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Faculty of Tropical AgriSciences

Formulation and Evaluation of Chocolate Spread with addition of Oats and Linseed

MASTER'S THESIS

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In Prague, 23rd April 2026

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Adil Mushtaq

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Knowledge is limited, and time is short to express the dignity of Almighty ALLAH, the Propitious, the Benevolent and Sovereignty, the entire source of all the knowledge and wisdom endowed to the mankind. Lips are trembling, and eyes are wet to pray for the Last Holy Prophet HAZRAT MUHAMMAD (ﷺ); the beacon of enlightenment, the fountain of knowledge and the messenger of peace and forever torch of guidance for humanity.

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Abstract

Chocolate spread is a popular food product widely consumed across different age groups and cultures. Known for its smooth texture, rich flavour and versatility, chocolate spread has become a common accompaniment to bread, toast, pancakes, waffles and other bakery products. Chocolate spread is classified as an energy-dense food due to its high sugar and fat content. This limits its consumption, especially for individuals managing weight or metabolic conditions. From the mid-20th century onwards, diet began to receive increasing attention as an important factor in promoting overall health. This growing awareness led to an intensified interest in specific functional components of foods, particularly dietary fibres such as beta-glucan and omega 3 fatty acids, commonly found in oats, barley and linseed. Chocolate spread is widely consumed and often regarded as a comfort food, making it an appealing vehicle for nutritional enhancement. The chocolate spread was developed with addition of oats and linseed to improve its health aspects (for example content of fibre). The developed spread was then sensory evaluated by a panel of fifty-five (55) untrained panellists (22 males and 33 females), who were students, aged between 21 and 28. The spread was then observed for 4 weeks, kept in glass jars (full and half conditions) at room temperature (24±2 °C), regarding its physicochemical properties. During storage, the moisture content reduced from 22 to 18 % and the spread-ability on average went down from 72 to 60 mm. The values of induction period for the treatments in full conditions were recorded around 16 to 15:30 hours, while the values of treatments in half conditions were recorded around 14:15 to 13:45 hours. The results of this study emphasize the importance of optimizing packaging conditions to minimize physicochemical degradation and preserve the overall stability of food products during storage.

Key words: Chocolate spread, *Linum usitatissimum*, *Avena sativa*, omega-3, dietary fibres, functional food development, storage stability, lipid oxidation

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List of the abbreviations used in the thesis

CZ:	Czech Republic
FTZ:	Faculty of Tropical AgriSciences
CZU:	Czech University of Life Sciences, Prague
IP:	Induction Period
LDL:	Low-density Lipoprotein
HDL:	High-density Lipoprotein
ALA:	Alpha-linolenic Acid
Fig:	Figure
ASLT:	Accelerated shelf-life Test

2. Introduction and Literature Review

2.1. Introduction

Chocolate spread is a common foodstuff that is consumed by various age groups and cultures. Chocolate spread is known to have a smooth texture, rich flavour and versatility and has become a popular accompaniment to bread, toast, pancakes, waffles and other bakery items. It is commonly served as breakfast, snacks and desserts and is a common ingredient in most households. Chocolate spread has over the years developed to be a complex processed food product that integrates taste, convenience and long shelf life as opposed to a cocoa-based paste. Its popularity is mostly explained by its attractive sweetness, creamy texture and convenience (Acan et al., 2021a). Chocolate spread is a significant type of processed and semi-processed food in the modern food systems. It is an indication of food technology, food preservation and mass production. Although traditionally chocolate was eaten primarily in solid form, food processing innovations allowed the creation of spreadable chocolate products. The products were made in such a way that they could be stored, transported and consumed without any additional preparation. Consequently, chocolate spread has been adopted as a symbol of convenience-based lifestyles particularly in urban and high paced societies (El-Hadad et al. 2011).

Nutritionally and scientifically, chocolate spread is a complicated food product that consists of a combination of different ingredients that interact to produce its typical taste, texture and stability. It is important to know its composition and ingredients to determine its health implications, quality standards and place in human diets. Chocolate spread composition is the mixture of macronutrients, micronutrients and functional components that define the physical, chemical and sensory characteristics of chocolate spread. Typically, chocolate spread consists of carbohydrates, fats and traces of proteins, flavouring and stabilizing agents. These ingredients combine on a molecular level to create a smooth, homogeneous and spreadable product (Acan et al. 2021b). Nutritionally and scientifically, chocolate spread is a complicated food product that consists of a combination of different ingredients that interact to produce its typical taste, texture and stability. It is important to know its composition and ingredients to determine its health implications, quality standards and place in human diets. Chocolate spread composition is the mixture of macronutrients, micronutrients and functional components that define the physical, chemical and sensory characteristics of chocolate spread. Typically, chocolate spread consists of carbohydrates, fats and traces of proteins, flavouring and stabilizing agents. These ingredients combine on a molecular level to create a smooth, homogeneous and spreadable product (Said et al. 2019).

The smooth and spreadable texture of chocolate spread is impossible without vegetable oils and fats. Oils that are commonly used are palm oil, sunflower oil, soybean oil and occasionally cocoa butter. The use of palm oil is frequently explained by its semi-solid state at room temperature, which contributes to consistency (David et al. 2021). Nevertheless, environmental sustainability and health issues have caused a rise in interest in alternative fats. Fats contribute significantly to the taste and feel of food. It influences texture, mouthfeel, aroma and flavour. Due to this, manufacturers have resorted to fat replacers to cut down on calories and still make food enjoyable. These may be carbohydrate, lipid or protein based. This is usually done using natural ingredients such as pawpaw puree, avocado puree, pumpkin seed oil, cocoa fibre and apple sauce (Dotto & Chacha 2020).

The main sweetener in chocolate spread is sugar and it makes a large proportion of the overall weight of the chocolate spread. Saccharine sugars are commonly used such as sucrose, glucose syrup and occasionally fructose. Sugar makes food more palatable and gives instant energy. It is also a preservative as it reduces moisture content and prevents the growth of microbes. Nevertheless, high sugar consumption is linked to such health issues as obesity, diabetes and dental issues, which is why it is a significant aspect of nutritional assessment (DiNicolantonio et al. 2016). Proteins are found in lesser amounts and are primarily obtained through milk solids, cocoa and nuts. Protein is not the main nutritional focus of chocolate spread, but it helps to create texture, flavour development and nutritional value. Proteins are also involved in chemical reactions during processing and affect colour and aroma (Plazzotta et al. 2023).

Chocolate spreads often contain milk, milk powder, whey powder and skimmed milk solids. These ingredients add creaminess, slight sweetness and nutritional value. Milk ingredients contain proteins, calcium and lactose that add flavour complexity and texture. They also enhance emulsification, which enables fats and water-based ingredients to mix (Espert et al. 2021). Functional ingredients include emulsifiers and stabilizers, which aid in ensuring uniformity of products. Lecithin is a common emulsifier that is usually obtained by extracting soybeans or sunflower seeds. It does not allow the separation of fats and solids, which makes the texture smooth. To improve viscosity and shelf stability, stabilizers and thickeners can be incorporated, including guar gum or carrageenan. Taste and aroma are improved with flavouring agents. These can be natural vanilla extract, synthetic vanillin or other approved flavour compounds. Flavourings are used to balance the sweetness and bitterness to provide a pleasant sensory experience.

Besides macronutrients, chocolate spread has micronutrients like minerals and trace vitamins, depending on the quality and proportion of raw materials used. Nuts, especially hazelnuts, almonds or peanuts are found in many chocolate spreads. Nut pastes are applied to add flavour, aroma and nutritional value. Nuts contain healthy fats, proteins, vitamins and minerals. They also add to a unique taste profile and enhance consumer appeal. Minerals such as magnesium, iron and potassium are found in cocoa and nuts, and milk ingredients can be a source of calcium and vitamin B complexes. Nevertheless, these micronutrients are usually found in moderate quantities relative to whole foods (Aila Mohd Hassim & Haqim Ismail 2018).

Chocolate is a favourite snack among children and adults. It is a food that is rich in energy and is easy to digest, yet it is also rich in fat. The need to reduce fat and make chocolate enjoyable has become a big challenge to food manufacturers. Nowadays, individuals are more concerned with consuming foods that promote physical and mental well-being as opposed to just filling up. Fat is a significant component of the human diet, and its excessive consumption, particularly saturated fat, has been associated with health problems like obesity and heart disease. Production is a very important part of the formulation process because manufacturers have to strike a balance between taste, cost, nutrition and stability. The changes in the ratios of ingredients can have a great impact on the quality of the product. As an example, adding more cocoa will add flavour but increase production costs, whereas decreasing fat will add nutritional value but decrease texture (Erdoğan & Gökçe, 2021; Fayaz et al., 2017).

