CHARACTERISATION OF BABY CORN AND ITS VALORISATION FOR POWDER DEVELOPMENT

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in

Food Science and Technology

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DECLARATION

I, hereby declare that the presented work in the Project entitled **"Characterisation of Baby Corn and its Valorization for Powder Development"** in fulfilment of degree of **Doctor of Philosophy (Ph.D.)** is outcome of research work carried out by me under the supervision of **Dr. Sawinder Kaur**, Professor and Associate Dean (Food Technology and Nutrition) of School of Agriculture, Lovely Professional University, for the award of degree Ph.D Food Science and Technology.

Date: 04/02/2025

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I certify the above statement made by the student is correct to the best of my knowledge and belief.

Date: 04/02/2025

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Signature of External Examiner
(Dr. Balmeet Singh Gill)

CERTIFICATE

This is to certify that the work reported in the Ph. D. thesis entitled **"Characterisation of Baby Corn and its Valorisation for Powder Development"** submitted in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the **Department of Food Technology and Nutrition, School of Agriculture,** is a research work carried out by in the Department of Food Technology and Nutrition/ School of Agriculture of is a research work carried out by Ubaida Akbar (11919021) is bonafide record of her original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

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ABSTRACT

Baby corn, highly perishable high value vegetable is susceptible to spoilage due to its high water activity and respiration rate, presents a significant preservation challenge, hampering its commercial viability and post-harvest practices. This study emphasizes on two baby corn varieties—Syngenta 5417 and Sheeshu (Pusa HM 4 male sterile) procured from Punjab and Haryana. Classification based on size (short, medium, and long) reveals distinct physical attributes within each category. Physical measurements, such as length and diameter, revealed significant variations among the varieties, indicating differences in maturity stages. the length and diameter for Syngenta 5417 and Sheeshu (Pusa HM 4 male sterile) were found to be 88.61±3.05, 102.52±4.24, 133.34±7.23mm; 75.08± 2.95, 110.92±5.30, 128.42±5.20 mm and diameter 11.20±1.67, 15.23 ±1.21, 17.63±0.81 ; 16.07±5.84,18.30±7.81,20.3±8.68 for short, medium and long category respectively. Yield analysis showcases an ascending trend from short to long varieties, shaped by genotype potential and environmental factors. While proximate composition remains consistent across varieties, antioxidant activity peaks in long-graded cobs, followed by short and medium. Mineral composition analysis underscores the enrichment of vital micronutrients in long-graded cobs. These findings furnish a comprehensive understanding of baby corn varieties, guiding informed selection and processing decisions. The preference for Syngenta 5417 for further processing, driven by its higher yields and farmer acceptance, underscores the study's practical significance for agricultural and food processing industries.

In order to extend the longevity of baby corn, different blanching treatments along with its effects on Characteristics and physico-chemical properties were analysed. Three blanching methods were employed: hot water blanching (HWB) at temperatures ranging from 70°C to 90°C for 30 to 240 seconds, steam blanching (SB) at 100°C for 30 to 240 seconds, and microwave blanching (MWB) at power levels of 360-900W for 30-300seconds.Results indicated that 90% peroxidase enzyme inactivation occurred at specific conditions: 90°C for 60 seconds for HWB, 100°C for 60 seconds for SB, and 540W for 30 seconds for MWB. These blanching methods had significant impacts on the physico-chemical properties of baby corn, affecting water activity, total soluble solids (TSS), bulk density, true density, ascorbic acid content, antioxidant activity, and

color values. MWB demonstrated the highest antioxidant activity and minimal color changes ($\Delta E = 5.72$). Our findings suggest that MWB holds promise as a processing method to extend the shelf-life of baby corn with minimal nutritional loss, although the choice of specific time-temperature/power combinations should consider potential physical, chemical, and textural alterations. This research addresses a critical challenge in preserving baby corn and advancing its commercial potential.

Long-graded baby corn cobs were dried using a tray dryer within the temperature range of 50-70°C and a tray load of 0.30-0.45g/cm².Various thin layer drying models including Page, Lewis, and Henderson-Pabis,logarithmic were employed to analyze the drying data, with the Page model, Lewis, and Henderson-Pabis exhibiting the best fit. The effective moisture diffusivity ranged from 2.40×10^{-11} to 8.01×10^{-12}(m²/s) across different temperatures and tray loads. Activation energy varied from 36499.29 to 57416.48 (J/mol) for different tray loads. Microwave blanching led to a decline in ascorbic acid content, while higher drying temperatures resulted in better retention of ascorbic acid and total phenolic content. Antioxidant activity, assessed by DPPH (% radical scavenging activity) and FRAP, was measured at 38.00±0.01% and 124.63±0.01µg/ml, respectively. Notably, significant alterations in color values were observed, potentially attributed to thermal degradation or browning reactions.

In the realm of food product design and application, particle characteristics play a pivotal role. The obtained powder was then sieved and through sieve analysis, diverse particle sizes were identified, ranging from >500 to 53 µm. The particles exhibited stability with an average size,a polydispersity index and a zeta potential of 208.8, 0.133 nm and -20 mV respectively. Bulk density (BD) and true density (TD) showed an inverse relationship with sieve size, with BD ranging from 0.552±0.02 to 0.238±0.01 gcm^{-3} for particle sizes >500 to 53 µm, respectively. Carr index and Hausner ratio indicated better flowability in particles up to 300 µm. By understanding these techno-functional nuances, the study aims to unlock the full potential of baby corn powder as an ingredient in various functional foods.

The study examined how storage conditions and packaging materials impact the quality of baby corn powder over 104 days. Samples, processed via microwave blanching and tray drying, were kept in Low-Density Polyethylene (LDPE), Polypropylene (PP), and

Aluminum (AL), and stored under varying conditions. LDPE showed weaker barrier properties, leading to higher moisture absorption compared to PP and AL, especially in accelerated conditions. Color changes, attributed to the Maillard reaction, were more pronounced in LDPE and PP over time. Microbiological analysis revealed consistent Total Plate Count (TPC) levels, with AL packaging offering superior microbial preservation, particularly at higher temperatures. Physical properties like bulk density increased and true density decreased during storage, affecting flowability. LDPE and PP experienced more significant declines in technofunctional properties compared to AL.

The study focused on characterizing baby corn powder (BCP) and its integration into muffins to enhance both their nutritional value and sensory appeal. Through Dynamic Light Scattering (DLS), researchers determined that BCP had an average particle size of 208.8 nm, with a narrow size distribution (PDI < 0.5) and a zeta potential of -20mV, indicating stability. Differential Scanning Calorimetry (DSC) revealed endothermic reactions with onset and end temperatures of 29.55°C and 100.31°C, respectively, while Thermogravimetric Analysis (TGA) showed a total mass loss of 98.07%. Scanning Electron Microscopy (SEM) revealed closely packed BCP particles with no discernible shape.

Muffin samples with different baby corn powder (BCP) levels displayed varying moisture and ash content, which increased with higher BCP levels. About 61% increase in dietary fibre was observed with higher BCP levels. BCP-enriched muffins were less cohesive, suggesting a crumblier texture, but still maintained chewiness. This research highlights the potential of BCP incorporation to boost the nutritional value of muffins.Additionally, the cost analysis for control and fibre enhanced fomulation showed the total cost for muffins incorporated with 10, 20 and 30% baby corn powder to be Rs 32.15, 34.81, 37.47,40.13/pc respectively.

Keywords: Baby corn, perishable, high value vegetable, grading, blanching, bioactive components, drying kinetics, powder properties, techno-functional, characterization, storage studies, muffins

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Ubaida Akbar

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CHAPTER 1

INTRODUCTION

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Maize (Zea mays L.) stands as the third most extensively cultivated crop globally, boasting a diverse array of types such as field crop, sweet corn, popcorn, quality maize protein (QPM), and the diminutive yet captivating baby corn (Yadav and Supriya, 2014). Renowned for its adaptability, varied types, and multifaceted uses, maize occupies a unique position among cereals (Aremu et al., 2015). This grain is not merely a staple; it is a versatile agricultural entity finding applications as food, feed, and an essential raw material in various industries. The sheer magnitude of maize production globally is awe-inspiring, with nearly 1148.5 million metric tons harvested across 173 countries, spanning an extensive 197 million hectares (FAOSTAT 2020). Within this expansive network of maize cultivation, India emerges as a significant player, ranking 4^{th} in cultivation area and 7^{th} in production volume (Parihar et al., 2016). Contributing approximately 4% to the global maize cultivation area and 2% to the overall production, as reported by iimr.icar.gov.in, India's role in the maize sector is both substantial and noteworthy. Beyond its sheer quantitative contribution, maize is a nutritional powerhouse, embodying a rich composition comprising starch (72%), protein (10%), oil (4.7%), fiber (8.5%), sugar (3.0%), and ash (1.6%). This intricate blend provides an energy density of around 365 Kcal/100 (Renum et al., 2014 & Kazerooni et al., 2019). Such a robust nutritional profile not only makes maize a fundamental dietary component but also positions it as a key player in addressing global nutritional needs.

Baby corn (Zea *mays* L.) is a type of corn known for its distinct features, harvested at an early, immature stage before fertilization. These tender cobs, which have 2-3 cm of silk on the ear, are typically 60-110 mm long and 10-15 mm in diameter with regular row arrangement makes them suitable for consumption in different forms (Singh et al., 2014). Mini corn is harvested-1-3 days after emergence of silk and when the length of silk is about 0.5-1 cm prior to fertilization. A single-day delay in harvesting deteriorates the quality and taste of the baby corn making harvesting a crucial step (Singh et al., 2020). It is the only vegetable considered to be free from pesticide residues and its nutritional value is also comparable to many high value vegetables. Due to its delicious and succulent taste, it can be consumed raw or cooked in the form of salad, soup, pickles, and other savory and sweet dishes (Rani et al., 2017).

Baby corn, characterized by its high water activity and elevated respiration rate, poses a formidable obstacle to prolonged storage under standard ambient conditions and necessitates specialized treatments for transportation to distant locations (Mehan et al., 2014). Post-harvest challenges in baby corn primarily revolve around its perishability, storage conditions, and quality maintenance. The optimal storage temperature for baby corn is identified as 16 °C under a controlled atmosphere, which significantly extends the shelf life of the crop, with maximum preservation times of four days for spikelet in straw and two days for husked spikelet (Silva et al., 2019). Additionally, nitrogen fertilization is crucial in enhancing agronomic yield without compromising post-harvest quality, with optimal nitrogen levels yielding up to 4.4 t ha-1(Batista et al., 2022). Varietal differences also impact post-harvest quality, as certain hybrids demonstrate superior storability and marketability when harvested at specific times (Shehata et al., 2016). Furthermore, the increasing demand for baby corn necessitates effective post-harvest strategies to ensure quality and reduce losses (Swapna et al., 2024). Overall, addressing these challenges is vital for maximizing the economic potential of baby corn production. The strategies used for improving the shelf life include an innovative approach of the combination of Modified Atmosphere Packaging (MAP) and High-Voltage Electrostatic Field (HVEF) treatments for extending the shelf life of baby corn (Huang et al. 2021). Also, The use of CO_2 laser perforated biodegradable films for modified atmosphere packaging (MAP) significantly enhanced the gas permeability of films. By adjusting the laser fluences between 37.0 to 369.8 J/cm^2, the films exhibited a substantial increase in oxygen transmission rates (up to 77,500 cm^3/m^2.d) and carbon dioxide transmission rates (up to 80,000 cm^3/m^2.d). When baby corn was packed in these microperforated films, it retained its freshness for more than 7 days at 15°C, with a weight loss of less than 5%. This method effectively extended the shelf life of baby corn by creating optimized atmospheric conditions, providing an environmentally friendly packaging solution (Winotapun et al., 2023).

One of the primary postharvest challenges associated with baby corn is the occurrence of brown pigment formation at the apex of its immature ovules, cut surfaces and silk attached to the young ears (Attia et al., 2011). Furthermore, browning is a common phenomenon in many fruits and vegetables and the underlying mechanisms for the same is either enzymatic or non-enzymatic (Moon et al., 2020). The prominent factor influencing the acceptability by consumers is cut surface browning of baby corn that is consequence of intercellular enzymes like peroxidase and polyphenol oxidase (PPO) after harvest which affects the quality attributes like nutrients, colour, texture and flavor (Wang et al., 2017).The principal cause of browning is the excess weight loss of young ears that causes the breakdown of vacuoles releasing the phenolic compounds that comes in contact with PPO resulting in the development of brown pigments (Attia et al., 2011).

Prevention of enzymatic browning is primary concern that can be done by inactivating the activity of enzymes by either physical or chemical methods. Blanching can easily inhibit the enzymatic browning by denaturation of the enzymes. Novel blanching technologies include microwave blanching (MWB), infra-red blanching, high-pressure blanching (Ranjan et al., 2017), nevertheless, chemical approaches involve processes such as acidification or reduction utilizing antioxidants, chelating agents, and natural extracts (Ruiza and Penas 2013). Different time-temperature combinations influence the effectiveness of blanching. Various studies have been reported on the blanching of vegetables and crops. However scanty of literature is available on addressing the impact of blanching treatments on the quality of baby corn.

