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Comprehensive Quality Evaluation of Chia Seeds Roasted at Varying Temperatures and Durations

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Abstract
This research aimed to evaluate the physicochemical, nutritional, functional characteristics of chia seeds (Salvia hispanica L.) roasted at three temperatures of 160°C, 170°C, and 180°C for 15, 25, and 35 minutes; The increased shelf stability was linked to the reduced moisture content achieved by relatively higher roasting temperature and processing time, which correlate well with the decreased brightness (L* values) by reflectance measurement as best characterized by Maillard reaction products. Proximate composition analysis showed that leaf protein dry matter also decreased from 25.25% (raw) to 27.33% (180°C) and crude fat was reduced from 29.54% to 27.39% (181). Its usage for food formulations has been limited owing to the negative impact on useful characteristics include oil absorption capacity (OAC) and water absorption capacity (WAC). Moderate roasting (170 °C, 25 min) enhanced flavour and aroma based on sensory analysis, but increased roasting levels resulted in bitterness. Roasting chia seeds in the range 160°C–170°C for 15–25 min likely entail an optimal ambience with a good overall trade-off of retaining nutrients, functional properties, and sensory acceptability. A fact that makes them a coveted ingredient in baking and health-conscious foods.

Keywords: Chia seeds, Functional properties, Lipid oxidation, Roasting, Sensory evaluation.

1. Introduction

The Lamias circle of relatives includes the annual chia seed (Salvia Hispanica L.), which is valuable due to its high nutritional content. It contains greater protein after rice,wheat, corn, oats, and barley, which incorporates its essential proteins with globulin and albumin, which are easily digestible and make a contribution to excessive-seed oil and water-keeping capability (Sandoval - Oliveros and parades-lopes, 2013). According to Imran et al. (2016) and Gafoor et al. (2020), chia seeds are also a great source of oil that is high in polyunsaturated fatty acids. Chia seeds have significant health benefits and are an essential functional meal component because of their homes. Their exact polycecaride form enhances their ability to retain water, and they also contain about 5% mucus (Capitani et al., 2012). Accordingly, chia seeds exhibit have a number of biological properties like lowering blood cholesterol and promoting the growth of antioxidants and anti- inflammatory sports (Sargi et al., 2013).

Seeds are generally covered in powder to enhance the nutrients and sensory properties of meal merchandise inclusive of chips consisting of snacks (Corey et al., 2014). The purposeful houses of the dough-oil absorption potential, water absorption and solubility index and antioxidant activity play a crucial position in determining its suitability for various meals yogas (Olivos-Lugo et al., 2010). These residences affect gluten formation and basic product fine. Various thermal processing techniques, which include microwave heating, autoclaving and roasting, are used to alter the feel, practical chracter and storage stability of seeds. In those techniques, roasting is an easy and effective approach normally accomplished at temperatures starting from 150 ° C to 400°C (Ismail et al., 2020). The roasting oxidative balance improves the shade, flavour and shade of the seeds, deactivating enzymes and microorganisms and lowering toxins and contaminants (rig at al., 2021). Previous studies have validated the impact of roasting on sensory and purposeful residences of diverse seeds. For example, (Jannat et al., 2010) examined sesame seeds' antioxidant properties. and the effects of frying on the entire phenolic material (TPC), for 200 ° C at 129 ± 5 mm after 200 ° C at 200 ° C at 129 ± 3.5 mm. Reporting the increased in TPC from 9 mm. This growth becomes attributed to the warmth - brought on by a crack of covalent sure phenolic compounds. Similar studies on walnut flour, chickpeas and barley have shown improvement in sensory and practical traits due to roasting (Wang et al., 2019). Given the substantial impact of the nation of frying on the bodily-regional and nutritional properties of seeds, the edition of roasting parameters is essential to reap the ideal product high-quality.

Despite tremendous studies on roasting results in one of a kind seeds, no research has specifically tested the

impact of varying roasting times and temp. at the chia seed flour's physicochemical facilities. As a result, the current check examines the effects on the physicochemical properties of roasting chia seeds at 160°C, 170°C, and 180°C for 15, 25, and
35 minutes. The results will provide information about roasted chia seed flour's ability programs in food formulations.