2.2. Literature Review

Chocolate spread is categorized as an energy-rich food because it contains a lot of sugar and fat. It is a fast source of energy and helps to satisfy hunger, which makes it an attractive breakfast or snack. Nevertheless, it is rich in calories, which should be consumed moderately, particularly by people who are controlling their weight or metabolic disorders. Chocolate spread is a sweet, creamy product that is usually served on bread, toast, waffles, pancakes and muffins. It is typically prepared using milk powder, sugar, fat, cocoa powder and lecithin. Although it appears and tastes like chocolate, it remains soft at room temperature. Chocolate spreads may be consumed directly or as a filling in baked goods. They are usually appealing due to their high fat and sugar content, yet both are related to health issues such as obesity, diabetes and heart disease. High-added sugar diets may significantly contribute to cardiovascular mortality and saturated fats may be even more dangerous (Bascuas et al. 2021).

Chocolate spread is functionally a convenient source of flavour and texture in food. It enhances the palatability of food and promotes food consumption, especially in children and those with low appetite. It is also convenient to use at home and in the business because of its long shelf life and convenience in storage. Meanwhile, contemporary consumers are becoming more health- and sustainability-conscious. Consequently, numerous producers are creating low-fat, reduced sugar, organic and plant-based chocolate spreads. The alternatives are meant to maintain sensory appeal and enhance nutritional value and environmental performance (Tolve et al. 2021; Tirgarian et al. 2023).

The increased interest in healthier diets has been driven by the growing awareness of health issues worldwide, the increasing cost of medicine and the aging population since the mid-20th century. Fibre in the diet, particularly oats and barley beta-glucan, has become popular due to its ability to reduce cholesterol and decrease the risk of heart disease. Fibre in the diet is a vital part of a healthy and balanced diet. It is the components of plant foods that are not completely digested or absorbed by the human body. Fibre, unlike carbohydrates, fats and proteins, is absorbed into the digestive system in a relatively intact form, and has a number of significant functions on the way. Dietary fibre is found primarily in fruits, vegetables, whole grains, legumes, nuts and seeds, and is important in keeping the body physically healthy and avoiding numerous chronic diseases. Over the past few years, there has been a growing scientific interest in the role of fibre in the long-term health and overall quality of life (Bouaziz et al. 2017).

There are two broad categories of dietary fibre, namely soluble fibre and insoluble fibre. Soluble fibre is dissolved in water and it forms a gel-like substance in the digestive tract. It is usually present in oats, beans, apples and citrus fruits. Insoluble fibre is not soluble in water and can be found in whole wheat, bran, nuts, and vegetables. The two kinds of fibre have different effects on health and a balanced diet must have sufficient quantities of both. Among the greatest advantages of dietary fibre is the fact that it has a positive impact on the digestive health. Fibre increases the bulk of stool and regulates bowel movements, which decreases the chances of constipation. The insoluble fibre facilitates the easy movement of waste along the intestines, whereas the soluble fibre makes the stool soft and enhances its consistency. Fibre intake regularly prevents digestive disorders like haemorrhoids, diverticulosis and irritable bowel problems. Moreover, fibre helps to promote the development of healthy gut bacteria, which are crucial in digestion, immunity and nutrient absorption (Kim et al. 2021).

Dietary fibre is also a significant factor in heart health. Soluble fibre also reduces the amount of low-density lipoprotein (LDL) cholesterol, or bad cholesterol. It attaches to cholesterol in the digestive tract and does not allow it to enter the bloodstream. Consequently, the risk of heart disease, high blood pressure and stroke is lowered by regular intake of fibre-rich foods. Moreover, fibre is known to control the level of lipids in the blood and enhance the overall cardiovascular performance. The other important advantage of dietary fibre is that it helps in the control of blood sugar. Fibre reduces the rate of digestion and absorption of carbohydrates, avoiding the sudden rise in blood glucose levels following meals. This assists in stabilizing energy levels and enhances insulin sensitivity (Zhu et al. 2018).

The increased interest in diet as a means of promoting overall health resulted in increased interest in particular functional properties of foods, especially dietary fibres, including beta-glucan, a soluble fibre that is present in oats and barley. Meanwhile, omega-3 fatty acids found in such foods as linseed were known to have great health benefits. Beta-glucan and omega-3 fatty acids have been particularly appreciated in promoting cardiovascular health. Beta-glucan has been known to reduce blood cholesterol levels, and omega-3 fatty acids are known to reduce the risk of heart disease due to their anti-inflammatory and lipid-lowering properties. Collectively, these ingredients have emerged as major areas of concern in the production of health-based food products. Since chocolate spread is a popular food and is regarded as a comfort food, it can be used as a good source of health-promoting ingredients. As an example, omega-3 fatty acid-enriched spreads or various forms of dietary fibre have been researched and published in the scientific literature. Jeyarani et al. (2015) conducted one clinical trial that examined the impact of omega-3 fatty acids on coronary artery disease by comparing a group of participants who took approximately 1.8 grams of alpha-linolenic acid per day to a control group who took less than half that amount. Two years later, the group that had a higher intake of omega-3 had much fewer cardiac events, which demonstrates the beneficial effect of these nutrients.

Chocolate spread is a popular food that is commonly considered a comfort food and thus a good target of nutritional fortification. Due to its popularity among various age groups, it offers a viable foundation on which health promoting ingredients can be added without causing a major change in consumer acceptance. This provides a chance to enhance the nutritional value of a popular product by adding healthy ingredients to it. Specifically, dietary fibres and omega-3 fatty acids have been the focus of research. Several studies have investigated chocolate spreads enriched with these ingredients, and they have shown that they can provide additional health benefits without compromising on the desirable taste and texture. These advancements underscore the fact that familiar foods can be re-packaged to promote improved nutrition without compromising on pleasure.

2.2.1. Proven Health Benefits of Oats

Oats are one of the most nutritious and popular whole grains in the world. Oats are known to be versatile, affordable, and rich in nutritional value, making them a part of healthy diets in many cultures. Frequent intake of oats helps a great deal in physical health by promoting cardiovascular health, digestion, weight control, and general metabolism. Oats are becoming a crucial part of a balanced diet as scientific studies continue to emphasize their importance (Duan et al. 2023). Among the greatest advantages of oats is their outstanding nutritional value. They contain high amounts of complex carbohydrates, dietary fibre, high-quality protein, and essential vitamins and minerals, such as iron, magnesium, zinc, and B-complex vitamins. This is a balanced nutrient profile that assists in providing long-term energy and normal body functions. Oats are also a better option in the long term because they do not lose their natural nutrients like refined grains (Paudel et al. 2021).

Oats are especially famous in terms of their heart health promotion. They also have a soluble fibre known as beta-glucan that has been found to lower low-density lipoprotein (LDL) cholesterol, also known as bad cholesterol. Oats reduce the risk of atherosclerosis, hypertension and other cardiovascular diseases by lowering cholesterol levels. Oats have been linked to better blood flow and heart performance, and therefore, they are particularly helpful to those who are worried about heart-related diseases (Alemayehu et al. 2023). Besides cardiovascular, oats are also important in keeping the digestive system healthy. Their high fibre content aids in regular bowel movements and prevents constipation. Fibre also helps to increase the growth of good gut bacteria, which are necessary to digest and protect against infections. A well-functioning digestive system helps to improve the absorption of nutrients and minimizes the chances of gastrointestinal diseases, which also improves the overall health (Rasane et al. 2015).

Another area where oats have great benefits is in weight management. Oats contain high levels of fibre and protein, which makes them make one feel full and less hungry between meals. They are slow in digestion and this aids in controlling appetite and overeating. Consequently, people who consume oats in their daily meals tend to have an easier time keeping their body weight healthy. This renders oats especially appropriate to individuals who want to lose weight or maintain it in the long run. Oats are also beneficial in the regulation of blood sugar. Their soluble fibre content and low glycaemic index delay the absorption of glucose into the bloodstream. This will assist in avoiding the sudden spikes and drops in blood sugar levels, enhancing insulin sensitivity. As a result, oats are particularly useful to individuals with diabetes or those who are prone to developing metabolic disorders (Zhang et al. 2021).