Drying is one of the economical methods for extending the shelf life of perishable agricultural produce together with other acceptable preservation techniques such as canning and freezing which are costlier and require specific packaging or storage requirements (Ingle et al., 2019). Baby corn is normally graded into different sizes for application purposes. While short and medium baby corn are meant for direct consumption the long-sized cobs find applications in canning or freezing as whole or cut vegetables (Aggarwal et al.,2010).

Vegetables stand as a nutritional powerhouse, providing an abundance of macronutrients such as protein, fiber, carbohydrates, and fats, alongside micronutrients like minerals and vitamins, and a plethora of phytochemicals including polyphenols, flavonoids, and carotenoids (Li et al., 2021, Augustin et al.,2020). These constituents collectively contribute to the overall well-being of individuals, promoting health and preventing diseases. The inherently perishable nature of vegetables necessitates swift action to prevent their loss. A transformative solution lies in the transormation of such produce, which would otherwise be discarded, into shelf-stable products. Among these preservation methods, the conversion into powders emerges as a straightforward yet effective approach to safeguard the nutritional integrity of these perishable goods. By reducing perishables to powder form, the shelf life is extended, and the risk of nutrient degradation is minimized (Ying et al., 2021).

Moreover, beyond their nutritional significance, macronutrients plays a crucial role in shaping the physical and functional attributes of formulated foods. These components contribute not only to the nutritional profile but also influence the textural, color, and sensory properties of the end product. Thus, the incorporation of surplus or aesthetically suboptimal perishables into food processing, and particularly their transformation into powders, serves a dual purpose—preventing waste and enhancing the quality of formulated foods (Bhandari et al., 2013) .In conclusion, addressing the issue of fruit and vegetable loss and waste is not merely an environmental or economic concern; it is a strategic imperative for sustaining human health and well-being. The transformation of surplus produce into value-added products, particularly powders, stands as a tangible and effective solution that aligns with both nutritional and sensory considerations, contributing to a more sustainable and resourceful food supply chain (Ying et al., 2021). The literature available on drying of baby corn as powder and its associated powder properties is scanty.

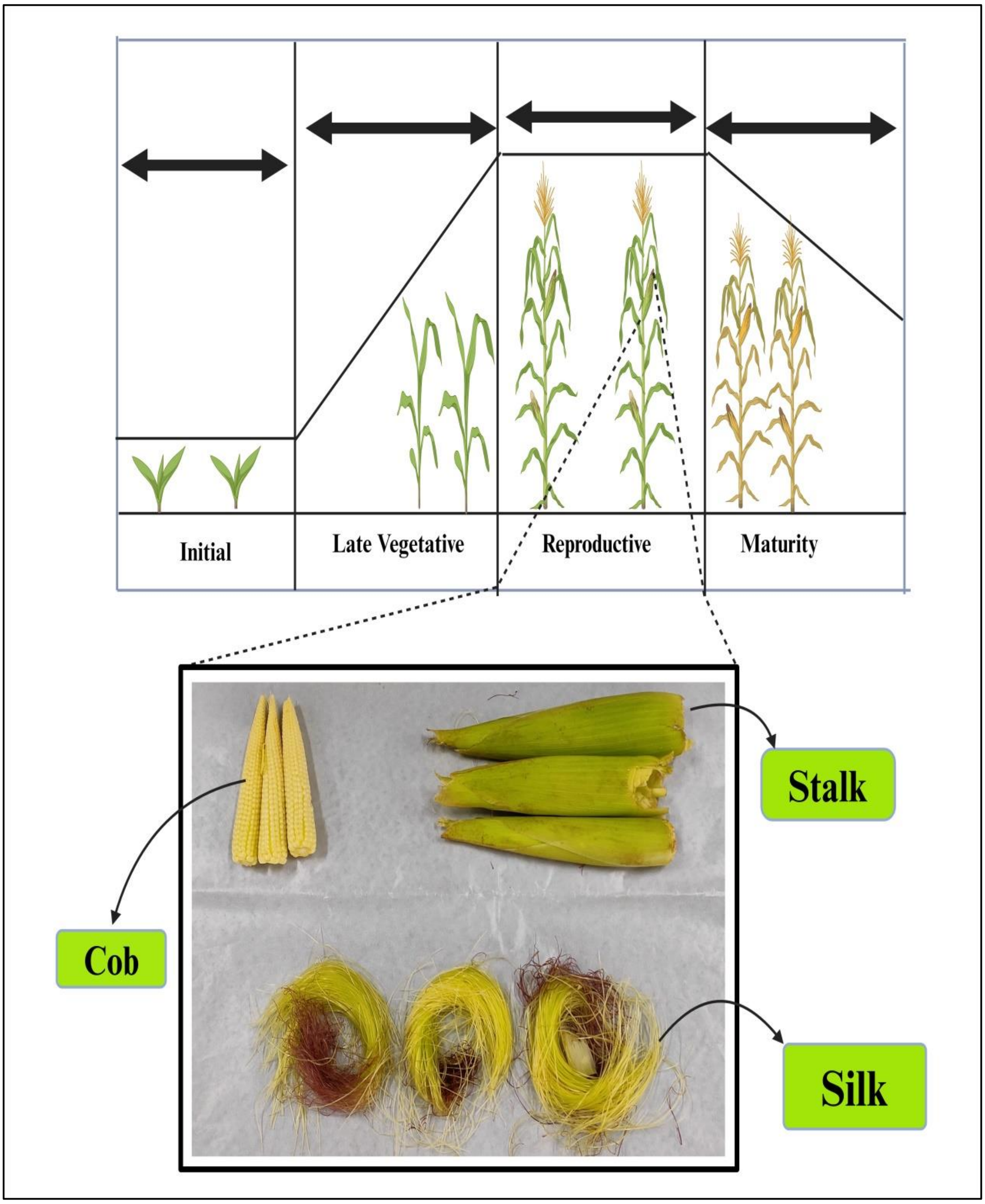


Figure 1: Baby corn growth stages and different parts of baby corn

CHAPTER 2

REVIEW OF LITERATURE

CHAPTER 2- REVIEW OF LITERATURE

The cultivation of baby corn is currently in its early stages in India, yet it is rapidly gaining popularity worldwide, serving as a significant source of income for farmers and contributing to the overall economic development of the country. Ongoing research is focused on various aspects of baby corn production, preservation, post-harvest handling, and processing. A thorough review of existing studies and literature conducted by researchers provides valuable insights into the current state of knowledge in this domain.

2.1 Different types of corn and their nutritional and chemical composition

Corn, commonly known as maize and recognized as the queen of cereals, presents a diverse array of types, including quality maize protein (QPM), sweet corn, popcorn, dent corn, pod corn, and baby corn, as depicted in Figure 2. These categorizations are determined by factors such as endosperm characteristics, kernel color, and composition, as elaborated by Huma et al., (2019) and Yadav and Supriya (2014). Moreover, the nutritional composition of these various corn types undergoes fluctuations due to distinct varieties, cultivation methods, environmental influences, and the timing of harvest, as detailed in Table 1**.**

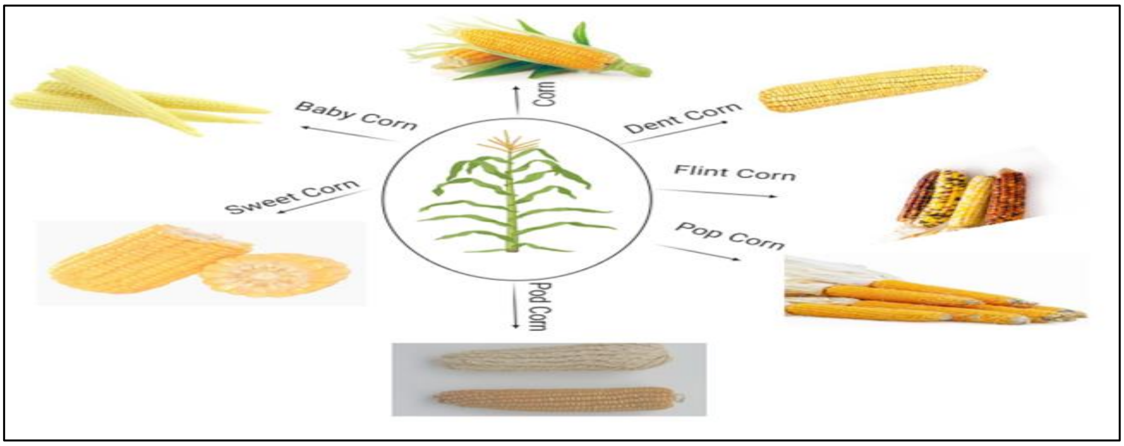


Figure 2: Different types of corn

Table 1: Nutritional composition of corn and its types

Type	Moisture (%)	Crude fat	Crude protein	Total Ash (%)	Crude fibre	Carbohydrate	Lysine (%)	Tryptophan (%)	References
Normal maize	7.65-10.23	4.50-4.57(%)	8.84-9.80(%)	1.62-2.33	2.15-2.60(%)	71.88-73.83 (%)	1-1.80	0.6	Tandzi et al., 2017; Rouf et al., 2016; Abiose and Victor 2014.
Quality protein maize (QPM)	7.9	4.85(%)	9.72	1.5	2.05	73.98 (%)	2.64-4.1	2.7	Tandzi et al., 2017; Rouf et al., 2016 & Abiose and Victor 2014.
Sweet corn	75.7	1.18-1.26(g/100g)	3.20-3.24(g/100g)	3.4	2.35-2.7(g/100g)	18.86-19.02(g/100g)	0.31-0.36	0.06-0.08	Swapna et al.,2020; Siyuan et al.,2018; Geeta et al.,2017 & Parihar et al.,2016

Popcorn	11-17	1-2(g)	2-4(g)	-	-	10-22(g)	-	-	Rakshit et al.,2003; Yadav and Supriya 2014 & Ademiluyi and Oduola ,2011
Dent corn	-	3.81-4.65(%)	-	-	-	-	-	-	Susilowati et al.,2018
Baby corn	86-92(%)	0.90-2.13(%)	1.90-2.90(g/100g)	0.46-1.34(%)	2-5(%)	9.13(%)	-	-	Shubhadarshi and Priyadarshini, 2021; Saha et al.,2019;Shoba and Sreedevi, 2018

2.2 Factors affecting production of baby corn

The technical factors influencing the production of canned baby corn was reported by Minh et al., (2019).Despite its initial freshness, baby corn faces perishability challenges due to weather conditions and inadequate storage facilities. The lack of awareness about its nutritional value and production techniques hampers its popularity. The researchers explored lactic acid fermentation as a preservation method and examined parameters like blanching, salt concentration, and fermentation time. Their findings indicated that blanching baby corn for 10 seconds in water at 95°C with 0.25% $CaCl_2$, 6% salt, and 3% sugar resulted in high-quality pickled baby corn after 9-day fermentation. This preservation method could contribute to the well-being of the economically disadvantaged, enhance food security, and reduce post-harvest losses. The use of lactic acid fermentation has proven effective in enhancing the flavor, texture, and nutritional value of baby corn, as highlighted in studies. However, significant gaps remain, including the need for comparative studies to assess the effectiveness of various preservation techniques, such as Modified Atmosphere Packaging (MAP). Research on long-term storage, economic feasibility, and microbial behavior during fermentation is limited. Additionally, further studies are required to evaluate the scalability of these methods and their effect on nutritional retention over time.

The influence of ultraviolet-C (UV-C) irradiation on the physicochemical changes of fresh-cut baby corn during storage was investigated by Lwin et al., (2019). Baby corn, known for its nutritional value and global demand, faces post-harvest challenges. The study aimed to mitigate these losses by examining the effects of UV-C irradiation on physiochemical changes. Fresh-cut baby corn underwent various UV-C exposure levels, with 4.4 $KJ.m^{-2}$ proving most effective in preserving fresh weight, firmness, and delaying the decline in antioxidant capacity during 7-day storage at 5°C. Notably, UV-C showed no impact on color values and ascorbic acid content throughout the storage period. This research highlights UV-C irradiation's potential for enhancing post-harvest qualities in baby corn but also gaps remain, such as the need for comparative studies with other methods. The long-term effects on nutritional quality and shelf life are underexplored, as well as the cost-effectiveness and feasibility of large-scale application. Further research is also needed on consumer acceptance and the impact on sensory properties like taste and texture.

Baby corn, recognized as a green and pesticide-free vegetable, has gained global significance. The researchers Joshi and Chilwal (2018) investigated the impact of integrated nutrient management on the growth of baby corn, employing 11 treatments that involved the application of NPK fertilizer, Azobacter, and Azospirillum individually and in combination. The diverse treatments exhibited varying effects on the Total Soluble Solids (TSS) and protein content of baby corn. Notably, the application of 75% NPK along with Azos and Azot yielded the highest TSS content, while 100% NPK combined with Azot and Azos demonstrated the highest protein content. Sensory evaluation revealed that 80% of respondents favored baby corn treated with 100% NPK+Azot+Azos, while 70% preferred the variant treated with 100% NPK+Azot+Azos. In contrast, baby corn treated with Azobacter received favorable responses from 40% of respondents, with 30% expressing moderate liking. The study concluded that the combined application of chemical fertilizers and bio-fertilizers proved beneficial in enhancing the quality of baby corn, offering a comprehensive understanding of integrated nutrient management's positive impact on this crop.

