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Functionality Valoraization of Eggshell Waste for the Development of Calcium-Enriched Functional Food Product

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Abstract: This review discusses the use of eggshell powder as a bioavailable source of calcium to be used in food fortification in order to contain calcium deficiencies in the world. Eggshells are a by-product of the poultry industry which has a calcium carbonate content of approximately 35 percent but these are usually disposed of thus creating waste in the environment. We consider methods of preparation benefits of foods fortified with calcium and difficulties in incorporating the eggshell powder. Among the major factors it is possible to single

out calcium bioavailability, nutritional enrichment, consumer acceptability and profitability. Eggshell powder will facilitate sustained food production circular economy and even fight calcium deficiency at the global level. Fortified doughnuts recorded better ash (0.65-1.92%), stable protein (8.4-8.9%), fat (15.2-15.8%) levels, lower moisture (18.20-20.10%) and longer shelf life (4-5 days), and higher calcium (22-142 mg/100g) in the treatments (T2), which were more acceptable to the consumers. All in all eggshell powder fortification improves the nutritional value of the product and its stability and it provides a cost-efficient and environmentally friendly method of valorization of calcium-fortified bakery products.

1.Introduction

Calcium is a crucial mineral in the nutrition of human beings which plays a crucial role in many physiological processes and essential to the sustenance of the bones muscle contraction blood clotting and nerve transmission. Calcium is essential in the lifespan and especially in proportion on the development of bone in childhood, its maintenance in adulthood and prevention of bone loss during aging (Rahman et al., 2022). Nevertheless, global calcium deficiency is a significant problem although its significance should not be underestimated. Still is a major health issue among the general population especially in those that do not have a good access to dairy fortified foods and calcium supplements or products. It has been endorsed by the World Health Organization (WHO) reported that one of the major causes of osteoporosis and bone fracture is calcium deficiency especially in areas that have low dairy and other foods rich in calcium in their diets (Ponzoni et al., 2019). Conventional sources of calcium like dairy products are not necessarily always available especially in developing nations owing to some reasons such as dietary limitations lactose intolerance and the increasing number of dietary concerns consume less milk and its dairy products costs (Sarwar et al., 2021). Therefore, the need to find out is increasing other viable inexpensive and environmentally friendly sources of calcium which can easily be added into the diet. Food fortification has become a critical measure in this regard to combat micronutrient deficiencies and enhance the nutritional condition of the populations in general (Alam et al., 2020). Enrichment of dietary products like bread, cereal, and drinks with calcium is on the rise momentum as an effective means of communicating with large masses of people without having to invest much changes in dietary habits.

A novel solution can be seen in eggshells which are typically considered as a by-product of the poultry industry waste to this problem. Eggshells are a rich source of calcium carbonate ($CaCO3$) which is only partly composed of it but untapped which is about 35 percent calcium in weight (Sharma et al., 2020). Incinerating the eggshells and using them as a sustainable supply of calcium presents benefits of environmental and nutritional benefits. Eggshells Recycling of eggshells helps in the reduction of waste and the minimization of the effects on the environment not only cause an impact but also an opportunity to solve the issue of calcium deficit that is a global problem. (Banik et al., 2021).

The shells of the eggs are disposed in landfills or fed on by animals so they cannot be exploited as another possible source of functional food ingredient. A number of studies have however

shown that it is possible recycling eggshells to produce a bio available source of calcium which can be used in other things food products. When well processed eggshell powder is very bio available that is it is readily assimilated and used by the human body and so is a perfect candidate food fortification (Rahman et al., 2022). Eggshell powder contains calcium that has been shown to be absorbed like the synthetic calcium supplements and providing a natural and effective one substitution of the conventional sources of calcium (Ponzoni et al., 2019). Besides the supplementary presence of other minerals such as magnesium, phosphorus and collagen increases the health benefits in general of eggshell powder and thus not only a sustainable source of calcium but a complete one vitamin to build up bone health and well-being (Sarwar et al., 2021). This review aims to discuss the opportunity of the eggshell powder as a sustainable source food fortification with calcium.