According to Soycan et al. (2019) oats aid in energy production and immune functioning. Oats contain complex carbohydrates that supply the body with a constant supply of energy, which helps to reduce fatigue and enhance physical stamina. Moreover, oats also have antioxidants, including avenanthramides, which can reduce inflammation and boost the immune system. These properties help to enhance resistance to illness and quicker recovery of physical stress. Oats are also beneficial to the skin, hair and bone. Their antioxidant and mineral properties are beneficial in keeping the skin healthy, reducing irritation and strengthening hair. Calcium, phosphorus and magnesium are minerals that increase bone density and prevent age-related bone disorders. This is why oats are frequently prescribed as a component of a diet that should help maintain long-term structural health.

To sum up, oats are a very useful food that offers numerous health benefits. Their high nutritional value, capacity to maintain heart and digestive health, weight management and blood sugar regulation make them a perfect option to all people of any age. With the help of oats in everyday meals, individuals can improve their physical health and decrease the chances of chronic illnesses. Oats are a simple but effective tool in ensuring lifelong health as a component of a balanced diet.

2.2.2. Proven Health Benefits of Linseed

Flaxseed or linseed is one of the most nutritionally potent seeds that are consumed by humans. It has been used as a medicine and food since ancient times. Scientific studies in recent years have also validated its contribution to overall health and prevention of chronic diseases. Dietary fibre and bioactive compounds, as well as the abundance of essential fatty acids, have made linseed a significant part of contemporary balanced nutrition. The outstanding nutritional composition of linseed is one of the greatest health advantages of this product. It is a rich source of omega-3 fatty acids, especially alpha-linolenic acid (ALA), which is crucial in the maintenance of cellular functions and in the reduction of inflammation. Moreover, linseed is a good source of plant protein, soluble and insoluble fibre, vitamins and essential minerals like magnesium, phosphorus and potassium. This mix of nutrients promotes various physiological functions and improves general well-being (Bernacchia et al. 2014).

Outzen et al. (2024) examined the health outcomes of higher flaxseed intake among Danish individuals, particularly cardiovascular health. The omega-3 fatty acids found in linseed aid in reducing bad cholesterol (LDL) and raising good cholesterol (HDL). This helps in better blood flow and decreases the chances of heart disease, stroke and high blood pressure. Moreover, lignans in linseed have antioxidant and anti-inflammatory effects, which prevent the damage of blood vessels and the development of atherosclerosis.

The other significant benefit of linseed is that it has a beneficial impact on digestive health. The fibre content is high and this helps in regular bowel movements and constipation is avoided. Soluble fibre makes stool soft, whereas insoluble fibre makes intestinal bulk, which is easily digested. Moreover, linseed helps to increase the number of good gut bacteria, which enhances the digestive system and enhances the absorption of nutrients. A well-functioning digestive system is also important in boosting immunity and preventing gastrointestinal diseases (Mueed et al. 2022). Linseed is also a good source of weight management. Its fibre and healthy fat content make one feel full and lessen the appetite between meals. Linseed slows down the digestion process and thus controls hunger and overeating. Consequently, people who incorporate linseed in their meals might be able to achieve a healthy body weight and minimize the amount of excess fat (Katoch & Bhatia 2021).

Another significant advantage of consuming linseed is blood sugar regulation. The linseed soluble fibre delays the rate at which glucose is absorbed into the blood stream, avoiding sudden rises in blood sugar levels. This enhances insulin sensitivity and helps to maintain better metabolism. Linseed is therefore especially useful to people with diabetes or those who are prone to developing metabolic disorders (Nowak & Jeziorek 2023).

Besides metabolic and cardiovascular advantages, linseed helps to maintain hormonal balance and prevent diseases. Linseed contains lignans that are natural phytoestrogens, which can be used to control hormonal activity in the body. These compounds have been linked to lower chances of hormone related cancers, including breast and prostate cancer. In addition, linseed has antioxidant effects that prevent oxidative stress and early aging of cells (Sangiorgio et al. 2023). Linseed also helps in maintaining healthy skin, hair and bone. Its omega-3 fatty acids aid in keeping the skin hydrated, decreasing inflammation and enhancing elasticity. Frequent use can lead to healthier hair and less hair loss. Minerals like magnesium and phosphorus maintain bone density and prevent age related bone disorders, which makes linseed useful in long-term structural health (Chauhan et al. 2025).

To sum up, linseed is a very nutritious and functional food with a wide range of health benefits. Its high levels of omega-3 fatty acids, fibre, antioxidants and lignans are beneficial to the heart, digestion, weight, blood sugar and hormonal balance. Including linseed in the daily meals, be it in the form of powder in the smoothies or sprinkled on the cereals and salads, one can greatly improve his or her overall well-being. Linseed is a natural and effective means of lifelong health promotion as a part of a balanced and healthy diet (De Silva & Alcorn 2019).

2.2.3. Possible Anti-nutritional Aspects of Oat and Linseed

Oats are commonly known to be nutritionally beneficial, yet they also have some anti-nutritional compounds that may affect the absorption and digestion of nutrients. Phytic acid is one of the main anti-nutrients in oats and has the ability to bind minerals like iron, zinc, calcium and magnesium, thus lowering their bioavailability in the body (Leszczyńska et al. 2023). This might not be beneficial, but phytic acid is also an antioxidant and can help to prevent the risk of some chronic diseases when oats are eaten as a part of a balanced diet. Besides phytic acid, oats have enzyme inhibitors such as trypsin inhibitors that may disrupt the digestion of proteins by inhibiting the action of digestive enzymes. Nevertheless, these inhibitors are relatively low in oats and are greatly decreased by common food processing techniques like soaking, cooking, or fermenting (Petroski & Minich 2020).

Some polyphenolic compounds are also present in oats and can react with proteins and minerals, which can have some impact on their absorption, but these compounds are also commonly linked to positive antioxidant effects (Gemede & Ratta 2018). The presence of dietary fibre components, especially beta-glucans, is another factor to consider, as, despite being very beneficial to heart health and blood sugar regulation, may occasionally slow down the absorption rate of some nutrients when taken in very large amounts. All in all, oats are a very nutritious food despite these anti-nutritional factors and their health benefits such as better cholesterol levels, digestive health and long-lasting energy release usually outweigh any small drawbacks of their anti-nutrient content, particularly when cooked properly (Alemayehu et al. 2021).

Linseeds also have a number of naturally occurring anti-nutrient compounds, such as phytic acid, cyanogenic glycosides, trypsin inhibitors and oxalates. One of the most important is phytic acid, which is able to bind such important minerals as iron, zinc, calcium and magnesium, making them less bioavailable in the digestive system. Nevertheless, it is not entirely detrimental, and it also has antioxidant properties and can be used to provide protective health benefits when taken as a part of a balanced diet (Russo & Reggiani 2016). Cyanogenic glycosides, including linamarin and linustatin, are another significant group of compounds in linseeds that may release small quantities of cyanide during digestion. This might be alarming, but the amounts found in normal dietary consumption are extremely small and the human body can effectively detoxify these substances. Moreover, their levels can be greatly decreased by processing techniques such as heating, baking or roasting (Mueed et al. 2023).

Linseeds also have trypsin inhibitors, which may disrupt protein digestion by lowering the activity of digestive enzymes, but their effect is not as strong as some legumes. Another anti-nutrient that is found in linseeds is oxalates; they have the ability to bind calcium and can lead to the formation of kidney stones in people who are predisposed to this condition. Although these compounds are present, linseeds are generally considered to be a very nutritious food because of their high fibre content, omega-3 fatty acids and other plant compounds that are beneficial like lignans. In moderation and when cooked or ground e.g. by grinding, their nutritional value usually overrides any adverse effects of anti-nutrients (Pramanik et al. 2023).

2.2.4. Technological Aspects of Adding Oat and Linseed in Chocolate Spread

Oat and linseed powders can influence sensory quality as they do not only alter texture but also flavour, colour, mouthcoating and particle perception. Sensory wise, moderate inclusion can help to add a richer body and more natural cereal or nutty flavors, but high inclusion can diminish the creamy, smooth, indulgent flavor desired in chocolate spread. Excessive use of oat can add cereal-like flavour and a pastier texture, whereas excessive use of linseed can add nuttier flavour but can also produce bitterness, astringency or rancid flavours should oxidation occur. The same influences their technological behaviour; they are not inert fillers, but compositionally active ingredients with fibre, proteins, polysaccharides and in the case of linseed a more oxidation-sensitive lipid fraction. These ingredients alter oil binding, viscosity, yield stress, lubrication and microstructural homogeneity, such that they may alter processing behaviour during mixing, refining, pumping and filling, and the ultimate texture experienced by consumers. That is, addition of oat or linseed powder can enhance nutritional profile, but will cause the system to lose the traditional fat-based creamy texture of a traditional chocolate spread unless the fat phase, emulsifier level and particle size distribution are re-engineered to suit (Bascuas et al. 2021).