Prajwal et al., (2018) investigated the influence of foliar feeding on the nutritional composition of baby corn (Zea mays L.) and a dehydrated baby corn-based product. The study identified that the application of 75% recommended dose of fertilizer (RDF) along with 1.5% 19:19:19 spray, 0.5% $ZnSO_4$, and 0.1% $FeSO_4$ resulted in elevated levels of crude protein and sugar, accompanied by reduced crude fiber in baby corn, specifically measuring at 18.72%, 0.028%, and 5.78%, respectively. Furthermore, the concentration of nitrogen (0.96%), phosphorus (3.00%), potassium (3.12%), zinc (46.33 ppm), and iron (52.67 ppm) was notably higher in babies treated with 75% RDF + 1.5% 19:19:19 spray + 0.5% $ZnSO_4$ + 0.1% $FeSO_4$. The researchers emphasized the efficacy of bio fortification in overcoming nutrient deficiencies. The findings concluded that dehydrated baby corn powder, obtained from fresh baby corns that can be employed in bakery items to boost their nutritional content and overall quality.

2.3 Production and nutritive evaluation of Corn and Baby Corn

The investigation conducted by Rani et al., (2017), focused on the cultivation and potential benefits of baby corn, alternatively known as young corn. This particular crop has been gaining widespread recognition on a global scale. The researchers highlight that baby corn is harvested at an early stage, before the fertilization of silk, and can be cultivated year-round. The economic significance, diverse nature, and nutritional value of this crop underscore its importance. The study emphasizes the potential of baby corn to contribute to a country's economy, especially given its short cultivation duration and the absence of the need for pesticides. Recognizing its high nutritional content, the researchers advocate for promoting the cultivation of baby corn in rural areas. However, due to its highly perishable nature, the study suggests the necessity of establishing adequate harvesting, transportation, and storage facilities to ensure its quality and availability. Furthermore, the researchers recommend the development of entrepreneurship facilities to support the growth of the baby corn industry. Additionally, the study emphasizes the importance of focusing on the creation of genotypes specifically tailored for canning purposes. This comprehensive approach aims to not only popularize baby corn but also address the challenges associated with its cultivation, storage, and utilization.

Parihar et al., (2016) conducted a comprehensive study on specialty corn, focusing on its role in ensuring nutritional security and dietary diversification. Their research revealed that maize, or corn, is extensively utilized in various forms such as feed, food, and industrial applications. In India, maize contributes to more than half of the total production of coarse cereals. Globally, it possesses the capacity to address the hunger of millions of people, offering versatility for the creation of numerous products. The study emphasizes the significant contribution of maize to fullfill the nutritional requirements of the underprivileged section, particularly through the cultivation of Quality Protein Maize on a large scale. Additionally, the production of mini corn and sweet corn is highlighted for not only enhancing livelihoods but also contributing to the economic growth of the country.

Ranum et al., (2014) conducted an extensive study on maize/corn, encompassing its production, utilization, consumption, and origin. The research posits that maize, an ancient wild grass, originated in Mexico, with Native Americans being the first to transform it into a significant food source. The composition analysis reveals that maize has a starch, protein, and fat percentage of 72, 10, and 4, respectively, providing an energy density of 365 Kcal/100g.Productivity data from the study indicates that the United States is the leading global producer of maize, followed by China, Brazil, and India. Maize serves various purposes, including feed, fodder, fuel, medicinal applications, and industrial uses. Its widespread consumption across the globe is attributed not only to its health benefits but also its affordability. The research suggests that fortifying this cost-effective cereal could effectively address numerous micronutrient deficiencies.

Kumar and Jhariya, (2013) explored the historical, health-related, dietary, and economic significance of corn. Their analysis reveals that corn is not a recent addition to cereals but has a long history of use since ancient times. The review underscores the substantial benefits of corn, extending beyond its role as a food source or for medicinal applications. Notably, the by-products of corn have diverse applications in various industrial sectors. The authors emphasize that there is still a significant amount of research to be undertaken to fully understand and explore the multitude of uses and benefits associated with corn.

2.4 Evaluation of the nutritional composition of Baby Corn and other vegetables:

The HM 4 cultivar of baby corn (Zea mays) was the subject of a nutritional investigation by Hooda and Kawatr, (2013). In vitro digestibility, proximate analysis, anti-nutrients, mineral content vitamins, and amino acid analysis were all part of their research. By weight, the HM 4 baby corn variety had 9.03 % moisture, 5.30 % ash, 17.96 % protein, 2.13 % fat, and 5.89 % crude fiber. Results from in vitro tests showed that protein digestibility was 72.18 % and starch digestibility was 28.80 milligrams of maltose released per gram. As shown in Table 2, the nutritional value of HM 4 baby corn is higher than that of regularly consumed vegetables, leading the researchers to this conclusion. In the experiment conducted by Daglioglu et al., (2022), baby corn emerges as a nutritional powerhouse, surpassing certain vegetables and whole grains in its outstanding nutrient profile. Going beyond its role as a significant protein source, baby corn excels in delivering crucial vitamins, iron, phosphorus, and phytochemicals. The noteworthy high iron content in baby corn contributes to supporting blood health, while its abundance in phosphorus plays a role in promoting bone health and energy metabolism. The inclusion of phytochemicals further amplifies its nutritional value, providing antioxidant properties that contribute to overall well-being. As a versatile and nutrient-dense dietary option, baby corn is demonstrated to be a praiseworthy addition to health-conscious diets, offering a diverse range of essential nutrients, but gaps remain. There is limited research on the bioavailability of nutrients and the effects of processing methods. The study also lacks insights into antioxidant properties, health benefits, and nutritional variability across different varieties and conditions. Additionally, exploration of value-added products and their functional properties is insufficient.

Prasanthi et al., (2017) carried an investigation into the variations in nutrient and phytochemical composition in processed corn. The study involved the analysis of different corn samples, including sweet corn, fresh baby corn, dent corn, processed and cooked popcorn, corn flakes, corn flour, and corn grits, with a focus on determining xanthophyll and phenolic contents. Proximate analysis was also carried out on all these samples. The researchers found that popcorn exhibited a higher proximate composition compared to the other samples. Dent corn displayed the highest polyphenolic content and showed a notable prevalence in xanthophyll and zeaxanthin levels compared to the other samples. The study further revealed that the processing and preparation methods led to a reduction in xanthophyll's and polyphenols. The study highlights nutrient and phytochemical variations in corn products but lacks insight into the bioavailability of these compounds. The long-term health impacts of consuming processed versus whole corn remain unexplored. Additionally, the effects of storage conditions and advanced processing techniques on nutrient retention are not addressed. Research on developing fortified corn-based products to address specific nutritional needs is also needed.

Table 2: Nutritional value of baby corn as compared to popular vegetables

Content	Baby corn	Lady's finger	Tomato	Cauliflower	Radish	Brinjal	French bean	Spinach	Cabbage
Moisture (%)	89.10	89.60	93.10	90.80	94.40	92.70	91.40	92.10	91.90
Protein (g)	1.90	1.90	1.90	2.60	0.70	1.40	1.70	2.00	1.80
Iron (mg)	0.10	1.50	1.80	1.50	0.40	0.90	1.70	10.90	0.90
Calcium (mg)	28.00	66.00	20.00	33.00	50.00	18.00	50.00	73.00	18.00
Riboflavin	0.08	0.01	0.01	0.10	0.02	0.11	0.06	0.07	0.11
Carbohydrates (g)	8.20	6.40	3.60	4.00	3.40	4.00	4.50	2.90	4.60
Thiamine	0.04	0.07	0.07	0.04	0.06	0.04	0.08	0.03	0.04
Phosphorus (mg)	86.00	56.00	36.00	57.00	22.00	47.00	28.00	21.00	47.00
Ascorbic Acid	11.00	13.00	31.00	56.00	15.00	12.00	11.00	28.00	12.00

Source: Saha et al.,(2019), Parihar et al., (2016), Hooda et al., (2011)

2.5 Cultivars for baby corn production

Investigations were conducted for phytochemical analysis of baby corn silk extracts by Limmatvapirat et al., (2019). Pacific 271 and Zeba SG 17 were both hybrid kinds that were examined for the purpose of the inquiry. Both extracts were produced by distilling a mixture of ethanol and water at a ratio of forty percent volume to volume. Following the completion of the necessary research and experiments, it was discovered that the extracts PE and ZE include flavonoids, tannins, terpenoids, and steroids that are all present. Flavonoids and tannins were the components that made up PA and ZA, respectively.While comparing these higher total phenolic, flavonoid and antioxidant activity was found in PE and ZE than that of PA and ZA concluding that the PE and ZE is a good choice to be used as natural extract of phenolics and flavonoids along with antioxidant activity.The study highlights baby corn silk extract as a natural antioxidant source but identifies gaps, including limited research on its long-term efficacy, bioavailability, and stability in formulations. The impact of processing on phytochemical retention and its interactions with dietary components remain unexplored. Further studies are needed to standardize extraction methods and conduct toxicological evaluations to ensure consistent quality and safety for dietary supplements.

The biochemistry of 10 genotypes/ varieties of baby corn was studied by Singh et al., (2006), assessing their quality attributes, total sugars, protein, phosphorus, and ascorbic acid content. The findings revealed that among the examined genotypes, R-2005-8 demonstrated superior characteristics in terms of total sugars, reducing sugars, phosphorus, and protein content.

Removing the initial female inflorescence in corn promotes the development of more female inflorescences,which in turn makes it possible to harvest the first ear of corn as baby corn (BC), and successive ears as green corn (GC) or dry corn (DC). Based on Castro et al., (2013) flexible strategy, which allows for successful reactions to market situations, the authors conducted their research. Following the first harvest of BC, an analysis of BC, GC, and DC yields in maize cultivars AG 2060, BRS 2020, and AG 105 revealed that individual harvesting of MM, MV, and MS resulted in greater yields than harvesting in combination with BC (BC + GC and BC + DC). This was determined by comparing the yields of BC, GC, and DC. BRS 2020 stood out as the premier cultivar for exclusive BC production, excelling in various parameters, including The quantity and weight of viable unhusked ears and the count of usable husked ears.AG 1051 demonstrated superior performance in the weight of marketable husked BC ears. Harvesting strategies involving BC + GC and BC + DC resulted in lower BC yields compared to harvesting all ears as baby corn. BC + GC harvesting yielded lower GC compared to harvesting all ears as GC, and BC + DC harvesting provided lower kernel yield compared to harvesting all ears as DC. In conclusion, BRS 2020 and AG 1051 exhibited commendable performance in specific aspects, emphasizing the importance of strategic harvesting approaches for growers aiming to optimize yields for different corn products.

The research conducted by Chauhan et al., 2009 evaluated twenty maize cultivars for their suitability in baby corn cultivation during the kharif 2007 and rabi 2007–08 seasons. Key productivity traits, including flowering, days to first cob picking, and various ear and plant characteristics, were considered. HM 4 and HQPM 1 emerged as superior cultivars , exhibiting notable performance in husked cob yield, de-husked cob yield, quantity of cobs harvested per plant, and fodder yield. Vivek Hybrid 17 and Vivek Hybrid 9 demonstrated early maturation compared to other cultivars. Overall, HM 4 and HQPM 1 were identified as elite hybrids for baby corn cultivation, offering potential for further improvement and serving as valuable genetic resources. The study contributes to the identification of specific genotypes and lays the groundwork for the development of new cultivars tailored for enhanced baby corn production.

Meenaphan and Ketsa, (2002) conducted a study on post-harvest browning in baby corn, focusing on three selected varieties: Chiang Mai 90, CP 45, and Pacific 5. The analysis revealed that Chiang Mai 90 exhibited a higher degree of browning compared to the other two varieties. The researchers concluded that the development of browning in baby corn varieties was attributed to factors such as weight loss and total phenolics. However, this phenomenon was not found to be associated with the activity of phenylalanine ammonia lyase and polyphenol oxidase.

2.6 Processing methods

2.6.1 Blanching

Browning is a common phenomenon in many fruits and vegetables and the underlying mechanisms for the same is either enzymatic or non-enzymatic (Moon et al., 2020). Prevention of enzymatic browning is primary concern that can be done by inactivating the activity of enzymes by either physical or chemical methods. Blanching can easily inhibit the enzymatic browning by denaturation of the enzymes. Novel blanching technologies include microwave blanching (MWB), infra-red blanching, high pressure blanching. Moreover, different time temperature combinations influence the effectiveness of blanching (Ranjan et al., 2017).

Szymaneket al., (2020) explored how varying blanching durations affect the moisture content, sugar levels, protein content, and processing yield of sweet corn kernels.The study involved subjecting samples to three distinct blanching times (2, 4, 6, and 8 minutes) at 85°C. The findings emphasized the significance of pre-treatment in processing, highlighting its role in enhancing shelf life. Among the various time-temperature combinations studied, the researchers concluded that an 8-minute blanching time at 85°C was the most effective treatment for optimal processing outcomes. The study demonstrates the influence of blanching time on moisture, sugars, protein content, and kernel recovery in sweet corn. However, it does not address the impact on essential nutrients like vitamins, antioxidants, or enzyme activities. Additionally, sensory and textural changes due to blanching remain unexplored. Future research should evaluate alternative blanching methods, such as steam or microwave blanching, to enhance nutritional retention and processing outcomes.