Through the research of eggshells processing methods. This paper evaluates powder its bioavailability and a discussion of its use in foodstuff intends to emphasize the value of eggshell powder as a nutritional element of the world and sustainability. Also the issues associated with the addition of eggshell powder in the food products its business feasibility and how acceptable it is to the consumer will be discussed. The review will as well give future prospect on the application of eggshell powder in solving. calcium shortages and sustainable food production. Overall, this review aims to highlight the significance of utilizing eggshells to make an eggshell repurposing a useful idea and food industry resource. Through conversion into a functional ingredient this waste material can be utilized eggshell powder will be a viable solution to the approaching problem of calcium which is sustainable and nutritionally deficiency which is in line with global missions to use sustainable food systems and enhance public health outcomes.

2.Objectives:

1. To use agro-industrial waste through repurposing eggshells into a viable source of calcium.
2. To prepare food products fortified with calcium using an eggshell powder and test their nutrition and sensory properties.

3. METHODOLOGY

3.1Procurement of Raw Material

The ingredients used to prepare doughnuts were the refined wheat flour (maida), milk, salt, butter, powdered eggshells, sugar, eggs and yeast. These have been bought at local market of faisalabad. The preparation of the product was done at Government College University of Faisalabad, Department of Food Science.

3.2 Preparation of Eggshell Powder

The eggshells were rinsed with running water to eliminate albumen. They were separated manually and the shells were boiled (10 minutes) to minimize the levels of microbes as described in Onwubu et al. (2017). The shells were dried in the oven at 105 degree 2 hours ground in a laboratory grinder and sieved to achieve the size of the particles of less than 75 um just as done by Kumar et al. (2023). The powder was kept in airtight containers until it was used.

3.3 Development of Eggshell-Enriched Doughnut

The chicken egg shell powder was added into the doughnuts preparation in order to increase nutritional value and calcium level of the doughnuts. The case of adding the egg shell powder was done according to Table no.1. Doughnut was developed on the foundation of the ingredients that included refined wheat flour, sugar, egg white, yeast, table salt, milk, butter. The formulation approach was formulated to glorify food waste and to improve the mineral composition of a mainstream foodstuff consisting of bakery products (Sani et al.,2022). Doughnuts were prepared in the way of Product development. The preparations in the course of the phase of product development involved four treatment of calcium enriched doughnuts using varying amounts of powder of chicken egg shells in the fully hygienic setting (Table 1.2). T_0 was a control group that was used to make a comparison. T_1 sample was made by 0.5g chicken egg shell powder alone. Preparation of T_2 was done with 1g CESP alone. T_3 was prepared by 1.5g of CESP.

Table. 1. Doughnut formulation with different quantity of eggshell powder

Treatment	Refined Wheat Flour (g)	CESP (g)
Control T_0	400g	0
T_1	300g	0.5g
T_2	200g	1g
T_3	200g	1.5g

RWF: Refined Wheat Flour(Maida) **CESP:** Chicken egg shells powder

The necessary amounts of refined wheat flour, sugar, salt, yeast, and eggshell powder have been weighed depending on the formulation and blended in an electric stand mixer (Ambiano SMV2KT) in three minutes to have evenly distributed the eggshell powder. Milk was warmed to around 37ºC in order to activate the yeast and subsequently blended with melted butter. This wet mix was added into the dry ingredients as it blended to form a homogeneous dough. The dough was rolled on a floured surface between 10-15 minutes or until the dough was smooth and elastic to make sure that there was the proper growth of gluten and the eggshell powder

was evenly mixed into the dough. This kneaded dough was placed in a greased bowl and then subjected to first proofing in a proofing chamber at 30ºC of 1-2 hours till its volume doubled. Once the dough had risen, it was punched down to release the air held in it and then rolled out to a thickness of about 1 cm and cut using a doughnut cutter into doughnuts. The doughnuts in their shaped forms were put on a tray that was slightly greased and left to pass through second proofing of 30-45 minutes at 30ºC. The tried doughnuts were then fried in hot oil at 180ºC in 2-3 minutes on each side until golden brown drained on absorbent paper to get rid of excess oil and allowed to cool down to room temperature on a wire rack to avoid the formation of moisture. Finally, the airtight packaged cooled doughnuts were stored and to be analyzed later.