The structure of the continuous fat phase is the primary determinant of spread-ability in a chocolate spread, the quantity of solid fat at the serving temperature and the volume fraction, size and interactions of dispersed solid particles like sugar, cocoa, milk solids and any added ingredients. Chocolate spreads are viscoelastic, shear-thinning systems with a quantifiable yield stress, and thus the product can only be easily spread when the force applied to it breaks or deforms the fat-crystal network. Increased solid fat and crystal network tend to raise firmness and yield stress, and a weak structure or more lubricating fat phase reduces resistance to spreading. The presence of solid particles is also important: the higher the number of insoluble particles or coarse particles, the higher the viscosity and the thicker, even gritty texture (Principato et al. 2022). Their fibre-containing particles can also compete with oil when oat or linseed powder is added, raising the effective solid volume and enhancing particle-particle interactions, which can often make the spread less fluid and difficult to spread unless the fat phase is modified. Oat is particularly applicable since its β-glucan possesses a high water-binding and viscosity-forming capacity. Linseed also adds fibre and mucilage which may also add consistency. The effect in both instances is dependent on the particle size, dose and the ability of the formulation to compensate with fat, emulsifier or moisture (Majumdar et al. 2024; Puligundla & Lim 2022).

The more important ingredient in terms of oxidative-stability considerations is linseed powder since linseed contains polyunsaturated fatty acids, and highly unsaturated lipids are inherently more susceptible to oxidation during processing and storage. Thus, the addition of linseed powder can enhance the nutritional quality of spread but can also raise the chances of oxidative rancidity, off-flavours and reduced shelf life unless oxygen exposure, light, temperature, metal contamination and packaging are carefully managed. Simultaneously, flaxseed is also a source of lignans and other phenolic compounds with antioxidant properties, and its actual impact is a trade-off between pro-oxidative vulnerability of its oil fraction and protective action of endogenous antioxidants (Takić et al. 2024). Oat tends to be less oxidatively risky than linseed, and can even provide some protection due to the presence of antioxidant phenolics like avenanthramides; but their protective effect is generally less than the effect of adding a highly unsaturated lipid source such as linseed. Practically, when the linseed powder is incorporated into a chocolate spread, oxidative stability tends to be more formulation-dependent and increased antioxidant protection or reduced oxygen permeability packaging or less harsh storage conditions might be required (Xie et al. 2024).

The addition of oat and linseed powder can also alter the behaviour of the spread during storage since the added ingredients alter the ratio between the fat network and the dispersed solid phase. Storage stability in cocoa and nut spreads relies on the ability to retain a stable crystal structure and to avoid oil migration, phase separation or progressive hardening. In certain situations, physical stability can be enhanced by the addition of fibre-rich powders which immobilise a portion of the free oil and enhance structural consistency. However, over addition can lead to a more heterogeneous matrix and disrupt fat-phase continuity, leading to non-uniform texture or long-term instability (Al-Madhagy et al. 2023). Oat ingredients, particularly β-glucan-containing fractions, have been known to bind water/oil and increase viscosity, and thus moderate concentrations can be used to stabilize the matrix. Linseed has the potential to act in the same way in terms of physical-structuring due to its mucilage and fibre, although the precise result varies intensely based on formulation and processing, as excessive added powder may cause the spread to be thicker, less homogeneous and more prone to change in texture over time (Cheng et al. 2021).

3. Aims of the Thesis

The aim of this thesis is to develop and optimise a chocolate spread enriched with oats and linseed. Furthermore, the study seeks to evaluate the developed product through sensory analysis and to assess consumer preferences in order to determine its overall acceptability.

3.1. Hypothesis

H_1: Different ratios of oat and linseed powder in the formulation will affect the sensory acceptability of the chocolate spread

H_2: Packaging conditions (full vs half jar) significantly affect moisture content, spread-ability and oxidative stability of selected chocolate spread formulations during storage

3.2. Objectives

1. Optimization and Formulation: development of a recipe through hit and trial method and formulation of the product with addition of oat and linseed powder
2. Evaluation: assessing the sensory profile and consumer preference of developed chocolate spread and possible changes in physicochemical properties during storage
3. Assessment: the effect of packaging condition during 4-week storage on moisture content, spread-ability and oxidative stability of the selected formulations

4. Material and Methods

4.1. Procurement of Raw Material

All the added ingredients (Dark chocolate, vegetable oil, coconut milk, sugar syrup, oats and linseed powder) shown in Fig.1 below, were purchased from retail supermarkets of Prague, CR and processed in the sensory lab of FTZ, CZU.

Figure 1: Raw material used for formulation of chocolate spread

4.2. Sample Preparation

The chocolate, in the form of small cubes and the vegetable oil were taken in a bowl and sugar syrup was added. The ingredients were melted, in a bowl putted in a pot with hot water on the hotplate, until a smooth chocolate mixture was obtained. The mixture was then added with coconut milk, together with the oat and linseed powder, while stirring. After that the mixture was well blended with a blender for 30 seconds to distribute the ingredients evenly. The spread was then packed in the glass jars and stored on a room temperature in dry place as shown in Fig. 2 below.

Figure 2: Pilot scale formulation of chocolate spread (recipe development)

Treatments

Once the recipe was developed, three treatments were made with different combinations of oat and linseed powder while keeping the other ingredients unchanged. Table 1 below shows the developed recipe and treatment plan, while Fig. 3 below shows the final product formulation.

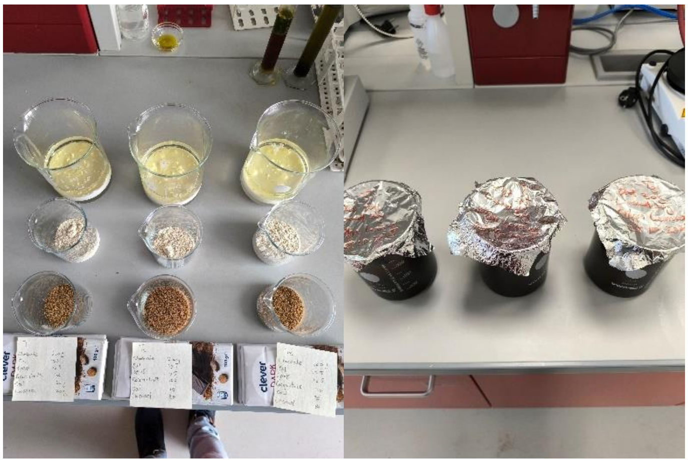

Figure 3: Formulation of the final product (T1, T2, T3)

Table 1: Developed recipe and treatments plan

Ingredients	T1	T_2	T_3
Dark chocolate	200	200	200
Vegetable oil	125	125	125
Sugar syrup	125	125	125
Coconut milk	100	100	100
Oat powder	20	10	30
Linseed powder	20	30	10

Note: All the values are in gram (g)

4.3. Sensory Evaluation of Samples

Amevor et al. (2018) used method was adopted for the sensory evaluation of the spread samples. The preference test was conducted at the sensory laboratory of the FTZ, CZU, on 4 and 5 November 2025, from 12:15 pm and 4:00 pm. Fifty-five (55) untrained panellists (22 males and 33 females), who were students, aged between 21 and 28 were asked to assess the coded chocolate spread samples in terms of the following sensory attributes:

- Appearance
- Aroma
- Taste
- Texture
- Overall acceptability

Figure 4: Sensory analysis of the formulated chocolate spread

As shown in Fig. 4 above, the sensory lab had adequate lighting and panellists were seated at individual booths. All 3 samples were served in white glass plates at the same time to panellists. The samples were also provided with 3 pieces of bread in order to taste the spread with bread. Water was provided for panellists to rinse their mouth with in-between tasting of samples. The line scale in printed form was given to each contestant to record their preference as shown below in Fig. 5. The first two samples with the highest overall acceptability mean scores were selected for further analysis: moisture content, oxidation stability test, spread ability and storage study.