Investigations were carried out by Kachhadiya et al., (2018) on different blanching treatments for sweet corn including steam, microwave, and hot water blanching. The study focused on assessing the effects of these methods on the physico-chemical properties and enzymatic activity of sweet corn. The research measured the loss of peroxidase activity during blanching; revealing that after 60, 90, and 120 seconds, microwave, steam, and hot water blanching resulted in respective k values of 0.016, 0.024, and 0.0285. The research findings indicated that among the different blanching methods tested, microwave blanching proved most efficient in preserving total sugar, vitamin C, moisture content, and mass. The research gap in blanching sweet corn lies in the limited studies on energy efficiency, long-term impacts on nutritional content, and bioactive compound retention. Additionally, there is insufficient data on microbial safety during blanching. The influence of different corn hybrids on the blanching process and its effect on sensory qualities needs further exploration to optimize processing methods and improve product quality.

Xiao et al., (2017) studied in detail about the recent developments and trends in thermal processing, focusing particularly on blanching as a crucial pre-treatment process for extending the shelf life of fruits and vegetables. The primary objective of blanching is to deactivate polyphenol oxidase (PPO) and peroxidase (POD). The review provides an extensive overview of the principles underlying various blanching methods, their applications, and inherent limitations. The findings of the study highlighted that within the different blanching methods investigated; hot water blanching emerged as the most effective. The review also emphasized that there is no universally ideal blanching treatment, as diverse products possess distinct attributes. Consequently, the choice of blanching treatment is determined based on the specific properties of different perishables. This tailored approach ensures optimal results considering the unique characteristics of each product.

Table 3: Utilization of blanching methodologies for vegetables.

Vegetables	Type of Blanching	Processing conditions	Findings	References
Green beans	Hot water (HWB) and Microwave blanching (MWB)	HWB (92 °C for 200 s) MWB (650, 750, and 900 W) for (50- 300 s).	Ascorbic acid retention (HWB)-48(%), for MWB 64%, 59% and 50% for low, medium and high power level, respectively.	Ruiz et al., 2013.
Carrot slices	Hot water, Steam and Microwave blanching	HWB (90°C for 4 min); SB (90°C for 3 min); MWB (1.25 Kw power and conveyor speed 0.5 m/min	Dry matter, sucrose, and carotene content experienced a remarkable increase, ranging from 11% to 39% compared to conventional steam and water blanching methods.	Xiao et al.,2017
Broccoli	Hot water, Steam and Microwave blanching	HWB (Boiling water (30-180sec); SB(over steam for 30-180 sec) and MWB (2750mHz at 900W for 30-180 sec)	Microwave blanching more effective than conventional methods.90% POD inactivation at (HWB for 90 sec); MWB (50sec) and SB (30 sec); Ascorbic acid for fresh broccoli (151.32mg/100g); HWB (80.13mg/100g); SB (112.92 mg/100g) ; MWB (165.13 mg/100g) respectively.	Severini et al.,2016
Green asparagus	Hot water blanching, Microwave blanching	Hot water blanching (HWB) (70, 80 and 90	Both blanching methods followed first-order kinetics, Microwaving before water blanching, promising strategy	Zheng and Lu (2011).

		°C) Microwave heating (900 W, 30 s)	to preserve the quality of asparagus by reducing nutrient degradation and accelerating enzyme inactivation	
Tomatoes	Hot water blanching (HWB)	HWB (85° C, 4 mins)	Lycopene and β-carotene content of blanched and unblanched tomato peel were found to be 24.7 and 12.35 mg/100g; 134.04 and 62.92 mg/100g respectively.	Urbonaviciene et al.,2012
Colored potato varieties (Purple potato PP-1901, Lady Rosetta (LR)	Hot water blanching (HWB), Steam blanching (SB), Microwave blanching (MWB)	HWB (85° C, 5mins); SB (100° C, 5 mins); MWB (100,300, 900 W for 5 mins)	Phenols (Fresh PP-1901)- 562.8mg GAE/100g : Control LR- 166.37 mg GAE/100g Phenols in both varieties after HWB – 607.2; 173.00 mg GAE/100g.MWB (766.67, 214.51 mg GAE/100g) Overall MWB proved to be best for retention of overall parameters.	Saini et al., 2023
Kale	Hot water blanching (HWB)	HWB(96-98°C,2.5 mins)	Overall losses were observed by HWB of kale. Vitamin C , Total phenol and antioxidant activity got decreased by 34, 51 and 33(%) respectively	Korus and Lisiewska,(2011).
Cauliflower	Steam blanching (SB)	SB (100°C, 20 mins)	Total phenols, Lutein, Quercetin and Kaempferol content decreased by 13%, 93%, 24% and 26% respectively.	dos Reis et al., 2015

2.6.2 Drying

The study investigated by Igbozulike et al., (2020) the drying characteristics of fluted pumpkin seeds at varying temperatures (70ºC, 60ºC, and 50ºC) and slicing thicknesses (5 mm and 10 mm). Drying occurred during the falling rate period, with higher temperatures reducing drying times. Moisture diffusivity increased with temperature, and the Page model proved to be the best-fitted model for describing the drying behaviour. The study offers valuable insights for optimizing the drying process of fluted pumpkin seeds. The research gap in this study on fluted pumpkin seed drying lies in exploring the effects of additional factors, such as relative humidity and air velocity, on the drying kinetics. While temperature and slice thickness were considered, the influence of these other environmental variables on moisture diffusivity and activation energy remains unexplored. Further research is needed to evaluate the scalability and energy efficiency of these drying methods for industrial applications. Additionally, there is a gap in optimizing the process to improve product quality, such as texture and nutrient retention, which has not been fully addressed.

Kaur et al., (2020) researched to examine how varied drying temperatures (40, 50, and 60 °C) and a storage time of 3 months affect the chemical and biological properties of dehydrated tomatoes and sweet peppers. Subjecting the substance to a temperature of 60 °C led to better preservation of phenolics, antioxidant activity, and flavonoids. Tomatoes dried at 60 °C and sweet peppers dried at 40 °C exhibited superior color retention. Storage experiments have shown that powders subjected to a drying temperature of 60 °C were able to preserve polyphenols for a duration of 90 days. The findings highlight that dehydration at 60 °C is crucial for effective preservation of bioactive components in sweet peppers and tomatoes, offering potential for standardized industrial drying to combat seasonal availability issues.

A comprehensive review was carried out by Javed et al., (2018) on foam mat drying, emphasizing its suitability for producing powders from heat-sensitive fruits and vegetables. The technique, involving foaming agents like egg, albumin, and egg white, alongside stabilizers such as cellulose and pectin, demonstrated a rapid powder production capability with minimal impact on quality parameters. The study concluded that this innovative foam mat drying method is effective in preserving the integrity of compounds sensitive to heat, marking a significant advancement in the preservation of quality attributes during the powdering process.

Marques et al., (2014) conducted a study where they used spray drying on green corn pulp to examine how different concentrations of maltodextrin and varying inlet air temperatures affect the physical characteristics of the resultant spray-dried green corn extract. The researchers found that effective drying was achieved when the green corn extract was treated with a maltodextrin concentration of 2.67% (w/w) and an inlet drying air temperature of 163°C. However, a research gap exists in exploring how various drying methods influence the bioactive properties of green corn extracts, particularly in terms of antioxidant activity and nutrient preservation under different humidity and storage conditions. Moreover, there is a need for further investigation into the effects of varying drying temperatures and maltodextrin concentrations on the functional properties of green corn, including its rehydration capabilities and potential uses in food processing.

Santos et al., (2012) developed a specialized rotating tray drier to dry tomato slices under diverse conditions, such as varying temperatures (45 to 60 °C) and air velocities (0.6 and 1.2 m/s). The degradation of lycopene, vitamin C, and TPP was minimized by drying at an ideal temperature of 60 °C, with an airflow rate of 0.6 m/s and minimal rotation of the trays. Tray rotation had a substantial impact on the color value, lycopene content, and ascorbic acid levels. The rotating tray dryer enhanced performance, reducing temperature variation and significantly impacting tomato quality indicators: 23.1% preserved lycopene, 2.5% preserved ascorbic acid, and a 7% effect on a* color value. The research revealed a strong association between a* CIELAB color value and lycopene (0.90) and ascorbic acid (0.91), suggesting that color measurement is a dependable indication of tomato quality throughout drying procedures. The study's strengths lie in its comprehensive assessment of drying variables and the application of the Page model for modeling drying kinetics. However, there are gaps in comparing various drying techniques, evaluating the influence of tray rotation on other product attributes like texture and flavor, and understanding the long-term storage stability of the dried tomatoes. Future research should focus on energy efficiency and explore the suitability of alternative mathematical models for drying kinetics.

Arslan and Ozcan (2010) investigated the drying behavior of onion slices using various methods, including sun drying, oven drying at 50°C and 70°C, and microwave drying at 210 W and 700 W. Their study focused on understanding the drying kinetics and assessing quality changes in the dried onion slices. They found that models such as Page, Modified Page, and Midilli and Kucuk had high coefficients of determination (R^2) ranging from 0.994 to 0.999. The effective diffusivity (Deff) values varied by drying method, with the lowest D_{eff} observed in sun drying (8.339×10^{-10}) and the highest in microwave drying at 700 W (4.869×10^{-8}). Both fresh and dried onion slices retained significant mineral content, with oven-dried samples showing the highest levels. Superior color values were achieved through sun drying and microwave drying at 210 W, while phenolic content was higher in microwave-dried samples at both 210 W and 700 W. Oven drying at 70°C resulted in increased mineral content but less desirable color values, similar to microwave drying at 700 W. Economically, oven drying at lower temperatures is often recommended. Research gaps in this study include the need for a detailed comparison of the energy efficiency and cost-effectiveness of different drying methods, particularly at an industrial scale. Further research is necessary to assess the long-term storage stability of dried onion slices, focusing on the retention of bioactive compounds, as well as changes in sensory properties such as flavor and texture. Additionally, there is a need to optimize microwave drying parameters to improve the quality and nutrient retention of dried products. Lastly, validating the drying models used in this study for real-world applications could help enhance process efficiency and product quality.

Table 4: Influence of Thermal Drying on Bioactive Phytochemical Levels in Vegetables

Vegetables	Type of Drying	Drying conditions	Findings	References
Bottle Gourd	Tray Drying (TD)	TD (50,55,60,65 & 70°C)	Drying time at 50,55,60,65 & 70°C were 630, 570, 450, 420 & 360 mins respectively. Handerson and Pabis model fitted best. With (↑) Temperature drying rate (↑). Moisture content fresh gourd 92.09 % (↓) to 7.08 (%) w.b.	Ingle et al.,2019
Spinach leaves	Convective tray drying	TD (50,60,70 & 80°C)	(↑) air temperature (↓) drying time. Temperature high, higher is Drying rate. Among 11 models, best fitted were Two term exponential, Page, modified page, hii and logarithmic models.	Ankita,2015
Coriander leaves	Convective dryer	Oven drying (40, 50, 60, 70°C)	Drying in falling rate period. 13 models were fitted and best among them were Hii et al., model. Effective moisture diffusivity ranged from 6.6577×10^{-12} to 16.18652×10^{-12} m^2/s and activation energy 19.84629 to 19.86699 KJ/mol	Olabinjo et al., 2015

Carrot slices	Vaccum drying (VD) and Ultrasonic Vaccum drying (USV)	VD (65, 75°C); USV (65, 75°C)	USV leads to 41-53 % (↓) in drying time. Drying time for USV and VD were 140, 340 mins. Ascorbic acid retention at 65°C for VD and USV was 35.5 % and 48.4%, at 75 °C it was 41.6% and 62.5% respectively.	Chen et al.,2016
Leafy vegetables	Sun drying (SD)	SD for 3 days	Carotenoid and ascorbic acid loss from 62.64 to 100 % and 58.41 to 100 %. Total phenol content (TPC) ↑ from 65.87 to 351.50 mg/100g. Antioxidant activity ↑ from 24.70 to 89.96 %.	Zoro et al.,2015
Fenugreek, Mint, Parsley and vegetative parts of leek	Vaccum drying (VD)	VD at 30.35 and 45°C	Drying rate ↓ with drying time. Maximum drying achieved at 30°C, time for Fenugreek, Mint, Parsley and vegetative parts of leek was 370,315, 210 and 540 mins respectively. Diffusion approximation model best fitted for fenugreek, mint and vegetative parts of leak whereas page model best fitted for parsley.	Zakipour and Hamidi (2011).
Loquat slices	Tray drying (TD), Vaccum drying (VD) and Freeze drying (FD)	TD (55°C) ; VD (55°C, 500 mm Hg); FD (-40°C ,0.006 bar)	Lowest water activity in FD (0.27) and highest in TD (0.41). Vitamin C retention more in FD (91.83 mg/100g) followed by VD (88.72 mg/100g). β-carotene maximum in FD (92.12 mg/100g), least in TD (78.43 mg/100g).	Mishra et al.,2021

2.7 Post-harvest changes and storage studies

The research conducted by Lochav and Salve (2023) examined the impact of Chitosan and Carboxyl methyl cellulose (CMC) edible coatings on the quality characteristics of young corn during a 15-day storage. The experiment included applying two different concentrations (1% and 2%) of each coating. The findings revealed that the coating with a concentration of 1% CMC produced the most favorable results. Baby corn treated with 1% CMC shown a significant reduction in weight loss (3.95%) and spoiling percentage (6.34%) in comparison to the untreated control (7.55% and 11.72%, respectively. Additionally, the 1% CMC-treated samples showed higher values for firmness (8.45 N), vitamin C (5.65 mg/100 g pulp), phenolic content (40.40 mg/100 g pulp), and titratable acidity (0.77%).The overall conclusion was that a 1% CMC concentration was the most effective in preserving the physical and chemical attributes of baby corn over the 15-day storage period, outperforming the untreated control. In summary, the application of CMC-based edible coatings, particularly at a 1% concentration, holds promise as a method to extend the shelf life of baby corn by minimizing weight loss, spoilage, and enhancing key qualitative properties.

