Loss Modulus	Loss Factor	Shear Strain	Shear Stress	Torque
	[rad/s]	[Pa]	[Pa]	[1]	[%]	[Pa]	[mN·m]		[rad/s]	[Pa]	[Pa]	[1]	[%]	[Pa]	[mN·m]
1	1	246.2	48.002	0.195	0.503	1.2605	0.005794	1	1	261.98	51.077	0.195	0.503	1.3413	0.006166
2	1.26	264.65	49.663	0.188	0.503	1.3531	0.00622	2	1.26	280.07	52.337	0.187	0.503	1.4318	0.006582
3	1.58	282.75	52.14	0.184	0.503	1.4448	0.006642	3	1.58	299.96	54.992	0.183	0.503	1.5325	0.007045
4	2	302.11	54.861	0.182	0.503	1.543	0.007093	4	2	320.16	57.827	0.181	0.503	1.6349	0.007515
5	2.51	320.44	57.66	0.18	0.503	1.6362	0.007521	5	2.51	339.09	60.517	0.178	0.503	1.7309	0.007957
6	3.16	336.8	60.304	0.179	0.503	1.7194	0.007904	6	3.16	357.17	63.234	0.177	0.503	1.8228	0.008379
7	3.98	351.59	62.87	0.179	0.503	1.7948	0.008251	7	3.98	373.94	65.819	0.176	0.503	1.908	0.008771
8	5.01	365.79	65.693	0.18	0.503	1.8676	0.008585	8	5.01	390.51	68.83	0.176	0.503	1.9927	0.00916
9	6.31	379.3	68.127	0.18	0.503	1.9366	0.008902	9	6.31	406.41	72.01	0.177	0.503	2.0741	0.009535
10	7.94	392.6	71.218	0.181	0.503	2.0051	0.009217	10	7.94	421.38	75.188	0.178	0.503	2.151	0.009888
11	10	405.4	73.848	0.182	0.503	2.0707	0.009519	11	10	435.84	78.571	0.18	0.503	2.2255	0.01023
12	12.6	417.99	77.161	0.185	0.503	2.136	0.009819	12	12.6	449.25	82.447	0.184	0.503	2.2953	0.010551
13	15.8	430.78	80.652	0.187	0.503	2.2024	0.010124	13	15.8	463.29	85.622	0.185	0.503	2.3676	0.010883
14	20	444.21	84.129	0.189	0.503	2.2719	0.010444	14	20	476.7	89.541	0.188	0.503	2.4374	0.011204
15	25.1	457.78	88.163	0.193	0.503	2.3428	0.01077	15	25.1	489.13	94.185	0.193	0.503	2.5031	0.011507
16	31.6	471.61	93.337	0.198	0.503	2.4159	0.011105	16	31.6	501.64	99.065	0.197	0.503	2.5696	0.011812
17	39.8	484.44	95.317	0.197	0.503	2.4811	0.011405	17	39.8	514.29	102.37	0.199	0.503	2.6351	0.012113
18	50.1	499.03	99.825	0.2	0.502	2.5573	0.011755	18	50.1	525.97	106.86	0.203	0.503	2.697	0.012398
19	63.1	512.56	103.81	0.203	0.503	2.628	0.012081	19	63.1	534.96	111.99	0.209	0.503	2.7465	0.012625
20	79.4	527.12	107.1	0.203	0.502	2.7029	0.012425	20	79.4	541.58	115.96	0.214	0.503	2.7836	0.012796
21	100	540.91	110.22	0.204	0.503	2.7741	0.012752	21	100	541.52	120.94	0.223	0.503	2.7885	0.012819