Figure 5: Sample plate given to the sensory panel

4.4. Storage Study

Storage stability refers to the ability of a product to remain un-changed over time, under reasonably expected conditions of storage and use. Formulated chocolate spreads were stored at room temperature (24 °C ± 2) for 4 weeks as shown below in Fig. 6.

Figure 6: Product storage in glass jars (full & half conditions) at room temperature.

Physical properties, fat stability indices, moisture content and spread ability were monitored at 1, 2, 3 and 4 wees. Table 2 below shows the storage study plan.

Table 2: Storage plan

Treatments	Temperature (ºC)	Packaging material	Packaging condition
T1	24±2	Glass Jar	Full
T1	24±2	Glass Jar	Half
T_2	24±2	Glass Jar	Full
T_2	24±2	Glass Jar	Half

4.4.1. Moisture Content

Moisture analysis is the determination of the water (present in the form of moisture) in a material. Moisture content strongly affects quality, shelf life, stability, processing behaviour and compliance of products in industries. Main components of the moisture analyser are a precision balance (to measure the weight) and a heating unit (to remove moisture). It determines moisture content by measuring the weight loss of a sample during controlled heating.

Yıldız & Çağındı (2023) used method for moisture analysis was implemented. The analysis was performed on a moisture analyser (RADWAG MAC 110), shown below in Fig. 7, present in the sensory lab of FTZ, CZU. The analyser was switched on and an empty pan (aluminium plate) was placed and tare the balance. Sample amount of 5g was added (spread the sample in layer form as possible) in the pan and analysis was started. Moisture % was noted after the completion. The analyser provides fast analysis (within 20 minutes for most of the samples), easy to operate, use no chemicals, have high accuracy and enables real-time monitoring.

Figure 7: Apparatus (RADWAG MAC 110) used for the analysis of moisture content.

The sample is weighed initially. It is heated to evaporate moisture. The sample is weighed continuously during drying. When weight becomes constant, drying stops. The weight loss is calculated as moisture.

Moisture (%) = Initial Weight – Final Weight / Initial Weight ×100

4.4.2. Spread-ability Test

A very simple, low-cost spread ability test was used for chocolate spread known as “Two-Plate Spread ability (Slip & Spread) Test”. It is quick, repeatable and needs only basic lab items (Sun & Gunasekaran 2009; Al-Barghouthy et al. 2025). Instruments needed:

- 2 flat glass plates (or acrylic tiles) of the same size
- Balance
- Standard weights (200 g or 500 g)
- Stopwatch
- Ruler or vernier calliper
- Spatula

- Template or marker to draw circles

Place bottom plate on a stable surface. Weigh sample: put 5 g of chocolate spread at the centre of the plate. Carefully place the top plate on the sample. Put a standard weight on top of the upper plate. Start the stopwatch and allow spreading for a fixed time (e.g., 60 seconds). Remove the weight and top plate gently. Measure the spread diameter of the chocolate circle.

Measure two perpendicular diameters (D1 and D2) and take the average:

$D_{avg} = (D1+D2) / 2$

Interpretation:

Higher diameter/area = more spreadable (softer, lower yield stress)

Lower diameter/area = less spreadable (stiffer, higher yield stress)

Note: If the spread is kept in the refrigerator, keep it at a fixed temperature (e.g., 25 ± 1 °C) for at least 1 hour before testing. Mix gently to remove air bubbles (do not whip).

For this research, the method was slightly modified by using only one glass plate (petri dish) on the top while pressing the spread. Instead of marker to draw the circle, we used a template (colourful circular lines of 60 mm on a white paper). Two perpendicular lines were also drawn to measure the diameter. For the weight, water was taken in a beaker and measured at 500 g as shown in the following Fig. 8. Mobile phone was used as an alternative to stopwatch.

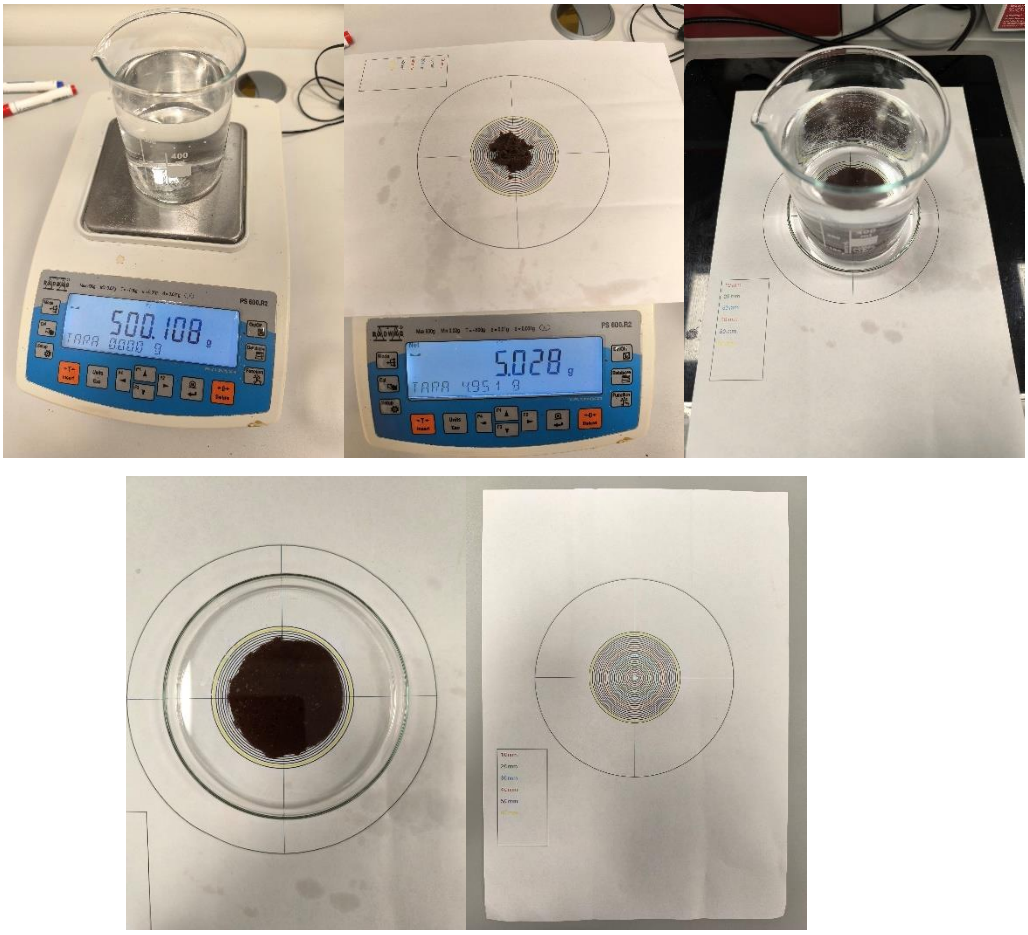

Figure 8: Pictures showing the methodology used for spread ability test.

4.4.3. Oxidation Stability Test

Caruso et al. (2017) and Pitirollo et al. (2025) used method was employed for checking the oxidation stability of chocolate spread samples during storage. The test was performed by an advanced oxitest analyser, an instrument developed by VELP Scientifica, shown below in Fig. 9. It determines the oxidation stability of oils, fats and lipid containing products under accelerated conditions. The VELP oxitest measures how resistant a sample is to oxidation by monitoring oxygen consumption under pressure.

The sample about 10g was placed in sample holders. The sample holders were then placed in reaction chambers, which were then closed. Oxygen is released, once the required test temperature (90 °C) is reached and analysis is started, while sealing the reaction chambers. The pressure vs. time curve is monitored and induction period (IP) is recorded from the results. The test may remain for 48h depending on the stability of the sample.