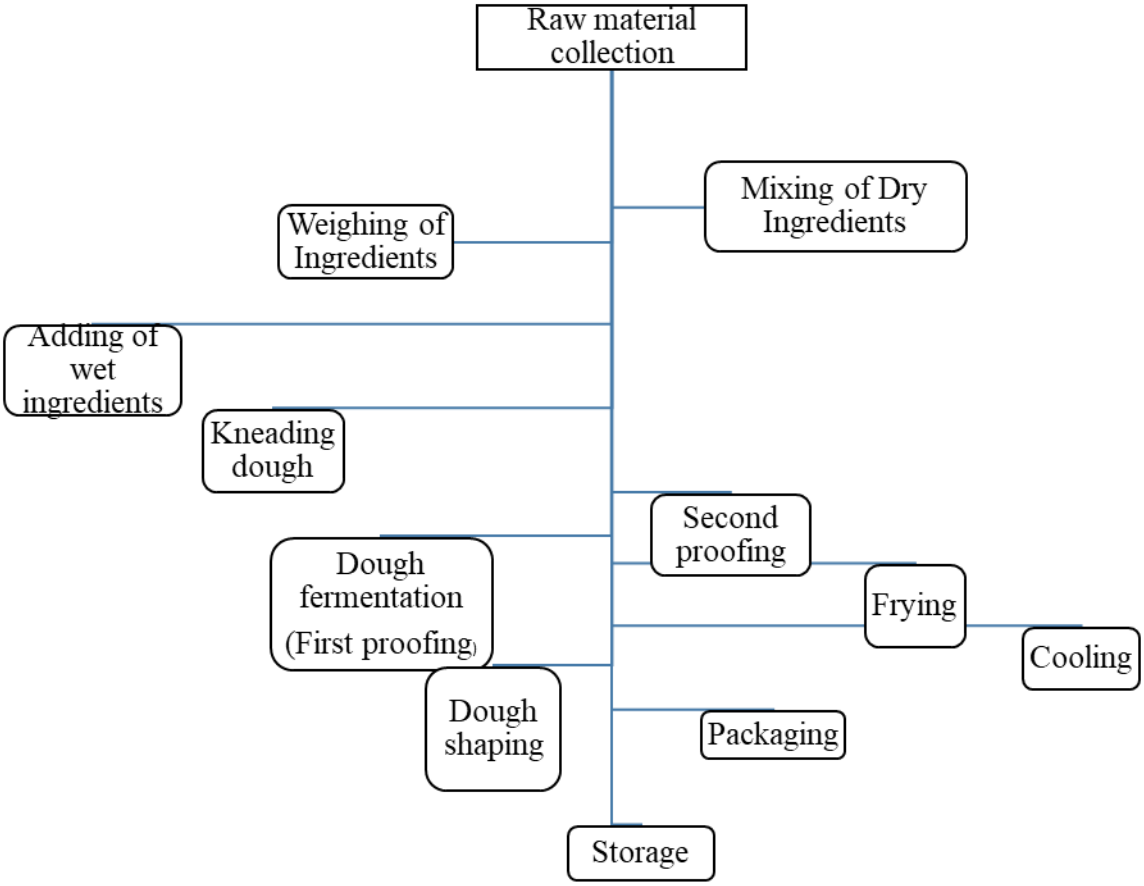

Figure.1. Systematic flow line of Doughnuts Preparation

4.Proximate analysis of Doughnut

There were four doughnut treatments that were developed and tested i.e., T_0 (control that had no eggshell powder added in it) T_1, T_2 and T_3 (with added increments of eggshell powder). The