Table 26. Frequency sweep test for chickpea

Point No.	Angular Frequency	Storage Modulus	Loss Modulus	Loss Factor	Shear Strain	Shear Stress	Torque	Point No.	Angular Frequency	Storage Modulus	Loss Modulus	Loss Factor	Shear Strain	Shear Stress	Torque
	[rad/s]	[Pa]	[Pa]	[1]	[%]	[Pa]	[mN·m]		[rad/s]	[Pa]	[Pa]	[1]	[%]	[Pa]	[mN·m]
1	1	440.72	78.343	0.178	0.503	2.2494	0.01034	1	1	329.46	64.797	0.197	0.503	1.6873	0.007756
2	1.26	476.76	82.803	0.174	0.503	2.4317	0.011178	2	1.26	361.62	68.793	0.19	0.503	1.8498	0.008503
3	1.58	510.77	87.717	0.172	0.503	2.6043	0.011972	3	1.58	389.92	73.103	0.187	0.503	1.9936	0.009164
4	2	536.33	91.469	0.171	0.503	2.7341	0.012568	4	2	412.96	76.48	0.185	0.503	2.1105	0.009702
5	2.51	555.45	94.099	0.169	0.503	2.831	0.013014	5	2.51	432.87	79.723	0.184	0.503	2.2119	0.010168
6	3.16	572.44	96.406	0.168	0.503	2.9171	0.01341	6	3.16	451.19	82.378	0.183	0.503	2.3048	0.010595
7	3.98	588.78	98.966	0.168	0.503	3.0002	0.013792	7	3.98	468.95	85.223	0.182	0.503	2.3952	0.01101
8	5.01	606.56	101.58	0.167	0.503	3.0905	0.014207	8	5.01	485.94	88.473	0.182	0.503	2.4821	0.01141
9	6.31	624.38	104.62	0.168	0.503	3.1814	0.014624	9	6.31	502.91	91.821	0.183	0.503	2.569	0.011809
10	7.94	642.58	108.14	0.168	0.503	3.2745	0.015052	10	7.94	518.33	95.235	0.184	0.503	2.6483	0.012174
11	10	660.33	112.07	0.17	0.503	3.3658	0.015472	11	10	533.33	98.73	0.185	0.503	2.7256	0.012529
12	12.6	678.13	116.05	0.171	0.503	3.4573	0.015893	12	12.6	547.46	102.03	0.186	0.503	2.7985	0.012864
13	15.8	696.1	120.06	0.172	0.503	3.5497	0.016318	13	15.8	563.43	105.74	0.188	0.502	2.8807	0.013242
14	20	715.16	124.86	0.175	0.503	3.6482	0.01677	14	20	577.2	110.29	0.191	0.503	2.953	0.013575
15	25.1	734.89	130.19	0.177	0.503	3.7504	0.01724	15	25.1	589.58	114.85	0.195	0.503	3.0184	0.013875
16	31.6	754.79	136.2	0.18	0.503	3.8542	0.017717	16	31.6	600.07	120.21	0.2	0.503	3.0753	0.014137
17	39.8	774.84	140.51	0.181	0.503	3.9571	0.01819	17	39.8	606.71	123.88	0.204	0.503	3.1117	0.014304
18	50.1	796.18	146.23	0.184	0.503	4.0679	0.0187	18	50.1	610.13	129.03	0.211	0.503	3.1339	0.014406
19	63.1	817.95	152.35	0.186	0.503	4.181	0.01922	19	63.1	606.44	134.22	0.221	0.503	3.1212	0.014348
20	79.4	839.13	158.74	0.189	0.503	4.2917	0.019728	20	79.4	589.9	140.24	0.238	0.503	3.0469	0.014006
21	100	862.03	162.61	0.189	0.502	4.4078	0.020262	21	100	557.45	147.34	0.264	0.503	2.8984	0.013323