Strawberries, a delicate and commercially significant fruit with a short postharvest life, are susceptible to fungal infection by Botrytis Cinerea. To address this vulnerability, Krusong et al. (2015) utilized baby corn fermented vinegar (BFV) containing acetic acid to inhibit B. cinerea growth. The study demonstrated complete inhibition with BFV containing 0.225% acetic acid. To overcome potential unfavorable odors associated with BFV, strawberry-flavored baby corn fermented vinegar (SF-BFV) was developed. Sensory evaluation confirmed the acceptance of strawberries treated with SF-BFV or exposed to BFV vapor by panelists. The researchers concluded that treating strawberries with SF-BFV extended their shelf life to 7 days at 40°C, while exposure to BFV vapor extended it to 11 days. This innovative approach offers practical solutions for enhancing the postharvest management of strawberries.

In the study conducted by Mehan et al., (2014) regarding the Impact of Storage on the Quality of Minimally Processed Baby Corn,a closed system technique was utilized to assess respiration parameters. The study focused on temperatures of 5°C, 12.5°C, and 20°C, with a relative humidity of 75%. The findings indicated that low-density polyethylene (LDPE) film with a thickness of 25 microns, featuring two perforations, proved to be a suitable packaging material for Modified Atmosphere Packaging (MAP). This packaging method demonstrated an extended shelf life for baby corn and effectively shielded it from microbial attacks during storage. While the findings demonstrate successful quality preservation, the literature lacks comprehensive analysis on long-term effects on nutritional value and sensory attributes. Further studies should explore the scalability, cost-effectiveness, and consumer acceptance of MAP, along with the impact of different packaging materials on nutrient retention.

Singh et al., (2014) undertook an advanced investigation into the respiratory behavior of fresh baby corn within altered atmospheric conditions, employing enzyme kinetics and non-linear regression methodologies.The research delved into estimating essential respiratory parameters like Michaelis-Menten and inhibition constants across varying relative humidities (RH). The findings highlighted the influence of container storage temperature on partial pressure within containers, impacting respiration rates. This analysis not only enhanced our comprehension of the respiratory mechanisms in fresh baby corn but also proved pivotal in devising modified atmosphere packaging for both fresh and minimally processed food items. The research provides valuable insights into optimizing storage conditions and packaging strategies, contributing to advancements in preserving and maintaining the quality of fresh produce. Future research on baby corn's respiratory behavior should focus on optimizing storage conditions, exploring the effects of headspace gas composition, and improving MAP for extended shelf-life and quality retention. Studies should assess the impact of temperature, packaging materials, and gas concentrations on nutrient preservation and microbial control.

An investigation by Singh et al., (2013) investigated the influence of cutting and storage temperatures on the transpiration rate and transpiration coefficients of freshly harvested baby corn.The investigation revealed varying transpiration rates for different baby corn cuts and temperatures. For whole baby corn, the transpiration rate ranged from 0.102 to 0.140 g h-1 at temperatures of 5, 12.5, and 20°C. Similarly, end cuts exhibited rates between 0.104 and 0.144 g h-1, while sliced baby corn showed rates ranging from 0.122 to 0.192 g h-1 at the respective temperatures. The transpiration coefficients followed a similar trend, with values increasing with higher temperatures. Specifically, for whole baby corn, the coefficients were 14.615, 18.340, and 20.060 g kg^{-1} h^{-1} kPa^{-1} at temperatures of 5, 12.5, and 20°C. End cuts displayed coefficients of 14.901, 18.627, and 20.633 g kg^{-1} h^{-1} kPa^{-1}, and sliced baby corn had coefficients of 17.480, 25.218, and 27.510 g kg^{-1} h^{-1} kPa^{-1} at the corresponding temperatures. The researchers highlighted that the transpiration coefficients demonstrated an increasing trend with temperature, with sliced baby corn exhibiting the highest coefficient. The study concluded that temperature is a crucial factor influencing the transpiration characteristics of baby corn, ultimately affecting its storage life. These findings contribute valuable insights to better understand and manage the postharvest behavior of baby corn, guiding improved storage practices.

Hooda and Kawatr (2012) investigated the impact of frozen storage on the nutritional attributes of mini corn, a highly perishable vegetable. Their primary goal was to prolong the shelf life of baby corn by standardizing freezing methods and examining how freezing affects nutritional components during a 90-day storage period. Over nine months, the researchers conducted analyses at 30-day intervals, focusing on proximate composition, protein digestibility, minerals, in vitro starch, and vitamins. The results indicated that frozen baby corn exhibited no significant changes in moisture, fiber, or crude fat content. However, there was a notable reduction in calcium, iron, and magnesium content. Conversely, in vitro starch and protein digestibility showed no significant alterations in frozen baby corn. The researchers concluded that freezing serves as an effective processing technology capable of successfully extending the shelf life of baby corn while maintaining stability in specific nutritional aspects but there is a need for further exploration of its long-term impact beyond 90 days, especially on bioactive compounds and antioxidants. Studies should focus on optimizing freezing methods to minimize nutrient loss, particularly for ascorbic acid and beta-carotene. Additionally, the effect of different storage conditions, packaging materials, and freezing techniques on sensory quality, texture, and flavor warrants investigation. Comparative studies on freezing versus other preservation methods could also offer insights into more effective strategies to reduce post-harvest losses.

The impact of anti-browning agents, specifically 1% ascorbic acid and 1% calcium chloride, as well as the influence of polypropylene and stretch wrapping films on various parameters of baby corn (ears 321 Tribal hybrid) were reported by Attia et al., 2011. The investigation aimed to assess the effects on reduction in browning, quality maintenance, and inhibition of pathogens. The treated samples exhibited weight loss, decreased total sugars, and reduced polyphenol activity, along with a lower microbial count compared to untreated samples. The study reported that baby corn ears subjected with 1% ascorbic acid or 1% $CaCl_2$ and wrapped with polypropylene films were effective in inhibiting browning, sustaining quality, and preventing pathogenic growth. These treatments demonstrated favorable results over a 15-day storage period at 5°C and 95% relative humidity. Overall, the investigation highlighted the potential of anti-browning agents and specific wrapping methods in preserving the quality of baby corn throughout storage. However, further research is needed to examine the long-term effects of these treatments beyond 15 days. Additionally, the interactions between anti-browning agents and packaging materials under different storage conditions, as well as their impact on the nutritional composition and sensory attributes of baby corn, require investigation.

Aggarwal and Kaur (2010) conducted a study on the preservation of baby corn by steeping. The study specifically examined dehusked corn that was collected either 2 or 4 days after silk emergence. The experiment included immersing liquids containing acetic acid at concentrations ranging from 0.5% to 2.0% and sodium chloride at concentrations ranging from 2% to 8%. Both blanched and unblanched samples were kept at ambient temperature and in a refrigerated environment. The analysis of baby corn that has been soaked involved the evaluation of many factors such as the overall amount of dissolved substances, the texture, the salt content, the acidity level, the sugar content, and the starch content. The best preservation was reported for baby corn that was harvested within 2 days of the appearance of silk. Blanching the food for a duration of 4 minutes resulted in improved color retention and decreased penetration of salt and acid. Acetic acid shown superior efficacy in microbial control. The researchers determined that the concentration of acid had a considerable impact on ear characteristics. A blend comprising of of 6% salt and 0.75% acid was found to be the most effective preservation method, enabling storage for a maximum of 45 days.

2.8 Product development and value addition

The research carried out by Kaur and Sharma, (2021) sought to transform baby corn by-products through the processes of drying and powdering, ultimately formulating blends of flours and muffins with diverse ratios of mini corn, defatted soya, plantain, and ragi flours. The investigation uncovered that the introduction of baby corn flour not only improved functional and pasting attributes but also increased antioxidant and metal-chelating activity. Moreover, it contributed to improved antioxidant retention during the baking process. Muffins containing higher proportions of baby corn exhibited heightened hardness and specific volume, alongside a reduction in total phenol content. Sensory analysis indicated a preference for muffins with a 20% inclusion of baby corn flour. In summary, the study concluded that baby corn flour serves as a fitting ingredient for the development of gluten-free muffins, characterized by favorable sensory attributes and an enriched nutritional profile. The findings propose potential applications in addressing celiac disease and stimulating innovation within the food processing industry. The study also recommends further research to explore additional culinary uses of baby corn flour in various food products.

Reena et al., (2017) highlighted the potential value addition of baby corn to the maize crop, underscoring its significance in enhancing the food processing industry. The researchers stressed the nutritional richness of baby corn and pointed out its value in agricultural practices, noting that its short duration and ability for multiple cultivations per year could contribute significantly to the economy and uplift the livelihoods of farmers.

Yasni and Maulidya, (2014) innovatively developed corn milk yogurt through the utilization of a mixed culture comprising Lactobacillus delbruekii, Streptococcus salivarus, and Lactobacillus casei. This pioneering venture involved the incorporation of fresh milk into heated corn extract, showcasing its potential for commercial scalability by employing a starter mixture of the aforementioned bacterial strains. The researchers systematically formulated diverse variations, subjecting them to evaluation via hedonic scales and meticulous weighing methods. Remarkably, the formulation enriched with 10% sugar and 5% full cream powder emerged as the most favorably rated, as discerned from the hedonic assessments. Significantly, the product's composition boasted a noteworthy 1.5 x 109 CFU/ml of lactic acid bacteria and a medium fat content of 1.8%, positioning it within the probiotic classification. Yasni and Maulidya's exploration not only unveiled a novel corn yogurt but also identified a formulation that balances sweetness and creaminess, paving the way for a potentially marketable product with health-promoting probiotic attributes.

Comprehensive studies were carried out by Sinha and Sharma, (2013) exploring the usage of baby corn in the creation of diverse culinary delights. The array of products crafted included preserves, candies, pickles, ladoos, halwa, and kheer. The formulations of preserved and sweet products involved the complete incorporation or partial substitution of baby corn. The resultant culinary creations underwent thorough analysis, encompassing assessments of both nutritional content and sensory attributes. The outcomes revealed that, with the exception of the taste and texture of the candy, all preserved products garnered acceptance through organoleptic analysis. This indicates that the sensory aspects of these culinary innovations, including flavor, aroma, and overall texture, were generally well-received. The meticulous evaluation of nutritional value further underscored the versatility and potential palatability of incorporating baby corn into various culinary applications.

Although young corn (Zea mays ears) is frequently employed as a vegetable, its potential as a raw food ingredient is often disregarded because of limited awareness concerning its nutritional advantages and functional characteristics. The researchers focused on analyzing dried young corn, aqueous extracts, and aqueous extract residues for total dietary fiber, discovering values of 30.4 g/100g, 40.91-57.17 g/100g, and < 1.0 g/100g, respectively. Fructose and sucrose were identified in the aqueous extracts, with sucrose being the predominant component. Aqueous extract residues contained the lowest concentration of total sugars (1.35-3.70 g/100g). The researchers also observed an increase in protein content when young corn powder was added to cookies. From their findings, the investigators concluded that Zea mays ears contain diabetic-friendly sugars (fructose and sucrose), while aqueous extract residues provide dietary fiber. This suggests that young corn has the potential to be utilized in processed food products as an alternative source of sugar and dietary fiber (Rosli and Anis, 2012)

The cultivation of baby corn, as elucidated by Dass et al., (2008), holds the promise of augmenting income when integrated into diversified crop growth strategies. Furthermore, the versatile nature of baby corn renders it conducive for the creation of value-added products, thereby contributing to the economic viability of its cultivation.Researchers focused on the development of nutrient-rich baby food made from soy, employing diverse formulations derived from soy milk and various cereals such as wheat, corn and rice. The prepared products underwent rigorous scrutiny, encompassing physiochemical analysis, microbiological assessments, and shelf life studies.

Researchers focused on the development of highly nutritious soy-based baby foods, employing diverse formulations derived from soy milk and various cereals. The prepared products underwent rigorous scrutiny, encompassing physiochemical analysis, microbiological assessments, and shelf life studies. The nutritional composition of the formulations, including soymilk with corn,rice and wheat was meticulously examined. The protein content ranged from 25.0% to 28.5%, fat content from 9.00% to 10.0%, and carbohydrate content from 54.9% to 58.5%. A comparative analysis of the protein content in the different formulations with that of casein revealed that the soy-based baby foods met the criteria for essential nutrients crucial for the optimal growth and development of infants and preschool children (Wadud et al., 2004).