samples of the doughnuts of both treatments were dried in the oven and then ground to fine particulate matter after frying and cooling. The FTIR spectroscopy was utilized to determine functional groups as well as the presence of the calcium silicate carbonate based on eggshell powder, according to the conventional methods introduced in the previous literature (Rodrigues et al., 2017; Hassan et al., 2020). A Fourier Transform Infrared spectrophotometer was used to record FTIR spectra in the mid- infrared region (4000 to 400cm-1) at room temperature with a spectral resolution of 4 cm-1. Each sample was scanned several times and averaged to enhance the clarity of the spectrum and its accuracy (De Alvarenga et al., 2018). The obtained spectra of fortified samples (T_1-T_3) were also compared to the control treatment (T_0) to determine the changes in the intensity of the peaks and the appearance of the typical absorption bands. Special attention was paid to the determination of absorption peaks, which are at 712 cm-1, 874 cm-1, and 1410-1450 cm-1 and can be attributed to the bending and stretching vibrations of carbonate ions (CO32-), as well as the formation of calcite (Stadelman, 2000; Al Omari et al., 2016). This discussion has allowed the validation of the effective integration and thermal stability of calcium carbonate that is obtained through eggshell in the doughnut structure.

4.1 Mineral Analysis

This was analyzed so as to determine the mineral content of fortified doughnuts. The samples were made by using the wet digestion procedure according to which 100 mL of each doughnut sample was weighed in the 100 mL conical flask and then it was digested using the 10 mL of nitric acid which was concentrated and kept in a hot plate at 70degC during 20 minutes. The solution was then added to a greater extent in higher temperature of 190degC with 5 mL of 60% per chloric acid (HClO4) to the extent that contents became clear. A 100 mL volumetric flask was then added, the amount was supplemented by the distilled and deionized water and the mixture was filtered using What man filter paper (Afzal et al., 2020). Mineral determination of the clear filtrate was done by use of Atomic Absorption Spectrophotometer (AAS, Model: Varian AA-240, Agilent Technologies, USA). Calibration curves were prepared with standard solutions of known concentration; each mineral element was used. Quantification of the doughnut samples mineral contents against the corresponding standard curves was then done as per stipulations of the American Association of Cereal Chemists (AACC, 2000).

4.2 Texture analysis

The texture of the eggshell fortified doughnuts since texture is a crucial property that can determine consumer acceptance and product quality. There were four treatments, T0 (control), T1 (0.5 g ESP), T2 (1.0 g ESP) and T3 (1.5 g ESP). A Texture Analyzer Model no. (TAXT plus, Stable Micro Systems,UK) was used to obtain the texture profile by adhering to standard procedures in compression tests under the basis of double compression. The samples of doughnuts of equal size (about 2 cm3) were made and a cylindrical probe compressed the samples to a height of 50% of their original height at both a pre-test speed of 2.0 mm/s test speed of 1.0 mm/s and post- test speed of 2.0 mm/s. Parameters measured consisted of hardness (N), cohesiveness, springiness (mm) and chewiness (Nm) and were measured in triplicate in each treatment to facilitate accuracy and reproducibility. The obtained data were tested using

one-way ANOVA to check whether there was a statistical significance of treatment differences at the level of 5%. The methodology in the study corresponds with the previous studies on bakery texture assessments that relied on similar instrumental tests to determine the stability of the structure, chewiness, and hardness of fortified and enriched products (Estelle Lane's, 2005; Wang et al., 2018).