2. Material and Method

The chia seeds (Salvia hispanica L.) were purchased from a Pune community market, in India. To ensure uniformity and purity, the seeds have been cautiously wiped clean by manually getting rid of visible debris and passing them through seen sorting. After cleaning, the seeds have been saved in hermetic boxes at refrigeration temperature (4°C) to save you publicity to moisture, oxidation, or microbial increase before further processing (Coorey et al., 2014).

All analytical-grade chemicals used for the physicochemical assessment of chia seeds have been acquire from laboratory. These chemicals were applied in numerous tests, which included oil absorption capacity, water absorption residences, and other practical opinions.

2.1. Roasting Process

2.1.1. Roasting Equipment and Procedure

The roasted process was performed using an electric-powered oven using a correct- managed laboratory oven appropriate for excessive-temperature roasting programs. The temperature becomes maintained appropriately at some point in the technique to ensure persistent warmth distribution.

Chia seeds have been subjected to roasting at three one-of-a-kind temperatures (160°C, 170°C, and 180°C) and three separate roasting times (15 minutes, 25 minutes and 35 mins), so that the results of heat remedy on their bodily chemical properties might be tested. Each roasting treatment changed into designed primarily based on preceding studies and preliminary exams to ensure effective amendment of chia seed properties without excessive fall (Pizaro et al., 2013).

2.2. Roasting Treatments

The experimental roasting conditions were categorized into nine treatments, designated as follows:

Table 1: Temperature and time of sample:

Sample	Temperature (°C)	Time (min)
1	160	15
2	160	25
3	160	35
4	170	15
5	170	25
6	170	35
7	180	15
8	180	25
9	180	35

Based on early tests and literature reviews, it was observed that at temperatures of more than 180 ° C, the reaction of becomes highly active, causing excessive darkness to chia seeds. For non-enzymatic browning maillard reaction are conducted process that occurs when sugars and amino acids occur when there are reactions under high heat. While this reaction enhances taste and aroma, excessive browning can result in undesirable sensory properties and potential nutrients (Jannat et al., 2010). To prevent excessive darkness and maintain optimal quality, the frying temperature for this study was limited to (160 – 170 - 180°C). During roasting, chia seeds were equally spread to ensure contact with similar heat in the same layer on a baking tray. At the end of each roasting period, the seed was before continuing, they were taken out of the oven and given time to cool at room temperature (Miranda-Ramos et al., 2019).

2.3. Analysis for Sample Preparation

2.3.1. Grinding Process:

To be ready for the physicochemical evaluation of the roasted chia seeds, they had been floor using a hand grounding technique. This grinding system turns out to be completed right now after roasting to reduce oxidation and make certain uniform particle size distribution. The grinding was conducted slowly to save you immoderate heat era, which would similarly regulate the chemical composition of the samples.

2.3.2. Sieving and Particle Size Standardization:

After grinding, the ground chia seed samples have been sieved manually with the usage of a first-class-mesh sieve to achieve an average particle period of <250 μm. This step ensured consistency in particle length, it truly is vital for functional and physicochemical analysis. Standardizing the particle length eliminates variability in experimental

consequences and permits correct comparisons between particular treatments (Valdivia-López and Tecante,2015).
The processed chia seed flour samples stored in hermetic bins at four degree celsius till in addition to assessment to prevent moisture absorption, lipid oxidation, and ability microbial contamination (Ghafoor et al., 2020).

2.4. Content of Moisture

The results from the use of the oven-drying method, a suggested technique for assessing moisture content in food products, were based on the moisture level in various samples of various patterns of chia seeds. There should be the use of an analytical balance to weigh approximately 5 gm of each pattern, which should then be dried at 55 - 60°C for three hundred minutes. Once dried, the samples were taken out of the oven, and transferred to a desiccator, then weighed. The material of moisture content is computed application of the following equation (AOAC, 2016):

$$\textit{Moisture Content (\%)} = \frac{M1-M2}{M1} \times 100$$

Where:
M1 = The sample's initial weight (g) prior to drying M2 = Final weight (g) of the sample after drying.
This method provides an accurate measure of the chia seeds moisture content, which is a critical variable for assessing the seeds' stability, processing characteristics, and potential for microbial growth.