CHAPTER 3

HYPOTHESIS

CHAPTER 3- HYPOTHESIS OF STUDY

Baby corn, a high-value vegetable prone to post-harvest losses due to its perishable nature, could be processed into a versatile powder, unlocking its capacity for the development of various functional food products. The incorporation of baby corn powder in muffin formulations can enhance their nutritional value and sensory appeal. These developed muffins suggest that baby corn powder has the potential to serve as a functional ingredient, meeting consumer demand for healthier food options while providing economic benefits to the food industry.

CHAPTER 4

OBJECTIVES

CHAPTER 4 – OBJECTIVES

1. To characterize baby corn varieties on the basis of physical, chemical, textural and functional properties.
2. To optimize the process parameters for the development of baby corn powder.
3. To investigate the effect of storage conditions and packaging materials on the quality of baby corn powder.
4. To incorporate a developed powder in food model.

CHAPTER 5

MATERIALS AND METHODS

CHAPTER 5 - MATERIAL AND METHODS

The present investigation, titled "Characterisation of Baby Corn and its Valorisation for Powder Development," was carried out within the Department of Food Technology and Nutrition at the School of Agriculture, Lovely Professional University, Jalandhar. This segment delineates the materials employed and outlines the experimental procedures undertaken during the study.

5.1 Experimental materials

Two distinct baby corn varieties, Syngenta 5417 and Pusa HM4-Male Sterile (Sheeshu), were meticulously cultivated in the agricultural expanses of Lovely Professional University (LPU). The Syngenta 5417 variant was not only grown in LPU's agricultural fields but also sourced from Field Fresh Foods Pvt Ltd. in Ladhowal, Ludhiana. Concurrently, Pusa HM4-Male Sterile (Sheeshu) was also procured from the fields of Aterna village in Sonipat, Haryana.

Chemicals

All chemicals utilized in this study were of analytical grade and obtained from reputable manufacturers adhering to industry standards.

5.2 Methodology

Objective 1

To characterize baby corn varieties on the basis of physico-chemical, textural and functional properties

5.2.1 Characterisation and grading of Baby corn varieties

After the procurement of the varieties, the samples from both cultivars underwent a nuanced process that encompassed not only classification and grading but also an exhaustive examination of physicochemical attributes and antioxidant properties.

5.2.2 Physicochemical properties Classification of baby corn was done on the basis of size i.e., long, short and medium. For this purpose, random samples were considered for measuring physical parameters like length and diameter using Vernier calliper

Size: The Vernier calliper or digital calliper was used to measure the length and diameter of baby corn cob. Length, breadth and thickness were expressed in terms of millimetres (Al-Mitewty et al., 2019).

The true density (ρt): It refers to the ratio of the sample's mass to its actual volume and was determined through the toluene displacement technique (Deshpande and Poshadri, 2011).

5.2.3 Estimation of chemical Properties of baby corn varieties

The chemical composition, encompassing moisture, protein, fat, and ash, was meticulously determined. The moisture content was assessed by oven dry method. For protein content, Kjeldahl's method was employed, involving the multiplication of nitrogen content by a factor of 6.25. Fat determination was executed through the Soxhlet method, utilizing petroleum ether as the extracting solvent (AOAC 2012). Crude fiber analysis was conducted using the digestion method (AOAC 2012). Carbohydrate content was calculated using the difference method.

Moisture content: The determination of moisture was done by means of hot air oven (Narang Scientific Works Pvt Ltd, Model: NSW-143, Ambala, India) method at 70 ± 5^0 C until constant weight was obtained (AOAC, 2012).The final moisture content was determined according to the formula:

$$Moisture\ (\%) = \frac{\text{Initial weight of sample} - \text{Final weight of sample}}{Final\ weight\ of\ sample} \times 100$$

Ash content

The determination of total ash content involved the combustion of the sample at 550°C in a muffle furnace (AOAC 2012). A sample weighing 5 grams was carefully placed into a pre-weighed porcelain crucible, charred over a Bunsen flame until no further smoke emanated, and subsequently incinerated in a muffle furnace at 550°C until achieving a homogeneous, grey material. After removal from the furnace, the crucible was left to cool inside a desiccator before being weighed. The ash content was then calculated using the given formula:

$$Ash\ (\%) = \frac{Ash\ weight}{weight\ of\ sample} \times 100$$

Crude protein

Crude protein content was assessed utilizing the Kjeldahl's method (AOAC, 2012). This sophisticated method involves a series of steps, including digestion, distillation, and titration. A 1-gram sample was carefully digested in a Kjeldahl flask using a digestion mixture that included copper sulfate, potassium sulfate (in a 1:10 ratio), and 20 ml of concentrated H_2SO_4 until a light green hue was obtained.After cooling, the volume was adjusted to 250 ml. Subsequently, ammonia released during the distillation of the digested sample (10 ml) with 25 ml of 40% NaOH solution was captured in 0.1 N boric acid and titrated with 0.1 N HCl to determine the percentage of nitrogen (N). A blank, treated similarly but with a Kjeldahl flask free of the sample, served as a control. The protein percentage was calculated using the formula:

$$Nitrogen\ (\%) = \frac{titre\ value - blank\ value\ \times NHCl\ \times 14\ \times Volume\ make\ up}{weight\ of\ sample\ \times aliquot\ taken\ \times 1000} \times\ 100$$

Crude protein (%) = Nitrogen (%) × 6.25

Crude fat

The determination of crude fat involved the utilization of a Soxhlet extractor, employing petroleum ether as the solvent. A precisely weighed sample of 1g was placed in an extraction thimble and subjected to extraction using petroleum ether (AOAC,2012).The resulting ether extract underwent evaporation, and the calculation of crude fat content was calculated by formula :

$$Crude\ fat\ (\%) = \frac{weight\ of\ fat\ (g)}{Sample\ weight} \times\ 100$$

Crude fiber: The determination of total crude fiber content was conducted using the Fibertec method. In this process, the moisture and fat-free sample undergoes a sequence of acid washing (H_2SO_4) followed by alkali washing (NaOH). The treated sample was then dried in a muffle furnace at 550°C. The disparity in weight before and after the drying and incineration phases provides the measurement for the total crude fiber content (AOAC, 2012).

Total Carbohydrate

The calculation of total carbohydrates was executed using the difference method (Ranganna, 2001).

Carbohydrates % = 100 - % (Moisture +Crude protein +Crude fat +crude fibre)

TSS (Total Soluble Solids)

The determination of Total Soluble Solids (TSS), a digital refractometer (model PT-32; ATAGO, Tokyo, Japan) with a measuring range spanning from 0 to 32 °Brix was employed (AOAC, 2012).

Ascorbic Acid

The technique used to determine ascorbic acid (vitamin C) followed the conventional approach described by Ranganna in 2001. The determination of Vitamin C required the preparation of a solution containing 0.4 percent oxalic acid. The measurement was performed using a titration method using a solution of 2,6-dichlorophenol indophenol dye (0.04 percent). The dye solution was calibrated using a known concentration of L-ascorbic acid (0.1 mg/ml) in a 0.4 (%) oxalic acid medium. A quantity of 1 gram from the sample was combined with a solution containing 0.4 percent oxalic acid. The volume was set to 100 ml, and then the mixture was filtered using Whatman filter paper no. 4. A 10 ml portion of the liquid that passed through the filter was measured and reacted with the dye solution that has a known concentration. The titration endpoint was determined by the presence of a consistent and lasting pink hue that lasted for a minimum of 15 seconds. The results of the analysis were presented as the concentration of ascorbic acid in milligrams per 100 grams of the sample.

$$Ascorbic\ acid\ (mg/100g) = \frac{Titre\ value\ \times Dye\ factor\ \times Vol. made}{Aliquot\ taken\ \times sample\ weight} \times\ 100$$

Titratable acidity:

The determination of titratable acidity was determined by method of Ranganna, (2001). The process involved titrating a known sample solution with 0.1 N NaOH solutions until achieving a faint pink color, facilitated by the use of phenolphthalein as an indicator. For the estimation, 2g sample was weighed and was then diluted to a volume of 100 ml with distilled water and subsequently filtered. A 5ml aliquot of the filtered solution was utilized for titration. To initiate the titration, 1-2 drops of phenolphthalein indicator were added, and the solution was titrated against 0.1 N NaOH until the faint pink endpoint was reached and calculated by using the formula

$$Titratable\ acidity\ (\%) = \frac{Titre\ value\ \times Normality\ of\ alkalo\ used \times volume\ made \times equivalent\ weight}{Aliquot\ used\ \times sample\ \ weight \times 1000} \times 100$$

Water activity: Water activity analyzer (Testo AG 400, Germany) was used for determining the water activity

Carotenoid content

The quantification of total carotenoid content was conducted through spectrophotometric analysis, following the method outlined by Huynh et al., (2020). Extraction of carotenoids was achieved utilizing hexane as the sole solvent. 0.5 g sample was subjected to a 15-minute incubation period with 10 ml of hexane. Subsequently, the mixture was centrifuged at 4000 rpm for 15 minutes at 4°C to facilitate the separation of components. The absorbance of the resulting solution was assessed with a UV spectrometer at a wavelength of 450 nm. The carotenoid concentration was reported in micrograms of β-carotene per gram of the sample (μg β-carotene g^{-1}).

5.2.4 Mineral profile

For the mineral analysis, 1 gram of sample was weighed for the digestion process. A diacid mixture comprising Nitric acid and Perchloric acid in a 4:1 proportion was added to initiate the digestion. The samples were then subjected to digestion in a digestor. Following digestion, a 0.5-1 ml aliquot of the digested samples was extracted and diluted with 100 ml of double-distilled water. Subsequent to the dilution process, the samples underwent analysis using an atomic absorption spectrometer (ICP-AAS), as per the methodology outlined by Hooda and Kawatra, (2013).

5.2.5 Determination of color values

The color values were recorded by colorimeter (Accuracy Micro sensors, Inc. Pittsford, New York) for fresh, blanched, and dried samples to observe the effect of drying on the color of treated samples. Changes in color were quantified in the L^*, a^*, b^* color system, L refers to the lightness and the two chromatic components: The pair of chromatic elements: the a* component shifting from green (-a) to red (+a) and the b* component transitioning from blue (-b) to yellow (+b). The L*, a*, b* values were employed to ascertain the overall color contrast through the equation provided below:

$$Total\ color\ difference, \Delta E = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2}$$

L_o^*, a_o^* and b_o^* represent the initial color values of L *, a* and b* respectively.

5.2.6 Textural properties

Hardness, cohesiveness, and resilience were determined by means of texture profile analyser (CT3 Texture Analyzer; Brookfield Engineering Laboratories) as followed by Zhao et al., 2017

5.2.7 Functional properties of baby corn varieties

Extraction for assessment of antioxidant activity of baby corn

Extractions were carried out utilizing two solvents: 80% (v/v) ethanol and distilled water, maintaining a sample-to-solvent ratio of 1:10. Fresh baby corn cobs were accurately weighed and subjected to maceration with 80% ethanol at a low temperature (0 °C) to preserve the integrity of the components. Following maceration, the extracts underwent centrifugation at 6000 rpm for 30 minutes, leading to the separation of the supernatant. This supernatant was then collected for the subsequent determination of antioxidant content and activity. Notably, the analysis was conducted on a fresh weight basis Limmatvapirat et al., 2020.

Determination of total phenol, flavonoid and free radical scavenging activity (DPPH)

Total Phenol content

The total phenolic content was assessed employing a method based on the procedures elucidated by Limmatvapirat et al., (2020).The process involved extracting 0.1 g of the sample using 80% ethanol, followed by centrifugation at 6000 rpm for 30 minutes. The resulting supernatant was isolated and subjected to boiling for a brief duration. The residue obtained was then mixed with 5 ml of distilled water. Subsequently, 0.5 ml of Folin Ciocalteu reagent was introduced into the mixture and allowed to stand for 3 minutes. Following this, 20% sodium carbonate (Na_2CO_3) was added into the samples, and the mixture was boiled for a minute. The solution's absorbance was recorded at 650 nm with a spectrophotometer, using gallic acid as the standard reference.

Total Flavanoid content:

A 0.1g sample of baby corn was extracted using 80% ethanol. Afterward, 0.25 ml of the acquired extract was moved to a test tube, and then 1.25 ml of distilled water was added. 0.75 ml of a 5% sodium nitrate solution was added to the mixture, and the amalgamation was left undisturbed for 5 minutes. Additionally, 0.15 ml of a 10% w/v solution of aluminium chloride was added, and the resulting mixture was allowed to react for an additional 5 minutes before being supplemented with 0.5 ml of a 1N solution of NaOH. The solution was diluted with 0.275 ml of distilled water, and its absorbance was measured at 510 nm using a UV-Vis spectrophotometer. Quercetin served as the standard reference, and the flavonoid content was quantified and expressed as milligrams of quercetin equivalents per 100 grams of the sample (Limmatvapirat et al., 2020).