4.3 ADVANCED ANALYSIS OF DOUGHNUT (FTIR)

There were four doughnut treatments that were developed and tested i.e., T_0 (control that had no eggshell powder added in it), T_1, T_2 and T_3 (with added increments of eggshell powder). The samples of the doughnuts of both treatments were dried in the oven and then ground to fine particulate matter after frying and cooling. The FTIR spectroscopy was utilized to determine functional groups as well as the presence of the calcium silicate carbonate based on eggshell powder, according to the conventional methods introduced in the previous literature (Rodrigues et al., 2017; Hassan et al., 2020). A Fourier Transform Infrared spectrophotometer was used to record FTIR spectra in the mid- infrared region (4000 to 400cm-1) at room temperature with a spectral resolution of 4 cm-1. Each sample was scanned several times and averaged to enhance the clarity of the spectrum and its accuracy (De Alvarenga et al., 2018). The obtained spectra of fortified samples (T_1-T_3) were also compared to the control treatment (T_0) to determine the changes in the intensity of the peaks and the appearance of the typical absorption bands. Special attention was paid to the determination of absorption peaks, which are at 712 cm-1, 874 cm-1, and 1410-1450 cm-1 and can be attributed to the bending and stretching vibrations of carbonate ions (CO32-), as well as the formation of calcite (Stadelman, 2000; Al Omari et al., 2016). This discussion has allowed the validation of the effective integration and thermal stability of calcium carbonate that is obtained through eggshell in the doughnut structure.

4.4 Sensory Evaluation:

The sensory analysis process outlined by Civiler and Car (2016) gives an excellent chance of acquiring a balanced evaluation of various characteristics of the product as perceived by the five senses of human beings. This plays a significant role as a tool of assessing the newly established products whereby quality and control of production can be gauged. Ten participants of sensory evaluation were presented with samples of doughnuts. Sensory analysis considered such characteristics as appearance, color, flavor, taste, aroma, mouthfeel, and consumer acceptability in general. The panelists were explained the method of evaluation and score sheet using a 9-point hedonic scale. To analyze, middle points were taken, with the highest points being a characteristic of good quality (1 had been extremely disliked and 9 extremely liked) (Wafiqah et al., 2019). The Sensory Evaluation Laboratory at the Government College University, Faisalabad, Department of Food Sciences judged Hedonic response.

4.5 Statistical analysis:

In order to establish the level of significance of each parameter, the data was analyzed statistically. The success of the mean was determined by means of the Tukey HSD test and

both one-way and two-way analysis of variance were performed in the analysis of variance. The results were expressed in the mean and the standard deviation.

5.Result and Discussion

5.1 Compositional Properties of Calcium-Enriched Doughnut

The doughnut samples fortified by a different level of eggshell powder Control (no fortification) T_1 (0.5 g), T_2 (1.0 g), and T_3 (1.5 g) per formulation and their proximate composition analyses. To measure the nutritional value and the compositional changes that are caused by fortification the following properties were checked such as moisture content, fat content, protein content and the ash content. To assess the importance of observed differences descriptive statistics (mean +- standard deviation) were calculated and ANOVA was conducted the slight increase in moisture as the levels of calcium carbonate increased was explained by the fact that calcium carbonate can form protein-starch-calcium networks and improve water holding capacity and inhibit evaporation thus have the potential to preserve crumb softness and increase storage life by delaying staling. It was found that the moisture content of the T_3 sample of a doughnut had (1.5g eggshell powder) which is a small increment of (8.25 +- 0.03) in Control T_0 to 8.25. Although the effects of components batches and interactions were not significant ($p > 0.05$), the two-way ANOVA proved the main influence of the amount of eggshell powder to be highly significant ($F = 89.69$, $p < 0.001$). The calcium carbonate in the eggshell powder has the capability to combine with the starch particles and the gluten proteins in order to create a more robust gel network that will retain the water molecules during frying. This network prevents the high speed movement of moisture and the loss of water by evaporation. As a result, even the minimal addition of moisture content is also observed on a regular basis. It has been demonstrated that calcium-enriched bread systems possess the same water-binding properties (Zulkeflee et al., 2020; Salama et al., 2025). The fat content in the sample of doughnut was small was the increase or decrease in the fat content between T_0 (3.50 +- 0.05) and in T_3 (3.55 +- 0.01). The ANOVA results showed that the main effect was significant ($F = 25.81$, $p < 0.001$) but the batch effect and the interaction effect was not significant. The presence of calcium in eggshell powder may have altered the crust porosity and surface tension during frying and this would have influenced the oil absorption. The calcium-protein/starch matrix could have indirectly changed the pattern of the oil uptake, and influenced the rate of moisture evaporation and to some degree, the rate of oil penetration into the crumb. These structural effects seem to be less severe, within the normal level of sensory tolerance since the increase that was measured was very small (0.05). The same small increases and decreases in the fat content of mineral-enriched cookies and fried snacks were also found (Hooyberghs et al., 2024; Chilek et al., 2018). The slight increase in protein content was probably as a result of protein matrices stabilized by the addition of calcium and this can decrease textural degradation caused by proteolytic enzymes by stabilizing the protein during prolonged storage. ANOVA revealed that the protein content had a significant effect of very high significance ($p < 0.001$) in T0(5.95 +- 0.02) to T_3, but no batch and interaction effects.