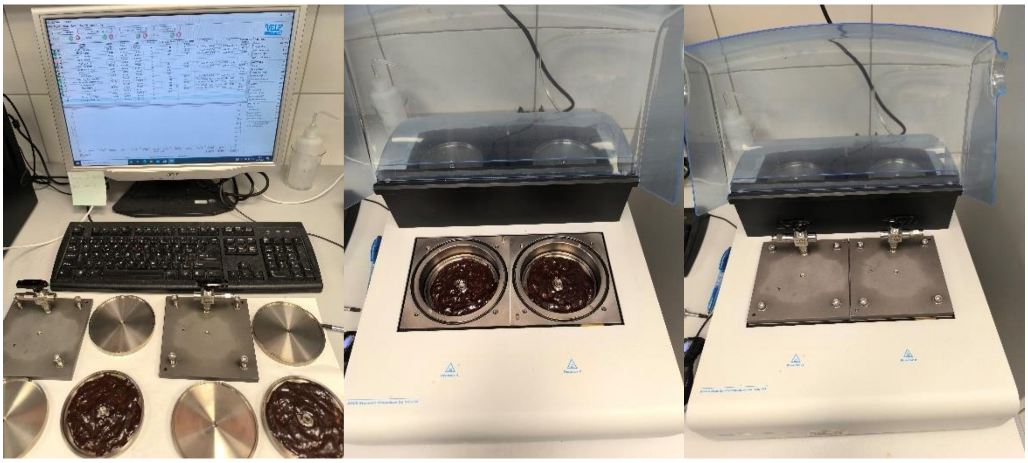

Figure 9: Apparatus (oxitest analyser, developed by VELP Scientifica) used for testing the oxidation stability of chocolate spread.

The oxitest provides: Pressure vs. Time graph, Induction Period (hours/minutes), test temperature and reaction curve. Results are stored digitally and can be exported. Samples with higher induction period (IP) means good oxidation stability and vice versa.

4.5. Statistical Analysis

The analyses were carried out and the reported data are expressed as mean value ±standard deviation. Comparison of means was conducted using the analysis of variance (ANOVA) with Post Hoc Tukey's test at $p < 0.05$. Statistical analyses were performed with the software IBM SPSS 27 and the graphs were plotted using software OriginPro 2025b.

5. Results

5.1. Sensory Evaluation

The sensory evaluation results presented in Table 3 represent the mean scores of responses of the panellists using a line scale, where higher values indicate greater acceptability. Overall acceptability was further summarized by ranking, where 1 corresponds to the most acceptable sample and 3 to the least acceptable. The results indicate that T1 is the most acceptable formulation followed by T2, while T3 requires improvement, particularly in aroma-related characteristics, values given below in Table 3.

Table 3: Table showing values of sensory evaluation

Samples	Sample codes	Appearance	Aroma	Taste	Texture	Overall Ranking
T1	125	5.72	5.67	6.18	4.86	1.78
T2	250	5.68	5.27	5.62	5.45	1.71
T3	375	5.75	4.68	5.01	5.93	2.18

Notes: Data are presented as averages

Ranking: 1 = most acceptable, 3 = least acceptable

Line scale values

- ≥1 ≤2 dislike very much
- ≥2 ≤4 dislike slightly
- >4 =5 neutral
- >5 ≤8 like slightly
- >8 ≤10 like very much

5.2. Storage Study

5.2.1. Moisture Content

Figure 10 below, shows the changes in moisture content of the samples over four weeks under four treatments: T1 (Full), T2 (Full), T1 (Half) and T2 (Half). Overall, moisture content gradually decreased with storage time in all treatments. At week 1, all samples had relatively similar moisture values (around 21–22%), although T1 (Half) showed the highest value while T2 (Full) was slightly lower than the others. From week 2 onward, the decline became more evident, particularly in the half treatments (T1 Half and T2 Half), which showed a sharper reduction compared to the full treatments.

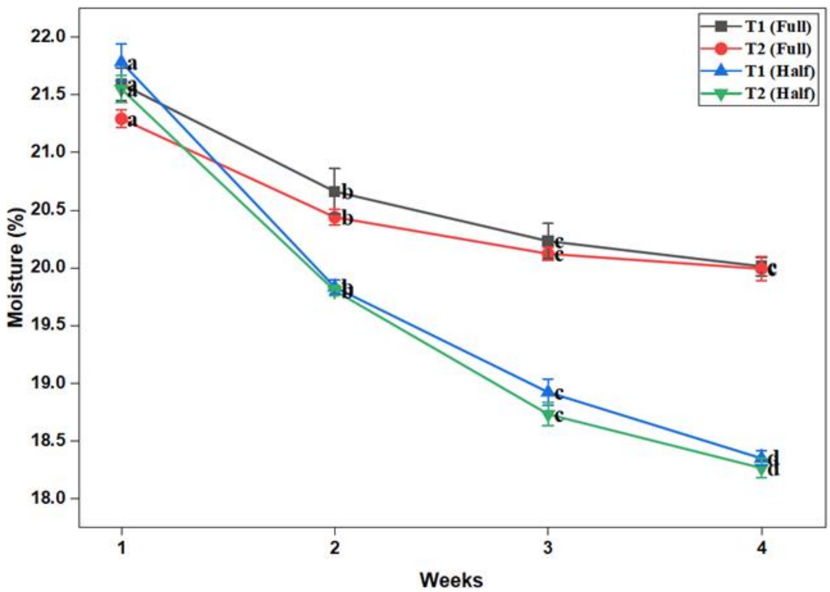

Figure 10: Graph showing the moisture vs weeks curves. The letters (a, b, c, d) above the data points indicate statistically significant differences among the weeks within each treatment.

By week 4, T1 (Full) and T2 (Full) retained higher moisture levels (around 20%), whereas T1 (Half) and T2 (Half) dropped to about 18–18.5%, indicating greater moisture loss. The letters (a, b, c, d) above the data points indicate statistically significant differences among weeks within each treatment. Overall, the results suggest that moisture content decreases during storage and that the full treatments help retain moisture better than the half treatments.

5.2.2. Spread-ability

Figure 11 below, illustrates the changes in texture values of the samples during four weeks of storage under four treatments. Overall, the texture values decreased steadily over time for all treatments, indicating a gradual loss of firmness during storage. At week 1, T2 (Full) showed the highest texture value, followed closely by T1 (Full), while the half treatments (T1 Half and T2 Half) had comparatively lower values. As storage progressed to weeks 2 and 3, all treatments exhibited a noticeable decline, with the half treatments showing a more pronounced reduction than the full treatments.

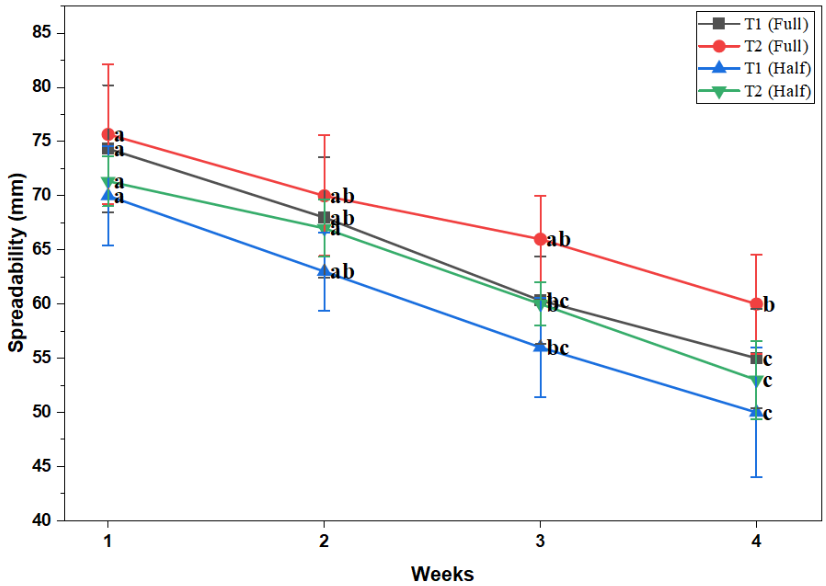

Figure 11: Graph showing the spread ability vs weeks curves. The letters (a, b, c) above the data points indicate statistically significant differences among the weeks within each treatment.

By week 4, T2 (Full) still maintained the highest texture value, whereas T1 (Half) showed the lowest, suggesting that the full treatments were more effective in preserving texture. The letters (a, b, c) above the data points represent statistically significant differences among the weeks within each treatment. Overall, the results indicate that texture gradually deteriorates during storage and the full treatments help retain higher texture values compared to the half treatments.

5.2.3. Oxidation Stability

Figure 12 below, shows the changes in Oxitest values (h:mm) of the samples during four weeks of storage under four treatments. Overall, the Oxitest values gradually decreased over time in all treatments, indicating a reduction in oxidative stability during storage. At week 1, the full treatments (T1 Full and T2 Full) exhibited higher Oxitest values, around 16 hours, compared with the half treatments (T1 Half and T2 Half), which were around 14 hours. As storage progressed from week 2 to week 4, all treatments showed a slight but consistent decline. However, the full treatments maintained higher Oxitest values throughout the storage period, while the half treatments showed lower values and a more noticeable decrease.