Free radical scavenging activity (DPPH)

The method described by Kaur et al., (2020) was employed for the purpose of determining free radical scavenging. An ethanolic solution of 2, 2-diphenyl-1-picrylhydrazyl (DPPH) at a concentration of 90 µmol/L was used in analysis. A 100 µl aliquot of the extract was carefully pipetted, and it was mixed with 1000 µl of the pre-

prepared DPPH solution in a test tube. The resulting mixture was thoroughly shaken and then left in darkness for duration of 60 minutes. Subsequently, the absorbance of the solution was quantified at 517 nm (UV/Vis Spectrophotometer, Shimadzu Corporation, Japan). This measurement was conducted in comparison to a blank sample, as detailed in equation below:

Antioxidant activity (%) = A_o- A/ A_o

Where, A_o= Absorbance of DPPH solution as blank

A = Absorbance of sample

Ferric reducing antioxidant power (FRAP)

The antioxidant capacity was assessed using a spectrophotometric method based on the procedure outlined by Benzie and Strain. This technique relies on the reduction of the colorless Fe^{3+}-TPTZ complex to a blue Fe^{2+}-tripyridyltriazine complex, a process that is enhanced by electron-donating antioxidants and occurs in acidic conditions. The progression of this reaction was monitored by measuring absorbance changes at 593 nm. The FRAP reagent, essential for this analysis, was prepared by combining 300 mM acetate buffer, 10 ml TPTZ in 40 mM HCl, and 20 mM $FeCl_3 \cdot 6H_2O$ in a 10:1:1 ratio at 37°C. For each test, a freshly prepared FRAP solution (3.995 ml) was mixed with 5 µl of appropriately diluted samples and thoroughly mixed. The reduction of the Fe^{3+}-TPTZ complex to the ferrous form produced a distinct blue color. Absorbance at 593 nm was recorded after a 30-minute incubation at 37°C, with a reagent blank consisting of 3.995 ml FRAP reagent and 5 µl distilled water. Each measurement was performed in triplicate. To generate the calibration curve, absorbance values at 593 nm were plotted against various concentrations of $FeSO_4$ and compared to those of the standard antioxidant trolox. The FRAP values were reported as milligrams of Trolox equivalent per gram of the sample (Rajurkar and Hande, 2011).

Objective 2

To optimize the process parameters for the development of baby corn powder.

5.3 Blanching followed by drying

Blanching was meticulously carried out with the primary objective of inactivating the peroxidase enzyme, a widely recognized marker enzyme associated with the blanching process.The effect of the treatments was studied on various physico-chemical properties of baby corn. Sample (100g) meticulously sliced in circular pieces, each having a diameter of precisely 15.23mm and a thickness within the range of 0.1cm to 0.2cm, were subjected to various distinct blanching treatments viz. HWB at 70°C, 80°C, 90°C for 30, 60, 120 180 and 240 s, SB for 30, 60, 120 180 and 240 s and MWB at 360-900W for 30-300 s. Treated samples were analysed in triplicates for shrinkage (%), mass of kernel (g), TSS, densities, color, enzyme inactivation and antioxidant assay.

5.3.1 Physical properties

Dehusked baby corn cobs were cut in circular shapes and blanching treatments were given one by one including HWB, SB and MWB. Moreover, diameters of round pieces were taken before and after blanching by means of Vernier calliper so as to find out the effect of blanching on diameter or shrinkage (%) (Al-Mitewty et al., 2019).

Determination of bulk density, true density and porosity

The determination of bulk density was accomplished by carefully transferring a known mass (g) of the sample into a measuring cylinder, and subsequently recording the volume occupied by roundels. The true density was precisely ascertained by toluene displacement method. Moreover, the specified quantity of toluene was put in a measuring cylinder followed by pouring the known mass of sample and the final volume was noted (Deshpande and Poshadri, 2011).Densities, both bulk and true, porosity (ε) were computed employing Equations below:

$$Bulk\ density\ (\mathrm{g/m^3}) = \frac{Mass\ of\ sample (g)}{volume\ of\ sample\ (m^3)}$$

$$\text{True density} = \frac{Mass\ of\ sample\ in\ air\ (g)}{Volume\ of\ displaced\ fluid\ (m^3)}$$

$$\text{Porosity } (\varepsilon) = \left(1 - \frac{\rho b}{\rho t}\right) \times 100$$

Where, ε represents the percentage of porosity, ρb denotes the bulk density in g/cc, and ρt signifies the true density in g/cc.

Determination of color values

The color values were recorded by Hunter lab colorimeter (Accuracy Micro sensors, Inc. Pittsford, New York) for fresh and blanched

5.3.2 Determination of Chemical Properties

Quantification of Moisture Content, water activity, TSS and ascorbic acid

The determination of moisture was done by means of hot air oven (Narang Scientific Works Pvt Ltd, Model: NSW-143, Ambala, India) method at 70 ± 5^0 C until constant weight is obtained (AOAC, 2012). Water activity analyzer (Testo AG 400, Germany) was used for determining the water activity. Similarly, for the determination of Total Soluble Solids (TSS), a digital refractometer (model PT-32; ATAGO, Tokyo, Japan) with a measuring range spanning from 0 to 32 °Brix was employed (AOAC, 2012) and the quantification of ascorbic acid content was conducted using the established standard procedure outlined by Ranganna (2001).

Determination of total phenol, flavonoid and free radical scavenging activity (DPPH)

The protocol outlined by Limmatvapirat et al., (2020) was adhered to for assessing the flavonoid and total phenol levels. Meanwhile, the procedure detailed by Kaur et al., (2020) was utilized for evaluating free radical scavenging activity.

5.3.3 Peroxidase enzymatic activity

The treated samples (HWB, SB and MWB) were analysed for enzymatic activity. Sample (1 g) was put in test tube, 0.5% guaiacol (10 ml) and 0.08% hydrogen peroxide (10 ml) was introduced followed by vigorous shaking. The test tube was then allowed to stand undisturbed for duration of 3 minutes, during which the color chang was observed and recorded. The transition in color from a clear, colorless state to a vivid brick-red hue signifies a state of incomplete enzyme activation. For quantitative results the absorbance was checked at 720nm in spectrophotometer (Kachhadiya et al., 2018).

5.3.4 Kinetics of variation in responses

The different responses during blanching methods at different time- temperature/ power combinations of baby corn were subjected to zero and first order equations. In order to assess the fluctuation in various responses during the processing, below mentioned equations were used.

$$C = C_0 \pm K_O \times T \pm K_1 \Theta$$

$$C = C_0 \exp(\pm K_O \times T \pm K_1 \Theta)$$

Here, C represents the approximate quantity of diverse responses at specific processing times (Θ) and temperatures (T) within various blanching treatments, C_0 represents corresponding response in fresh sample, K_O and K_1 represents kinetic rate constants.

5.4 Drying

The blanched samples 100±1 g per trial were kept on the trays with different tray loads (0.45, 0.40, 0.35 & 0.30g/cm^2) in a tray drier (Labfit India Pvt Ltd., Ahmedabad). They were dried at temperatures of 50°C, 60°C, and 70°C until equilibrium was reached.The sample weight was recorded every 15 min for a period of 2 hours and later after 30 min until a constant weight was achieved. The moisture content on a dry basis was calculated using the following formula

$$\%Moisture\ content = \frac{initial\ mass\ of\ the\ sample - mass\ of\ dried\ sample}{mass\ of\ dried\ sample}$$

5.4.1 Mathematical modelling

For most agricultural products, convection drying predominantly happens during the falling rate period. Therefore, previously established thin layer drying models, as shown in Table 5, can be applied to the moisture ratio (MR) over time. The mathematical models in this study are listed in the table.

Table 5 : Thin layer drying models

S.No.	Model name	Model equation
1.	Page Model	$MR=\exp(-kt^{n})$
2.	Modified Page Model	$MR=\exp[(-kt)^{n}]$
3.	Lewis Model	$MR=\exp(-kt)$
4.	Henderson and Pabis	$MR= a \exp(-kt)$
5.	Logarithmic model	$MR=a \exp(-kt^{n}) +C$
6.	Two term model	$MR= a \exp(-kt)+b \exp(-k_{o}t)$
7.	Weibull model	$MR=a-b \exp(-kt^{n})$
8.	Midilli and Kucuk model	$MR=a \exp(-kt^{n}) + bt$

Note: MR: Moisture ratio; k, and n are the model parameters; t: Drying time (minutes).

Effective Diffusivity

The effective diffusivity was determined by using Fick's second law of diffusion. A plot between the natural logarithmic of moisture ratio (MR) with time (t) was plotted using the following equation:

$$\ln(MR) = ln\frac{8}{\pi^2} - \frac{\pi^2 D_{eff} t}{4L_0^2}$$

Where D_{eff} indicates effective diffusivity (m^2/s) and L_0 is half of the drying thickness (m)

Activation energy

Arrhenius equation was used to determine the activation energy. A plot between the natural logarithm of effective diffusivity (D_{eff}) against the reciprocal of absolute temperature (1/T) was used to get the activation energy value as per the following equation.

$$D_{eff} = D_0 \exp\left(-\frac{E_a}{RT}\right)$$

Where E_a, D_0, R and T represents activation energy (KJ/mol), Arrhenius equation factor (m^2/s), gas constant (KJ/mol K), temperature(K) respectively.

5.5 Different types of drying of baby corn roundals

Three distinct drying techniques, namely tray, sun, and vacuum drying, were employed for processing baby corn, as illustrated in Figure (4). To ensure optimal conditions for each experiment, the desired temperature settings within the drying chambers for both oven and vacuum drying were attained and maintained for a minimum duration of one hour before commencing each procedure.

5.5.1 Tray drying The blanched samples 100±1 g per trial were kept on the trays with different tray loads (0.45, 0.40, 0.35 & 0.30g/cm^2) in a tray drier (Labfit India Pvt Ltd., Ahmedabad) and and were dried at different temperatures (50°C, 60°C, and 70°C) until equilibrium was reached.The sample weight was noted every 15 min for a period of 2 hours and later after 30 min till constant weight was achieved

5.5.2 Sun drying

The baby corn underwent precise slicing into roundels, and the resulting slices were thoughtfully arranged on a well-ventilated laboratory bench, strategically exposed to sunlight. This meticulous setup ensured a uniform and single-layer distribution on the sample tray. An average air temperature of 35-40 °C and a relative humidity of 30-35% were observed throughout the duration of the drying process, the weights of the sampes of baby corn were systematically measured at hourly intervals to monitor the progress. To prevent any post-drying moisture absorption and preserve the dehydrated samples, a strategic approach was taken. The desiccated baby corn slices were delicately stored in airtight LDPE bags, employing thermal sealing to guarantee optimal freshness and thwart potential rehydration.

5.5.3 Vacuum drying

The baby corn roundels were dried in a vacuum oven (Thermo Scientific Vacuum Oven, Model 3608-5, India) at temperatures of 50°C, 60°C, and 70°C, with a vacuum pressure of 25 mm Hg, till a stable and constant weight was achieved.

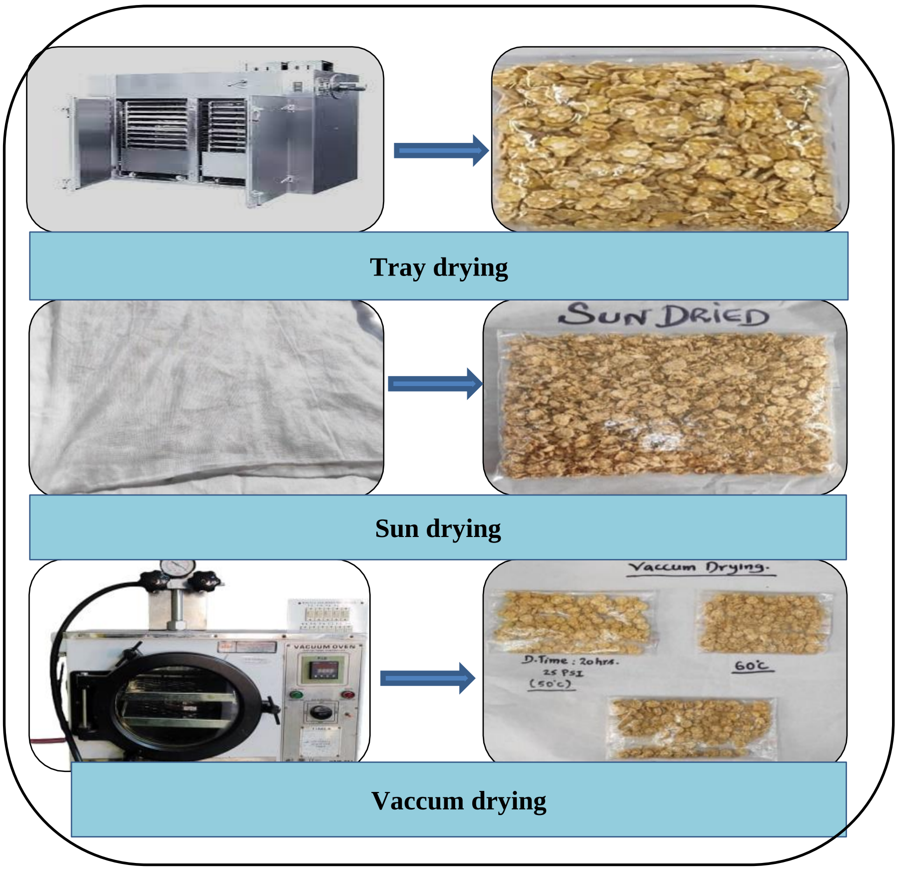


Figure 3. Different drying methods for baby corn

5.6 Comprehensive analysis of nutritional composition of baby corn powder

The determination of moisture was done by means of hot air oven (Narang Scientific Works Pvt Ltd, Model: NSW-143, Ambala, India) method at 70 ± 5^0 C till constant weight is obtained, total ash content involved the incineration of the sample at 550°C in a muffle furnace, crude protein content was assessed utilizing the Kjeldahl's method, crude fat involved the utilization of a Soxhlet extractor, total crude fiber content was conducted using the Fibertec method, (AOAC, 2012),calculation of total carbohydrates was executed using the difference method (Ranganna, 2001).