Table 27. Frequency sweep test for green lentil

Point No.	Angular Frequency	Storage Modulus	Loss Modulus	Loss Factor	Shear Strain	Shear Stress	Torque	Point No.	Angular Frequency	Storage Modulus	Loss Modulus	Loss Factor	Shear Strain	Shear Stress	Torque
	[rad/s]	[Pa]	[Pa]	[1]	[%]	[Pa]	[mN·m]		[rad/s]	[Pa]	[Pa]	[1]	[%]	[Pa]	[mN·m]
1	1	390.45	76.531	0.196	0.503	1.9995	0.009191	1	1	421.36	83.418	0.198	0.503	2.1585	0.009923
2	1.26	422.67	79.431	0.188	0.503	2.1612	0.009935	2	1.26	463.87	89.702	0.193	0.503	2.3743	0.010914
3	1.58	448.68	84.195	0.188	0.503	2.294	0.010545	3	1.58	504.39	97.606	0.194	0.503	2.5817	0.011868
4	2	469	88.873	0.189	0.503	2.3987	0.011027	4	2	533.6	102.17	0.191	0.503	2.7301	0.01255
5	2.51	486.68	91.944	0.189	0.503	2.4889	0.011441	5	2.51	556.8	104.94	0.188	0.503	2.8473	0.013089
6	3.16	504.44	94.335	0.187	0.503	2.5789	0.011855	6	3.16	575.16	107.17	0.186	0.503	2.9401	0.013515
7	3.98	521.29	96.889	0.186	0.503	2.6644	0.012248	7	3.98	593.13	109.46	0.185	0.503	3.0309	0.013933
8	5.01	538.41	99.578	0.185	0.503	2.7515	0.012648	8	5.01	610.19	112.03	0.184	0.503	3.1176	0.014331
9	6.31	556.01	102.23	0.184	0.503	2.8409	0.013059	9	6.31	626.87	114.74	0.183	0.503	3.2025	0.014722
10	7.94	573.31	105.66	0.184	0.503	2.9295	0.013467	10	7.94	644.03	117.72	0.183	0.503	3.29	0.015124
11	10	591.07	109.27	0.185	0.503	3.0206	0.013885	11	10	660.47	121.42	0.184	0.503	3.3746	0.015513
12	12.6	609.55	112.94	0.185	0.503	3.1152	0.01432	12	12.6	677.04	125.01	0.185	0.503	3.4598	0.015904
13	15.8	629.23	116.87	0.186	0.502	3.2159	0.014783	13	15.8	694.63	129.28	0.186	0.503	3.5505	0.016321
14	20	649.93	121.34	0.187	0.503	3.3225	0.015273	14	20	712.02	134.66	0.189	0.503	3.6415	0.016739
15	25.1	673.37	126.56	0.188	0.503	3.443	0.015827	15	25.1	728.36	140.45	0.193	0.503	3.7276	0.017135
16	31.6	700.02	132.51	0.189	0.503	3.5802	0.016458	16	31.6	744.14	147.09	0.198	0.503	3.8119	0.017523
17	39.8	730.89	136.99	0.187	0.503	3.7368	0.017178	17	39.8	755.96	152.68	0.202	0.503	3.8756	0.017816
18	50.1	769.31	143.15	0.186	0.503	3.9323	0.018076	18	50.1	764.27	160.58	0.21	0.503	3.9244	0.01804
19	63.1	818.76	149.46	0.183	0.503	4.1824	0.019226	19	63.1	763.74	168.65	0.221	0.503	3.9303	0.018067
20	79.4	886.36	155.72	0.176	0.502	4.5217	0.020785	20	79.4	749.39	176.99	0.236	0.503	3.8695	0.017788
21	100	978.68	162.88	0.166	0.503	4.9858	0.022919	21	100	710.63	183.2	0.258	0.503	3.6882	0.016954

Table 28. Frequency sweep test for fava bean

Point No.	Angular Frequency	Storage Modulus	Loss Modulus	Loss Factor	Shear Strain	Shear Stress	Torque	Point No.	Angular Frequency	Storage Modulus	Loss Modulus	Loss Factor	Shear Strain	Shear Stress	Torque
	[rad/s]	[Pa]	[Pa]	[1]	[%]	[Pa]	[mN·m]		[rad/s]	[Pa]	[Pa]	[1]	[%]	[Pa]	[mN·m]
1	1	493.94	94.374	0.191	0.503	2.5271	0.011617	1	1	533.47	106.08	0.199	0.503	2.7333	0.012565
2	1.26	541.83	101.96	0.188	0.503	2.7706	0.012736	2	1.26	582.8	112.97	0.194	0.503	2.9832	0.013713
3	1.58	578.59	108.86	0.188	0.503	2.9586	0.0136	3	1.58	631.91	121.52	0.192	0.503	3.2337	0.014865
4	2	606.14	112.97	0.186	0.503	3.0984	0.014243	4	2	669.65	128.09	0.191	0.503	3.4261	0.01575
5	2.51	630.3	116.39	0.185	0.503	3.2209	0.014806	5	2.51	700.11	133.04	0.19	0.503	3.5812	0.016462
6	3.16	651.38	119.31	0.183	0.503	3.3278	0.015297	6	3.16	729.99	137.07	0.188	0.503	3.7324	0.017158
7	3.98	670.9	122.29	0.182	0.503	3.427	0.015753	7	3.98	756.85	141.11	0.186	0.503	3.8689	0.017785
8	5.01	689.39	125.37	0.182	0.503	3.5212	0.016186	8	5.01	782.33	145.05	0.185	0.503	3.9983	0.01838
9	6.31	707.29	128.86	0.182	0.503	3.6128	0.016608	9	6.31	807.08	149.16	0.185	0.503	4.1244	0.01896
10	7.94	726.14	132.79	0.183	0.503	3.7095	0.017052	10	7.94	831.49	153.82	0.185	0.503	4.2494	0.019534
11	10	746.14	137.62	0.184	0.503	3.8128	0.017527	11	10	856.22	159.11	0.186	0.503	4.3764	0.020118
12	12.6	767.16	142.62	0.186	0.503	3.9213	0.018026	12	12.6	878.68	164.73	0.187	0.503	4.4925	0.020651
13	15.8	788.83	147.58	0.187	0.503	4.0329	0.018539	13	15.8	901.57	170.16	0.189	0.503	4.6104	0.021193
14	20	811.58	153.21	0.189	0.503	4.1503	0.019078	14	20	926.45	176.79	0.191	0.503	4.7396	0.021787
15	25.1	835.21	159.52	0.191	0.503	4.2729	0.019642	15	25.1	952.29	183.74	0.193	0.503	4.8736	0.022403
16	31.6	861.06	166.61	0.193	0.503	4.4072	0.020259	16	31.6	980.45	191.82	0.196	0.503	5.0204	0.023078
17	39.8	888.13	172.43	0.194	0.503	4.5464	0.020899	17	39.8	1009.6	198.42	0.197	0.503	5.1704	0.023768
18	50.1	919.62	179.99	0.196	0.503	4.7089	0.021646	18	50.1	1040.9	207.28	0.199	0.503	5.3333	0.024516
19	63.1	956.52	187.1	0.196	0.503	4.8979	0.022515	19	63.1	1074.4	215.61	0.201	0.503	5.5068	0.025314
20	79.4	1001.9	194.65	0.194	0.502	5.1283	0.023574	20	79.4	1110.3	224.4	0.202	0.502	5.6919	0.026165
21	100	1058.1	198.73	0.188	0.503	5.4111	0.024874	21	100	1147.6	231.51	0.202	0.502	5.8818	0.027038