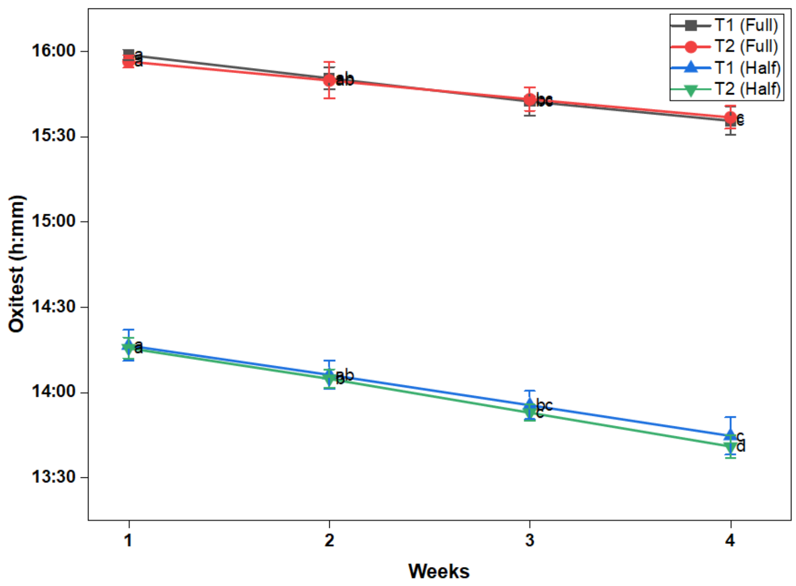

Figure 12: Graph showing the oxitest vs weeks curves. The letters (a, b, c, d) above the data points indicate statistically significant differences among the weeks within each treatment.

By week 4, T1 (Full) and T2 (Full) still retained the highest Oxitest values, whereas T2 (Half) showed the lowest. The letters (a, b, c, d) above the data points indicate statistically significant differences among the weeks within each treatment. Overall, the results suggest that oxidative stability decreases with storage time and the full treatments are more effective in maintaining higher Oxitest values compared to the half treatments.

6. Discussion

6.1. Sensory Evaluation

T1 (code 125) received the best overall acceptability rating (1) out of the three samples, meaning that it was the most preferred formulation. This sample scored consistently in the liked slightly category in such important attributes as appearance (5.72), aroma (5.67), and taste (6.18). Taste, specifically, scored the highest among all the attributes tested in all the samples, implying that it was a key factor in consumer preference. Even though the texture (4.86) and the attributes related to aftertaste (4.30-4.71) were rated as neutral, they did not significantly lower the overall acceptability. The comparatively equal performance of all the sensory parameters must have helped it to rank high.

T2 (code 250) was the second most acceptable. Like T1, it scored slightly higher in appearance (5.68), aroma (5.27), taste (5.62) and texture (5.45). It is worth noting that T2 scored higher on texture than T1, which may suggest a more favourable mouthfeel. Nevertheless, the pleasantness of aroma (4.01) and aftertaste attributes (4.38-4.62) were rated as neutral, which implies that there were certain constraints in flavour perception. These marginally lower scores in aroma-related attributes could have diminished its overall attractiveness compared to T1, although its sensory profile was otherwise acceptable.

Conversely, T3 (code 375) was the least acceptable sample (rank 3) although it exhibited strengths in some attributes. It scored the most on texture (5.93) and aftertaste (5.31) which were both in the liked slightly category, which means that panellists liked its mouthfeel and lingering taste. Also, its appearance (5.75) was similar to the other samples. T3 was however significantly constrained by low scores in aroma (4.68) and more crucially in the pleasantness of aroma (3.47) and the pleasantness of aftertaste (3.49) which are in the disliked slightly category. These negative attitudes must have significantly affected the overall acceptability negatively, which overshadowed its positive qualities.

The results indicate that aroma and taste-related properties are important in overall product acceptability, perhaps more so than texture. T3 was good in texture, but its low aroma perception resulted in a lower overall rating. On the other hand, positive scores of T1 on taste and aroma played a key role in its preference despite the fact that some of the attributes were neutral. This emphasizes the need to have a balanced sensory profile especially in flavour and aroma to increase consumer acceptance. The optimization of future products should be aimed at improving the quality of aroma and aftertaste without reducing other desirable features of the product like texture and appearance.

6.2. Moisture Content

The findings indicate a steady decrease in moisture content with storage time of both treatments (T1 and T2) and packaging (Full and Half). The values of moisture reduced steadily during week 1 to week 4, which means that moisture loss continued during the storage period. Figure 10 shows that all treatments had a relatively high moisture content (around 21-22%), and there was no significant difference between groups, as shown by the common letters of significance (a). This implies that the moisture content was similar at the start of the storage period, and it proves that the samples were similar. Since week 2, moisture was found to reduce significantly in all treatments. The moisture loss rate, however, varied among conditions of packaging. Samples in Half conditions exhibited a more pronounced decrease than Full conditions. T1 (Half) and T2 (Half) had already decreased to about 19.8% by week 2, but T1 (Full) and T2 (Full) still had higher moisture values (about 20.4-20.7%). This means that the Half condition probably enabled more exposure to environmental conditions like evaporation which resulted in more moisture loss. Verde et al. (2022) recommended in a study that fibre-based chocolates should be packaged in medium- to high-barrier water vapor to avoid rheological alterations during storage since some materials such as cellophane may cause rheological alterations with time.

The difference between Full and Half treatments was more pronounced by week 3 and week 4. Week 4 T1 (Full) and T2 (Full) had a moisture level of about 20, T1 (Half) and T2 (Half) reduced to about 18.2-18.4. The statistical groupings (a, b, c, d) also support the fact that there are significant differences over time and between packaging conditions. The slower decrease in Full treatments indicates an improved moisture retention capacity, probably because of a decrease in permeability and migration of moisture. When comparing T1 and T2 in the same packaging condition, the differences were not very significant, especially in Full storage. T1 (Full) tended to have a higher moisture content than T2 (Full) but the difference became smaller in week 4. At later storage stages, T2 (Half) showed a bit lower moisture value compared to T1 (Half), indicating that T2 can be slightly more prone to moisture loss when protective conditions are decreased. The same findings were addressed by Miranda et al. (2014) who suggested that the packaging material has a significant influence on moisture variation where dried apricots film packaging results in higher force value and lower moisture content with an increase in temperature and a constant value with glass packaging.

The gradual decrease in moisture content of chocolate with time can be explained by the natural water movement and evaporation during storage. Packaging permeability, storage temperature, relative humidity and product composition are usually the factors that affect the loss of moisture. Less moisture can influence the texture, structural integrity and the product quality. Thus, it seems essential to keep the packaging conditions optimal to retain product moisture and possibly prolong shelf life. On the whole, the results show that storage time has a significant impact on the moisture content and the packaging condition is a significant moderator of the moisture loss rate. The Full packaging treatment showed a better moisture retention than the Half condition. These findings underscore the significance of proper packaging measures in ensuring stability of products during storage. Conversely, Obeng et al. (2025) in a study discovered that milk chocolate maintains more moisture at higher fat levels, whereas dark chocolate exhibits the usual moisture reduction trends but it does not directly discuss the progressive decline in moisture content as time passes or the effects of packaging conditions.

6.3. Spread-ability

The findings show that all treatments (T1 and T2) in both packaging conditions (Full and Half) had a decreasing texture value over the storage period. This decrease indicates a slow loss of structural integrity and firmness of the product in storage. In week 1, the texture values were between about 70 and 76 with no significant difference between treatments as shown by the common significance letter (a). This indicates that the original texture of the samples was fairly homogeneous among all the treatment groups. T2 (Full) however had the highest texture value and T1 (Half) had the lowest value at the beginning of the storage. With the advancement of storage to week 2, a significant decrease in texture was noted in all treatments. The reduction was clear, but the statistical differences remained relatively low with most samples having similar significance groupings (ab). The decrease in texture can be explained by the loss of moisture, structural softening and biochemical alterations during storage. Such processes may undermine the internal matrix of the product resulting in reduced firmness. Miranda et al. (2014) discovered in a 12-month study that storage conditions affect food properties such as texture and shelf life.