The high heat resistance in the frying process could have been attributed to these ionic bonds that formed between the protein molecules that are, the egg protein and the gluten protein to the extra calcium. This led to a slightly higher protein retention rates through the slowing down of protein denaturation and loss in frying oil. It has been demonstrated that calcium-enriched pasta and bakery systems have this structural reinforcing effect (Zulkeflee et al., 2020; Nadeem et al., 2020). The highest relative change in the parameters was observed in the ash content which shot up between (2.10 +- 0.02) in T_0 and (3.10 +- 0.02) in T_3. The ANOVA demonstrated that there was a highly significant effect of level of eggshell powder ($p < 0.001$), but no effects of batches or interaction effects. The amount of the mineral total was determined through ash, whose calcium carbonate content of the eggshell powder was approximately 95 percent. By not being affected by cooking losses, a further and direct proportional increase in concentration of the product raised its mineral fraction. The gradual increase in batches indicated that ESP was now to be incorporated completely into the doughnut matrix. This important functional correlation between the level of fortification and the content of the mineral has been tested and confirmed in many studies involving bread, biscuits, muffins, and pasta (Salama et al., 2025; Arnold et al., 2022; Zulkeflee et al., 2020). Based on the findings, it is evident that the amount of eggshell powder was the primary factor that affected the of compositional changes made on enriched doughnuts. The functional processes involved direct mineral deposition (ash), proteins stabilization by the ionic bond (protein), morphological effects on the porosity of the crust (fat) and water retention via protein networks starch and calcium (moisture). These functional effects were found to be robust and repeatable because of the absence of significant batch or interaction effects. These findings were in line with the studies that ESP fortification maintained or slightly enhanced the functional quality indices but enhanced the nutritional content especially calcium content. Due to these attributes ESP was the ideal sustainable fortifier of baked goods.

5.2 Mineral analysis of Doughnut

The data obtained after Atomic Absorption Spectroscopy (AAS) analysis revealed that the fortification of the eggshell powder in terms of mass and concentration was a significant and proportionate increase of the calcium content. Calcium is a very vital mineral in the structural integrity of bones and teeth, which is also a very important mineral in the development of the skeletal system, muscle contraction, nerve transmission and enzyme activity. (Weaver, C.M., & Heaney, R.P. 2006). Poor dieting of calcium has been linked to decreased bone mineral density and susceptibility to osteoporosis. The mean calcium content of the control sample (T_0) in the current study was 78.4 +- 2.2 which was significantly lower than T_2 (238.6 +- 2.7) (1 g ESP addition). The statistically significant difference of 160.2mg/100g between T0 and T2 ($p < 0.001$) showed a significant nutritional gain. Calcium levels increased steadily between T_0 and T_3, with T_3 recording 315.8 +- 3.5 mg of calcium. These were in line with what other researchers have done about the fortification of baking, that concluded that addition of eggshell powder (95-98% CaCO3) was able to increase calcium levels substantially without compromising sensory properties. The breads, biscuits, and gingerbread supplemented with 0.5-1.5 g ESP/100 g flour have been observed to have similar degree of Ca augmentation. This

study showed that mineral distribution in this case had low SD values indicating that ESP was incorporated into the dough matrix. (Aditya, S., et al. 2021). In general, T_2 fortification was a notable and viable addition to calcium intake which was in line with sustainable nutrition practices, namely the reuse of agro-industrial eggshell waste as a useful fortificant in bakery products.