2.5. Water Solubility Index (WSI) and the Water Absorption Index (WAI)

The rehydration properties of the chia seed flour samples were evaluated using the water absorption index and water solubility index. These parameters are highly significant in assessing dough properties, the texture of products, and the water-holding capacity of flour mixtures because they influence these flour functional properties.(Capitani et al., 2012)

2.5.1. Determination of Water Absorption Index (WAI)

2.5 g powdered chia seed flour and 25 mL distilled water were mixed at room temperature (25°C) and allowed to rest for 30 minutes to ensure sufficient hydration to calculate WAI. After this period, a high-speed centrifuge was employed to centrifuge the mixture for 15 minutes at three thousand rpm. The liquid supernatant was discarded carefully after centrifugation and the weight of the rest of the hydrated material was recorded. The water absorption index was determined using the following formula (AOAC, 2016).

Where:

- M1 = The sample's initial weight (g) prior to drying
- M2 = Final weight (g) of the sample after drying.

This method provides an accurate measure of the chia seeds moisture content, which is a critical variable for assessing the seeds' stability, processing characteristics, and potential for microbial growth.

2.5.2 Water Solubility Index (WSI) Calculation

The supernatant, separated by centrifugation, was dried in the hot air oven at 105°C until a constant weight was obtained from it, following which Water Solubility Index (WSI) was calculated as given below.

$$WSI = \frac{WS}{WP} \times 100$$

- = Weight (g) of the residual material after centrifugation
- = Initial weight (g) of the sample

High water-absorption index values reflect improved water-retention ability, which is a worthwhile trait in food products, such as in bakery and extrusion-based foods, requiring moisture retention (Coorey et al., 2014).

2.5.3 Capacity to Absorb Water (WAC)

The Water Absorption Capacity (WAC) of chia seed flour can prove important property for food ingredients, more on bakery, meat, and dairy foods. It actually determined in order to ascertain the water absorption capacity (Coorey et al., 2014). In a check tube, 1g of powdered chia seed flour mix with 10mL of distilled water to achieve degree WAC. The mixture was allowed to sit at ambient normal temperature (25 degrees Celsius) for 30 minutes to allow proper hydration and interaction between the water and chia flour additions. After this period of hydration, gas was centrifuged in a high-speed centrifuge at 2000 rpm for 15 minutes. Thereafter, the supernatant was decanted carefully, and the wet sediment was weighed and recorded. Water Absorption Capacity (WAC) was calculated using a percentage equivalent to the gram of sample pattern using the formula below (AOAC, 2016).

Where:

$$WAC(\%) = \frac{WR - WP}{WP} \times 100$$

- WR = The hydrated sample's weight (gm) following centrifugation
- WP = The sample's initial weight (gm)

Higher WAC values indicate flour that's more valuable due to its ability to hold water. This has a positive impact on various food products improving dough texture, consistency, and how well it keeps moisture (Capitani et al., 2012)

2.6 Oil Absorption Capacity (OAC) Calculation

To figure out Oil Absorption Capacity (OAC), scientists used this formula (AOAC, 2016).

$$OAC(g/g) = \frac{Weight\ of\ oil\ absorbed\ (g)}{Weight\ of\ sample\ (g)}$$

When flour shows high OAC, it means that it is better to catch fat. This can help flavors to make the taste more stable, and can give your mo of your Mouth Mouth when you eat fat foods (Kuri et al., 2014).

2.6 Colour Measurement

Colour is a crucial spectacular feature in food products because it influences the reputation of the patron's imagination, sensory attraction and product (Pathar et al., 2013). The Conica Minolta CR-400 Colorimeter is used to measure the shade of roasted chia seeds. Before evaluation, the use of the shade eyimer elaborate white calibration plate becomes calibrated. Flour samples of floor chia seed flour were located in Petri dish with flat or perhaps the floor and 3 separate readings were recorded for each sample. The browning index (BI) is an essential parameter that shows the extent of the Maillard reaction and other browning processes that occur at some stages of roasting (Muscan, 2001). BI changed the calculation of the use of the following equation (Pathar et al., 2013):

$$BI = \frac{100(X - 0.31)}{0.172}$$

More browning from Maillard reactions and caran igher BI sc ave a

$$X = \frac{(a* + 1.75L*)}{(5.645L* + a* - 3.012b*)}$$

direct impact on BI because longer roasting produces more pigment and non-enzymatic browning processes, which raise BI values.