The deterioration of the texture became more noticeable in week 3. The reductions in samples kept under Half conditions were larger than those of samples kept under Full conditions. An example is that T1 (Half) went down to about 56, and T1 (Full) retained a higher texture value of about 60. This tendency indicates that Full packaging condition proved to be more efficient in preserving the structural stability and decreasing the texture degradation rate. The increased exposure of Half-packaged samples to environmental factors could have increased the rate of moisture loss and structural breakdown. The lowest values of texture were obtained at week 4 in all treatments, which means that the quality significantly declined with time. T1 (Half) had the lowest texture value (around 50), then T2 (Half) and T1 (Full), with T2 (Full) having the highest texture value (around 60). The statistical clustering of most treatments at week 4 (c) validates that there were significant decreases in the first storage period. Rodriguez Furlán et al. (2017) examined the impact of inulin addition as a stabilizing agent in chocolate kept at 7, 15 and 30 °C for 100 days. They monitored the rheological characteristics, sensorial characteristics, shelf-life and physical characteristics. The chocolate exhibited a thick matrix structure, which minimized the size and quantity of fat crystals that were formed in storage and enhanced resistance to degradation.

In the comparison of the treatments, T2 tended to have higher texture values than T1, especially in Full packaging conditions. This indicates that the T2 treatment might have helped in preserving the structural features of the product better in the course of storage. Also, Full packaging condition always showed greater texture values than Half condition, which suggests that better packaging integrity can be a decisive factor in maintaining the quality of texture. The noted reduction in texture with storage can be attributed to a number of factors, such as migration of moisture, degradation and weakening of the product structure due to the presence of protein or other structural components. Drying may decrease the firmness and lead to softening, and enzymatic or biochemical processes during storage can also lead to the further degradation of structural components. On the whole, the results indicate that storage time and condition of packaging have a significant effect on the stability of texture. Full packaging treatment was more effective in preserving texture than Half condition, and T2 tended to preserve texture better than T1. Kiumarsi et al. (2020) emphasize the role of proper packaging and treatment methods in maintaining the textural quality of the product in storage in the results of a study.

6.4. Oxidation Stability

Oxitest results indicate that the oxidative stability of the samples gradually decreases during the four-week storage period. Oxitest induction time is a widely-used measure of lipid oxidation resistance, thus longer induction times indicate increased oxidative stability whereas shorter induction times indicate increased oxidation susceptibility. The Full packaging treatments had significantly higher Oxitest values (around 16 h) than Half packaging treatments (around 14 h 20 min) at the onset of storage (week 1). This disparity indicates that the packaging condition had a direct impact on oxidative stability. The increased induction time of the Full treatments suggests that a more comprehensive packaging environment probably restricted the availability of oxygen, thus retarding the onset of oxidative reactions. In a study, Hidayati et al. (2022) determined the shelf life of instant chocolate using accelerated shelf-life test (ASLT) with Arrhenius equation. The chocolate was stored at 30°C, 40°C, and 50°C in polypropylene plastic packaging for 42 days under vacuum conditions. Shelf life was estimated based on free fatty acid levels and first-order reactions. The shelf life of chocolate stored at 30°C, 40°C, and 50°C was 281.58, 240.99 and 113 days, respectively.

As storage progressed, a gradual decrease in Oxitest values was observed for all treatments. This reduction indicates that the resistance of the samples to oxidation diminished over time. Such behaviour is expected during storage because lipids and other oxidation-sensitive compounds progressively react with oxygen, leading to the formation of primary and secondary oxidation products. These chemical changes reduce the induction time measured by the Oxitest instrument. The decrease was more pronounced in the Half packaging treatments. At week 4, T1 (Half) and T2 (Half) had reduced to about 13 h 40 min and 13 h 35 min, respectively. Conversely, the Full packaging treatments continued to have better oxidative stability, staying above about 15 h 30 min. This trend is a clear indication that packaging integrity is very important in ensuring that the product is not subjected to oxidative degradation. The Half condition probably led to faster oxidation processes due to increased oxygen exposure, which led to lower Oxitest values. In a study by Tolve et al. (2022), unsaturated lipids in chocolate spreads were found to undergo oxidative reactions to form hydroperoxides, which is in line with the common oxidation patterns of food products kept. They employed accelerated shelf-life test and peroxide values analysis based on Arrhenius model to forecast shelf-life and examine oxidative stability.

Comparing the treatments per se, there were only slight differences between T1 and T2 in the same packaging condition. The two treatments had similar downward trends during the storage period. Nonetheless, T1 (Full) always had a little higher Oxitest values than T2 (Full), which means that it is slightly more oxidatively stable. Under Half packaging, the two treatments were quite similar, which indicates that the protective effect of the treatment was less effective when the oxygen exposure was greater. The gradual decrease in Oxitest values of chocolate spread is in line with the normal oxidation trend of food products stored. Unsaturated lipids can be oxidized during storage to form hydroperoxides and other degradation products. These reactions slowly undermine the antioxidant protection of the product and lower its oxidative resistance. Consequently, the induction period of the Oxitest system decreases with time. According to another study, high content of unsaturated fatty acids in nut butters and nut spreads causes autoxidation, which influences sensory properties and nutritional value through storage, with high peroxide values and free fatty acids indicating a weak antioxidant protection (Shakerardekani et al. 2013). In general, the findings indicate that storage time has a negative impact on oxidative stability, whereas the state of packaging has a strong impact on the deterioration rate. Samples kept in Full packaging conditions were more oxidatively stable during the storage time than those kept in Half conditions. This observation underscores the significance of proper packaging systems in curbing the exposure of oxygen and maintaining the quality of products during storage.

7. Conclusions

The findings indicate that T1 was most acceptable, then T2, and T3 requires further refinement, particularly in aroma-related attributes. The results indicate that aroma and taste are important determinants of overall product acceptability and could be more significant than texture alone. T3 was the best in texture, but its poor aroma led to a lower ranking. Conversely, T1 was rated highly in terms of taste and aroma, which highly favoured its choice, despite the fact that some of the attributes were rated as neutral. All treatments exhibited a continuous loss of moisture over time, with the moisture content decreasing gradually during storage. The moisture decrease was higher in Samples under Half packaging than Full packaging. This implies that the open packaging condition was more open to migration and evaporation of moisture. Similarly, the texture values also decreased during the storage period, which means that the samples softened gradually and their structure was deteriorating. The decrease in firmness was more evident in the Half packaging treatments, which could be attributed to increased moisture loss and structure weakening. The Oxitest analysis also revealed that the oxidative stability decreased gradually over time during storage, as evidenced by the decreased induction time. This implies that the samples were increasingly susceptible to lipid oxidation with increased storage. Nevertheless, Full packaging samples always had longer induction times, which means that they were more resistant to oxidative deterioration than Half packaging samples. This observation underscores the protective role of appropriate packaging in minimizing oxygen exposure and delaying oxidative reactions. In general, proper packaging is significant to preserve the quality of products and prolong their shelf life. The findings of this research emphasize the importance of optimizing the packaging conditions to minimize physicochemical degradation and maintain the stability of food products during storage.

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Appendices

List of the Appendices:

Appendix 1: Sensory Evaluation Line Scale

Sensory Evaluation of Chocolate Spread (with addition of Oat and Linseed)

Panellist – gender: ☐ **female** ☐ **male** **Date:**

Samples: 125
250
375

Instructions:

- You are given three samples of chocolate spread.
- **Section I**: Please evaluate each sample individually. Use the 10 cm unstructured line scale to indicate your perception of each attribute. For each attribute below, mark a point on the line (and mention the sample code), that best represents how much you like or dislike it.
- **Section II**: Rank the samples according to your overall acceptability.
- Rinse your mouth with water and neutral. Work in silence and do not discuss with others.

Section I:

Appearance:

dislike very much | | like very much

Aroma:

none | | strong

Aroma – pleasantness of aroma (if any):

dislike very much | | like very much

Please name the strongest aroma notes for each sample:

____

Taste:

unpleasant taste | | pleasant taste

Texture / smoothness

very rough | | very smooth

Aftertaste:

none | | strong

Aftertaste – pleasantness of aftertaste (if any):

unpleasant | | pleasant

Section II:

Please rank the samples according to your overall acceptability.

Sample code	Rank (1 = most acceptable, 3 = least acceptable)

If you want, please write short reason for your choice of the most acceptable sample:

____

Comments (you can comment on anything regarding this sensory evaluation):

____

Appendix 2: Scale for Spread-ability Test