Table 29. Frequency sweep test for pea protein

Point No.	Angular Frequency	Storage Modulus	Loss Modulus	Loss Factor	Shear Strain	Shear Stress	Torque	Point No.	Angular Frequency	Storage Modulus	Loss Modulus	Loss Factor	Shear Strain	Shear Stress	Torque
	[rad/s]	[Pa]	[Pa]	[1]	[%]	[Pa]	[mN·m]		[rad/s]	[Pa]	[Pa]	[1]	[%]	[Pa]	[mN·m]
1	1	505.65	95.308	0.188	0.503	2.5857	0.011886	1	1	530.55	105.27	0.198	0.503	2.7181	0.012495
2	1.26	545.41	100.47	0.184	0.503	2.7869	0.012811	2	1.26	578.12	109.83	0.19	0.503	2.9572	0.013594
3	1.58	581.86	105.43	0.181	0.503	2.9716	0.01366	3	1.58	619.26	115.82	0.187	0.503	3.1659	0.014553
4	2	613.08	110.12	0.18	0.503	3.1302	0.014389	4	2	649.16	120.71	0.186	0.503	3.3181	0.015253
5	2.51	640.73	114.35	0.178	0.503	3.2707	0.015035	5	2.51	676.24	124.19	0.184	0.503	3.4551	0.015883
6	3.16	665.47	118.58	0.178	0.503	3.3968	0.015615	6	3.16	700.81	127.66	0.182	0.503	3.5796	0.016455
7	3.98	689.39	122.42	0.178	0.503	3.5186	0.016174	7	3.98	723.56	130.73	0.181	0.503	3.6949	0.016985
8	5.01	712.41	126.75	0.178	0.503	3.6363	0.016715	8	5.01	745.83	134.82	0.181	0.503	3.8087	0.017508
9	6.31	735.68	131.57	0.179	0.503	3.7556	0.017264	9	6.31	767.16	139.04	0.181	0.503	3.918	0.01801
10	7.94	759.45	136.53	0.18	0.503	3.8775	0.017824	10	7.94	788.91	143.43	0.182	0.503	4.0294	0.018523
11	10	783.57	141.98	0.181	0.503	4.0017	0.018395	11	10	811.75	148.19	0.183	0.503	4.1466	0.019062
12	12.6	809	146.98	0.182	0.503	4.1319	0.018994	12	12.6	835.82	153.31	0.183	0.503	4.2702	0.01963
13	15.8	835.02	153.15	0.183	0.503	4.2662	0.019611	13	15.8	860.17	158.85	0.185	0.503	4.3956	0.020206
14	20	863.62	159.44	0.185	0.503	4.4132	0.020287	14	20	885.88	164.7	0.186	0.503	4.528	0.020815
15	25.1	894.67	166.06	0.186	0.503	4.5725	0.021019	15	25.1	914.36	171.57	0.188	0.503	4.6749	0.02149
16	31.6	930.4	173.82	0.187	0.503	4.7563	0.021864	16	31.6	943.68	178.97	0.19	0.503	4.8266	0.022187
17	39.8	972.77	180.08	0.185	0.503	4.9715	0.022853	17	39.8	975.06	186.1	0.191	0.503	4.9883	0.02293
18	50.1	1027.6	188.31	0.183	0.503	5.25	0.024134	18	50.1	1010.9	193.71	0.192	0.503	5.1725	0.023777
19	63.1	1099.6	196.04	0.178	0.503	5.6128	0.025801	19	63.1	1053.5	202.21	0.192	0.503	5.3906	0.02478
20	79.4	1199.9	202.39	0.169	0.503	6.1157	0.028113	20	79.4	1102.4	210.15	0.191	0.503	5.6397	0.025925
21	100	1343	212.95	0.159	0.502	6.8321	0.031406	21	100	1168.3	219.78	0.188	0.503	5.974	0.027462