2.7 Identification of Phenolic Compounds

Phenolic compounds are critical bioactive additives in chia seeds, their anti -Oxidant capacity, oxidative balance and fitness benefits of capacity playing important functions (Muos et al., 2013). The identification and dose of phenolic compounds in chia seed floors was used in high-performance liquid chromatography (HPLC), which is widely applied analytical. Phenolic compounds from chia seeds, 5 grams of sample is mixed with 10 ml of 70% hydroathenolic answer (ethanol: 70:30 V/V), because of the protocol defined by the use of (Duert-Vasquaz et al., 2019). Inexperienced competent extraction of phenolic compounds is facilitated by allowing the sample combination to be changed at room temperature (25 °C) for four hours in an ultrasonic bath tub. Following sonication, the superonate was gently removed, and unwanted particles were removed by cleaning 0.2 µm membranes to filter the extract. After the extracts are filtered, the HPLC is kept in amber vials at 4 degrees Celsius to stop the phenolic chemicals from degrading.

2.7.1. Phenolic Standards and Quantification

Six milligrams of standard phenolic compounds, pyrocatechol and chlorogenic acid, were dissolved in ten millilitres of HPLC-grade methanol and used as reference standards to guarantee the precision of phenolic compound identification. Researchers compared how long it took for standards to come through the machine and how big their peaks were with the same info for phenolic compounds they got from chia seed flour.

2. Result and discussion

Roasting had a major impact on the functional characteristics and proximate composition. of chia seeds. As roasting temperature and time stepped forward, moisture content material decreased, maximum essential to a drier and similarly strong product at the same time as slightly growing the relative consciousness of carbohydrates and lipids. The protein content fabric remained alternatively sturdy, regardless of the truth that minor thermal degradation become determined at better roasting temperatures. Additionally, roasting superior oil absorption capacity (OAC), water absorption index (WAI), and water solubility index (WSI), making the chia flour greater appropriate for food programs along side bakery merchandise. Prolonged roasting at a 180°C triggered excessive browning and degradation of heat-touchy compounds, emphasizing the want for managed roasting parameters to balance capability and nutritional best.

Temperature & Time	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Fiber (%)	Carbohydrates(%)
De-roasted	6.5 ± 0.4	18.4 ± 0.5	30.9 ±0.6	4.5 ±0.2	34.0 ±0.8	5.2 ± 0.4
160°C – 15 min	4.2 ± 0.3	18.3 ± 0.4	30.8 ±0.5	4.5 ±0.2	33.8 ±0.7	7.1 ± 0.5
160°C – 25 min	3.5 ± 0.2	18.2 ± 0.3	30.7 ±0.5	4.4 ±0.2	33.6 ±0.6	8.3 ± 0.5
160°C – 35 min	1.0 ± 0.1	18.0 ± 0.3	30.5 ±0.4	4.3 ±0.2	33.3 ±0.5	10.8 ± 0.6
170°C – 15 min	4.0 ± 0.2	18.3 ± 0.3	30.9 ±0.5	4.5 ±0.2	33.6 ±0.6	6.8 ± 0.5
170°C – 25 min	3.1 ± 0.3	18.2 ± 0.3	30.7 ±0.4	4.5 ±0.2	33.4 ±0.6	7.9 ± 0.6
170°C – 35 Min	0.9 ± 0.1	18.0 ± 0.3	30.5 ±0.4	4.3 ±0.2	33.1 ±0.5	10.4 ± 0.6
180°C – 15 min	4.0 ± 0.3	18.2 ± 0.4	30.8 ±0.5	4.5 ±0.2	33.5 ±0.6	7.1 ± 0.5
180°C – 25 min	2.9 ± 0.5	18.0 ± 0.3	30.7 ±0.4	4.4 ±0.2	33.3 ±0.5	8.4 ± 0.6
180°C – 35 min	0.8 ± 0.1	17.8 ± 0.3	30.5 ±0.4	4.2 ±0.2	32.0 ±0.5	10.7 ± 0.7

Chia seed flour's physicochemical properties were greatly increased by roasting; remarkable changes were seen in the oil absorption capacity, water absorption and solubility index, water absorption potential. The OAC remained solid at one 160°C and 170°C for shorter roasting times but increased drastically at 170°C for 35 minutes (T1735) and a hundred and 80°C for all periods, reaching 5.Three ± zero.6 g/100 g in T1835.(Muhammad Imran, M. I., Muhammad Nadeem, M. N. at al., 2016) This suggests protein denaturation and the exposure of hydrophobic groups, improving oil-binding ability. Similarly, WAI and WSI showed an upward style with improved roasting temperature and time, indicating starch degradation and the formation of smaller molecular systems that enhance water retention and solubility. The most WAI (7.Four ± 0.6 g/g) and WSI (20 ± 2.6%) have been placed in T1835, In comparison to the unroasted sample, a significant development was also confirmed at the same time as T1735.