5.3Texture analysis of Doughnut

The other attribute of the doughnuts, but of considerable importance is the texture, which directly influences the consumer acceptance and mouthfeel, as well as the overall eating satisfaction. Objectively measured by TPA Hardness such parameters as hardness, springiness, cohesiveness, gumminess, chewiness and product volume, are subjectively measured in the current study by TPA Hardness when measuring the effects of ingredient changed e.g. (12.9 +- 0.6g) ESP (T_3) vs. (8.6 +- 0.3) control (T_0) when the added ingredient is the fortification of eggshell powder (ESP). This shows that the calcium-containing mineral particles strengthened the gluten starch framework to the point of reducing the phenomenon of strength of the crumb. The same augmented direction towards chewiness and gumminess was an indication of a smoother and more condensed structure. On the other hand, there was a reduced cohesiveness between T_0 (0.68 +- 0.02) to T_3 (0.60 +- 0.03) and less springiness between T_0 (0.87 +- 0.01) to T_3 (0.81 +- 0.02) indicating that there was a lack of elasticity and internal holding of the gluten because of the mineral component being diluted. The same direction of the increased tendency to chewiness and the gumminess was denoted in a compressed and concentrated structure. This volume itself tended to fall to 2.05 cm3/g/maximum, presumably because the higher the dough density and rigidity the less it would have tended to expand, although it had a maximum of 0.5 g ESP (2.28 cm3/g), which was enhanced stability at low inclusion levels. It has been established in prior studies of bakery that low levels of ESP favorably affect aeration and structure, whereas excessive fortification of the dough with minerals changes the rheology of the dough and gas retention and resulted in the dough being stiffer and lowering the volume (Zulkeflee et al., 2020; Therdthai et al., 2023; Asghari-pour et al., 2020).

5.4 FTIR analysis of Doughnut

The other attribute of the doughnuts but of considerable importance is the texture which directly influences the consumer acceptance and mouthfeel as well as the overall eating satisfaction. Objectively measured by TPA Hardness such parameters as hardness, springiness, cohesiveness, gumminess, chewiness and product volume, are subjectively measured in the current study by TPA Hardness when measuring the effects of ingredient changed e.g. (12.9 +- 0.6g) ESP (T_3) vs. (8.6 +- 0.3) control (T_0) when the added ingredient is the fortification of eggshell powder (ESP). This shows that the calcium-containing mineral particles strengthened the gluten starch framework to the point of reducing the phenomenon of strength of the crumb. The same augmented direction towards chewiness and gumminess was an indication of a smoother and more condensed structure. On the other hand, there was a reduced cohesiveness between T_0 (0.68 +- 0.02) to T_3 (0.60 +- 0.03) and less springiness between T_0 (0.87 +- 0.01) to T_3 (0.81 +- 0.02) indicating that there was a lack of elasticity and internal holding of the