Table 30. Frequency sweep test for mung bean

Point No.	Angular Frequency	Storage Modulus	Loss Modulus	Loss Factor	Shear Strain	Shear Stress	Torque	Point No.	Angular Frequency	Storage Modulus	Loss Modulus	Loss Factor	Shear Strain	Shear Stress	Torque
	[rad/s]	[Pa]	[Pa]	[1]	[%]	[Pa]	[mN·m]		[rad/s]	[Pa]	[Pa]	[1]	[%]	[Pa]	[mN·m]
1	1	491.45	93.888	0.191	0.503	2.5143	0.011558	1	1	458.67	92.079	0.201	0.503	2.3509	0.010807
2	1.26	536.29	100.34	0.187	0.503	2.7417	0.012603	2	1.26	504.79	99.666	0.197	0.503	2.5857	0.011886
3	1.58	569.1	105.6	0.186	0.503	2.9087	0.013371	3	1.58	540.76	106.39	0.197	0.503	2.7695	0.012731
4	2	597.9	109.67	0.183	0.503	3.0547	0.014042	4	2	566.71	110.65	0.195	0.503	2.9016	0.013338
5	2.51	623.16	113.27	0.182	0.503	3.1828	0.014631	5	2.51	588.19	113.03	0.192	0.503	3.0098	0.013836
6	3.16	646.2	116.72	0.181	0.503	3.2998	0.015169	6	3.16	607.92	115.41	0.19	0.503	3.1095	0.014294
7	3.98	665.88	121.02	0.182	0.503	3.401	0.015634	7	3.98	626.92	117.61	0.188	0.503	3.2054	0.014735
8	5.01	685.19	124.83	0.182	0.503	3.4999	0.016088	8	5.01	644.25	120.69	0.187	0.503	3.2938	0.015141
9	6.31	705.9	130.24	0.185	0.503	3.6072	0.016582	9	6.31	661.07	123.65	0.187	0.503	3.3796	0.015536
10	7.94	724.63	134.38	0.185	0.503	3.7035	0.017025	10	7.94	678.43	126.89	0.187	0.503	3.4683	0.015943
11	10	743.15	138	0.186	0.503	3.7983	0.01746	11	10	696.33	130.57	0.188	0.503	3.5602	0.016366
12	12.6	760.61	142.81	0.188	0.503	3.8891	0.017878	12	12.6	715.49	134.37	0.188	0.503	3.6583	0.016817
13	15.8	779.83	147.36	0.189	0.503	3.988	0.018332	13	15.8	735.17	138.92	0.189	0.503	3.7597	0.017283
14	20	796.53	151.93	0.191	0.503	4.0749	0.018732	14	20	755.87	143.81	0.19	0.503	3.8666	0.017774
15	25.1	813.42	158.17	0.194	0.503	4.1641	0.019142	15	25.1	778.1	149.78	0.192	0.503	3.9818	0.018304
16	31.6	831.53	164.67	0.198	0.503	4.2597	0.019581	16	31.6	802.22	156.42	0.195	0.503	4.1073	0.018881
17	39.8	846.96	170.72	0.202	0.503	4.3418	0.019959	17	39.8	828.85	162.26	0.196	0.503	4.2442	0.01951
18	50.1	861.32	177.48	0.206	0.503	4.4191	0.020314	18	50.1	861.29	169.64	0.197	0.503	4.4113	0.020278
19	63.1	872.26	185.05	0.212	0.503	4.4809	0.020598	19	63.1	901.32	176.96	0.196	0.503	4.6157	0.021218
20	79.4	876.32	192.9	0.22	0.503	4.5091	0.020728	20	79.4	954.17	186.5	0.195	0.502	4.8847	0.022454
21	100	869.54	202.58	0.233	0.502	4.4861	0.020622	21	100	1020	191.5	0.188	0.502	5.2152	0.023973