Capacity to absorb water (WAC) remained relatively

Treatments	OAC (gm/100 gm)	WAI (gm/gm)	WSI (%)	WAC (gm/100 gm)
De-roasted	3.8 ± 0.3	5.0 ± 0.1	15 ± 2.2	6.0 ± 0.3
160°C – 15 min	3.5 ± 0.4	6.0 ± 0.2	14 ±1.1	6.0 ± 0.2
160°C – 25 min	3.7 ± 0.1	5.4 ± 0.3	12 ± 0.5	6.1 ± 0.5
160°C – 35 min	3.6 ± 0.5	5.0 ± 0.2	17 ± 06	6.3 ± 0.1
170°C – 15 min	3.7 ± 0.3	6.2 ± 0.3	16 ± 1.2	6.1 ± 0.2
170°C – 25 min	3.8 ± 0.5	6.0 ± 0.4	15 ± 0.9	6.2 ± 0.3
170°C – 35 min	4.4 ± 0.4	6.1 ± 0.2	16 ± 1.3	6.4 ± 0.3
180°C – 15 min	3.4 ± 0.6	5.6 ± 0.7	14 ± 1.7	6.1 ± 0.3
180°C – 25 min	4.3 ± 0.4	5.7 ± 0.1	15 ± 0.7	6.3 ± 0.4
180°C – 35 min	5.2 ± 0.6	7.3 ± 0.6	19 ± 2.6	6.4 ± 0.2

stable across different roasting temperatures but slightly increased at 180°C for 35 minutes (T1835: 6.4 ± 0.2 g/100 g). This enhancement is attributed to starch gelatinization, mucilage expansion, and increased exposure of hydrophilic protein structures, which improve water retention. The browning index (BI) progressively increased with temperature and roasting time, signifying intensified Maillard reactions and caramelization. At 170°C, the browning index increased to 24 ± 0.5 in T1735, whereas the highest value (25 ± 0.5) was recorded for T1835, indicating greater color development at higher temperatures. The moderate browning increase at 170°C suggests that it can be used in applications that need a compromise between functional and sensory properties.

Water absorption capacity (WAC) remained relatively stable across different roasting temperatures but slightly increased at 180°C for 35 minutes (T1835: 6.4 ± 0.2 g/100 g. Because of starch gelatinization, mucilage swelling, and greater hydrophilic protein structure exposure with greater water retention, the process has the browning index (BI) increased progressively with temperature and roasting time, indicating that temperature and roasting time favors Maillard reactions and caramelization. Browning index is raised at 24 ± 0.5 for T170°C for 35 minutes while the highest is for T180°C for 35 minutes which is 25 ± 0.5 thereby proving that more color development is efficient at greater temperatures. A little increase at 170°C would indicate that it can be used for applications where a combination of functional and sensory properties may be required. Roasting chia seed flour at 170 and 180 °C enhanced its functional properties, making the flour applicable in food formulations like soups, baked products, and emulsified products. T170°C 35 minutes and T180°C 35 minutes samples had the most suitable combination of oil absorption, water absorption, and color enhancement, which could be utilized to enhance texture, stability, and nutritional value. Apparently, these kinds of modifications show potentiality for the controlled roasting conditions in maximizing the physicochemical characteristics of chia seed flour towards further application in the food industry.

1. Conclusion

Lately, roasting chia seed flour influenced WAS, OAC, WSI, WAC. This is similar with the fact that heat processing impacts on the nutritional and functional characteristics of grains and seeds, as supported by earlier findings. Earlier studies established the functional, technical and bioactive properties of seeds improved by roasting chia flour application in food Here, frying chia seed flour improves its functional and nutritional properties, thus making it a promising candidate for food product formulation. However, over-roasting would destroy heat-sensitive bioactive compounds, hence increasing the roasting parameters is imperative to harvest maximum health benefits from chia seed flour.

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