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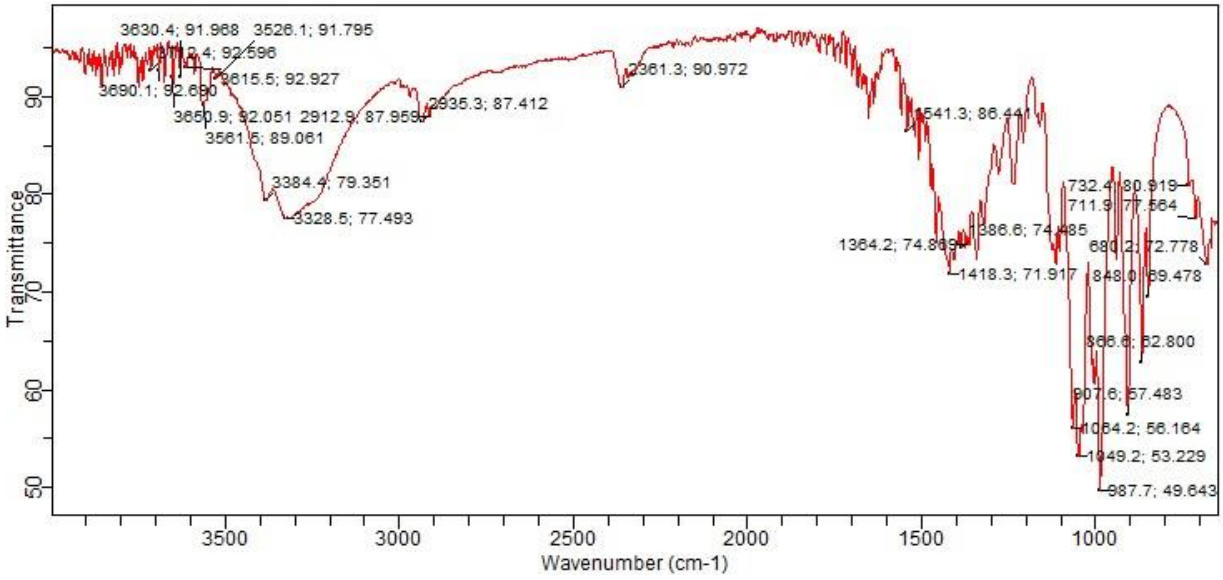

FIG 1. Calcite peaks of Doughnut Sample

5.5 Sensory Evaluation of Doughnuts Fortified with Eggshell Powder

The other attribute of the doughnuts, but of considerable importance is the texture, which directly influences the consumer acceptance and mouthfeel, as well as the overall eating satisfaction. Objectively measured by TPA Hardness such parameters as hardness, springiness, cohesiveness, gumminess, chewiness and product volume, are subjectively measured in the current study by TPA Hardness when measuring the effects of ingredient changed e.g. (12.9 +- 0.6g) ESP (T_3) vs. (8.6 +- 0.3) control (T_0) when the added ingredient is the fortification of eggshell powder (ESP). This shows that the calcium-containing mineral particles strengthened the gluten starch framework to the point of reducing the phenomenon of strength of the crumb. The same augmented direction towards chewiness and gumminess was an indication of a smoother and more condensed structure. On the other hand, there was a reduced cohesiveness between T_0 (0.68 +- 0.02) to T_3 (0.60 +- 0.03) and less springiness between T_0 (0.87 +- 0.01)

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6.Conclusion:

This research has established that the eggshell powder (ESP) obtained by the bakery and agro-industrial waste is viable in valorization into nutritionally enriched bakery products which increases environmental pollution but offers a sustainable source of dietary calcium. The fortified doughnut showed a substantial improvement in the level of calcium without the denatured influencing sensorial character and slight decrease in the moisture content extended shelf life. The present results indicated that bioavailable calcium carbonate was incorporated without protein denaturation through FTIR tests, and that (T_1/T_2) was selected as the optimal formulation of Doughnut and T_2 was selected as the optimal formulation of doughnut using texture profile analysis. Sensory analysis showed that there is high consumer acceptance and favorable scores of fortified treatments in terms of taste, texture, aroma, and appearance. The improved products had a good amount of calcium content as compared to the adult RDA of 0.8mg, which provides a low priced alternative to commercial products. In general the ESP fortification was found to be a cost-efficient environmentally friendly solution to the nutritional shortcomings and wastes management issues with great prospects of extensive use in the development of functional foods.

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