5.6.1 Determination of bioactive components

The quantification of ascorbic acid content was conducted using the established standard procedure outlined by Ranganna (2001).The methodology described by Limmatvapirat et al., (2020) was followed for determination the flavonoid and total phenol content. The method described by Kaur et al., (2020) was employed for the purpose of determining free radical scavenging.

5.6.2 Color analysis

The color values were recorded by colorimeter (Accuracy Micro sensors, Inc. Pittsford, New York) for dried samples to observe the impact of drying on the color of treated samples.

5.6.3 Physico chemical properties of baby corn powder

The blanched, tray dried sample was ground in a commercial mixer grinder (Kalsi Brand, Bhajan Singh and Sons Ludhiana, India) to convert into powder. The obtained powder was subjected to classification on the basis of particle size by sieving using electric sieve shaker (8'' Sieve Shaker SS 304, Harrisons Pharma Machinery Pvt. Ltd., Delhi, India) with different sieve sizes ranging from >500,500,420, 300, 150, 75 and 53 μm for approximately for half an hour at medium speed. The final powders of various particle sizes were sealed in ziplock pouches and stored under refrigerated conditions for subsequent analysis.

5.6.4 Granulometric study

The percentage of powder remaining on each sieve was calculated by dividing the mass fraction by the total mass of the sieved powder. Each experiment was replicated three times.

Bulk density (g/cc) was measured by adding a known mass of powder into a measuring cylinder without tapping and recording the volume it occupied (Kumar and Saini, 2016). The bulk density was then calculated using the equation.

$$\text{Bulk Density} = \frac{weight\ of\ measuring\ cylinder\ and\ sample - weight\ of\ meauring\ cylinder}{\text{Volume occupied by sample}}$$

True density (g/cc), also known as tapped density, was measured by tapping a known quantity of powdered sample in a pre-weighed measuring cylinder (Tze et al., 2012). The calculation was performed using the corresponding equation.

$$\text{True Density} = \frac{Mass\ of\ powdered\ sample}{\text{Tapped Volume occupied by sample}}$$

Flowability or Hausner ratio was determined by formula given in equation.

$$\text{Hausner Ratio} = \frac{\textit{Bulk density}}{\text{Apparent density}}$$

Carr Index or compressibility index was calculated by the formula given in equation

$$\% \text{ Carr's compressibility index} = \frac{\textit{Tapped density} - \textit{Apparent density}}{\text{Tapped density}} \times 100$$

The angle of repose (θ) was measured by method given by Al-Mitewty et al., (2019). The diameter (D) and height (H) of heap of dried powder was measured and angle of repose was computed by means of equation

$$\theta = \tan^{-1}(2H/D)$$

Where, θ = Angle of repose (deg.); H = Height of the cone (mm); D = Diameter of the cone (mm)

5.7 Techno functional properties of dried baby corn powder

Oil absorption capacity (OAC)

Oil absorption capacity (OAC) was evaluated following the procedure outlined by Chandra et al., (2015). A powdered sample (0.3 g) was placed in a pre-weighed centrifuge tube, followed by the addition of 3 ml of oil, and mixed vigorously. The mixture was then centrifuged at 2060 rpm for half an hour. After removing the supernatant, the centrifuge tubes were reweighed. The OAC was evaluated using the equation.

$$\text{OAC}(\text{gg}^{-1}) = \frac{\textit{Sample weigh} + \textit{oil}}{\text{final weigh}}$$

Water absorption capacity (WAC)

To measure the water holding/absorption capacity of flours, the procedure outlined by Sharma et al., (2015) was used. A 1 g sample of the powdered flour was combined with 10 ml of distilled water in a pre-weighed 15-20 ml test tube.The mixture was left to stand at room temperature for 30 minutes, followed by centrifugation at 4000 rpm for

30 minutes. After discarding the supernatant, the tube containing the pellets/residue was weighed. The water holding capacity (WHC) was calculated using the given equation.

$$\mathrm{WAC}(\mathrm{gg}^{-1}) = \frac{\textit{Weight of hydratted residue}}{\text{Dry weight of sample}}$$

Foaming capacity (%) and foaming stability (%) were measured using the method described by Singh et al., (2022). A 1 g powdered sample was mixed with 50 ml of distilled water at room temperature in a 45-50 ml centrifuge tube and shaken until foam formed. The foam volume was recorded 30 seconds after whipping to calculate the foaming capacity using the FC (%) formula. The suspension was then allowed to stand for 1 hour, and the volume was measured again to evaluate foaming stability using the formula.

$$\mathrm{FC}(\%) = \frac{volume\ of\ foam\ after\ whipping - volume\ of\ foam\ before\ whipping}{volume\ of\ foam\ before\ whipping} \times 100$$

$$\mathrm{FS}(\%) = \frac{Volume\ after\ standing - volume\ before\ whipping}{\text{volume before whipping}} \times 100$$

Emulsifying activity (EA) and emulsion stability (ES) were evaluated following method described by Jalal et al., (2018). A centrifuge tube (25ml) was filled with 1 g of sample, 10 ml of distilled water, and 10 ml of oil. The mixture was thoroughly combined by vortexing , then centrifuged at 5500 rpm for 15 minutes. The height of the emulsified layer was measured, and EA was calculated using the provided equation.

$$\mathrm{EA}(\%) = \frac{Height\ of\ emulsified\ layer}{\text{Total height}} \times 100$$

The emulsion in the centrifuge tube was subjected to heating in a water bath at 80°C for half an hour. It was then cooled under running water for 15 minutes and subsequently centrifuged at 6000 rpm for 10 minutes. The emulsion stability (ES%) was calculated using the equation.

$$\mathrm{ES}(\%) = \frac{Height\ of\ emulsified\ layer\ after\ heating}{\text{Total height}} \times 100$$

5.8 Characterization of powdered baby corn

5.8.1 Average particle size of powdered baby corn

Sample (2g) was soaked in deionized water for 12 hours at a temperature of 27 degrees Celsius. Following centrifugation at a speed of 5000 revolutions per minute for a duration of 10 minutes, the soluble components were collected, and the sample underwent particle size measurement. The sample was diluted at a ratio of 1:10 using deionized water and then treated with ultra-sonication in order to prepare it for analysis. An ultrasonic probe sonicator manufactured by Sonics and Materials Inc. (New Town, CT, USA) was used to perform ultrasonication. The whole mixture was subjected to final sample formulation at a temperature of 5°C, using a 5-second pulse for a duration of 20 minutes. The produced samples were thereafter kept in glass vials at a temperature of 25°C for future testing. A particle size analyzer (Zetasizer Nano ZS, Malvern Instruments Ltd., Malvern, WR14 1XZ, UK) was used to examine the dispersion of particles in a liquid medium for particle size analysis Chawla et al., (2021).

5.8.2 The Thermogravimetric analysis (TGA) and Differential Scanning Calorimetry (DSC)

Thermogravimetric analysis (TGA) is a thermal analytical technique that observes changes in the mass of a sample over time as it undergoes temperature variations. In the case of baby corn powder, TGA was conducted to track weight loss in relation to temperature, employing a heating rate of 10 °C/min under a nitrogen atmosphere. An analysis of the thermal properties of baby corn powder was conducted using a differential scanning calorimeter (Shimadzu, Kyoto, Japan). The thermograms were obtained by compressing 2 mg of finely powdered baby corn samples into a standard aluminum tray,subsequently subjected to heating from 30 to 450 °C at a rate of 10 °C per minute.During the whole operation, a continuous stream of nitrogen gas (20 mL/min) was maintained to guarantee that the environment remained inert.

5.8.3 Morphological structure The morphological characteristics of baby corn powder were examined using a scanning electron microscope (SEM; JOEL JSM-7610F). The dry baby corn powder was magnified at different levels using the scanning electron microscope

Objective 3

To investigate the effect of storage conditions and packaging materials on the quality of baby corn powder.

5.9 Assessment of sorption isotherm

The gravimetric method demonstrated by Majid et al., (2019); Debnath et al., (2002) was employed to determine moisture sorption isotherms. Seven desiccators, each containing a different saturated salt solution (LiCl,CH_3CO_2K,$MgCl_2$, K_2CO_3, KI, NaCl and KCl) to achieve various relative humidity levels (Table 6), were utilized. Baby corn powder samples (1 g) were placed in pre-weighed petri dishes placed on the upper desiccator plate above the saturated salt solutions with known relative humidity. The desiccators were placed in incubators set to 30, 40, and 50°C, allowing the samples to reach equilibrium, indicated by no noticeable weight change (±0.0001 g) over two consecutive weighings. To inhibit mold growth during storage, a test tube filled with thymol was placed inside the desiccators.The equilibration process usually took 16-24 days. To reduce the absorption of atmospheric moisture and guarantee accuracy and reliability, the analysis was performed three times.

Table 6: Relative humidity of different salt solutions at varying temperatures

Saturated salt solutions	**Relative Humidities (%)**		
	30°C	**40°C**	**50°C**
Lithium chloride (LiCl)	11.3	11.2	11.1
Potassium Acetate(CH_3CO_2K)	21.6	20.8	20.4
Magnesium chloride ($MgCl_2$)	32.4	31.6	30.5
Potassium carbonate (K_2CO_3)	43.2	40	38.5
Potassium Iodide(KI)	67.9	66.1	64.5
Sodium Chloride (NaCl)	75.1	74.7	74.4
Potassium Chloride (KCl)	83.6	82.3	81.2

5.10. Storage studies of baby corn powder

The powder obtained under various experimental conditions were subjected to distinct responses, including storage under ambient conditions and accelerated conditions (50°C, 90%RH). The selected packaging materials for storage encompassed low-density polyethylene (LDPE), polypropylene (PP), and aluminium laminates (AL). Continuous analyses were performed at regular intervals throughout a 90-day period, during which the below-mentioned parameters were consistently monitored. This systematic approach ensured a comprehensive assessment of the powder samples stability and behaviour under diverse storage conditions and packaging materials.

5.10.1 Moisture content determination

The determination of moisture was done by means of hot air oven (Narang Scientific Works Pvt Ltd, Model: NSW-143, Ambala, India) method at 70±5^0 C until constant weight is obtained, total ash content involved the combustion of the sample at 550°C in a muffle furnace (AOAC, 2012)

5.10.2 Powder properties

The properties of the powder, encompassing both physical and technofunctional attributes, were assessed using methodologies previously outlined in 5.6.4.

5.10.3 Color analysis

Color values were analysed as the method mentioned in 5.2.5

5.10.4 Microbiological analysis

Total plate count

TPC was determined by method of Singh and Kaur (2020) at regular intervals during storage. Total yeast count 4.2g of Potato Dextrose Agar (PDA) was dissolved in 100 ml of distilled water. It was autoclaved for 1 hour at 121 °C in an electric pressure steam steriliser and then allowed to cool to roughly 45 °C. 70 % alcohol was used to sterilise the work space. Using a micro pipette, 1mL of each sample was pipetted into labelled petri dishes (Gilson Pipetman, 060087N). To homogenise with the sample, the medium (PDA) was put into the petri dish and gently agitated. In the petri plate, this hardened and created a gel. It was then incubated for 24 hours at 37 °C. The calculation of the number of colonies (cfu/g) was executed by multiplying the plate count with the appropriate dilution factor.

Objective 4

5.11 To incorporate a developed powder in food model

The baby corn powder acquired was integrated into muffin formulation to elevate its nutritional content, particularly in terms of dietary fiber in the end product. Variations of 0%, 10%, 20%, and 30% of baby corn powder were meticulously incorporated. The resulting muffins underwent a comprehensive evaluation encompassing measurements of moisture content, total ash, fat levels, protein content, overall dietary fiber, textural characteristics, and sensory analysis

Table 7. Baby Corn Powder (BCP) muffin Formulation - Fiber Enrichment

Ingredients(g)	**Formulation (WF:YCP)**			
	100:0	**90:10**	**80:20**	**70:30**
Wheat flour	100	90	80	70
BCP	0	10	20	30
Baking powder	5	5	5	5
Sugar	81	81	81	81
Milk	90	90	90	90
Oil	55	55	55	55

5.11.1 Proximate composition of formulated muffins

The determination of moisture, total ash, crude protein, crude fat, total dietary fiber and total carbohydrates were analysed by the methods already mentioned in section 5.2.2

5.11.2 Textural characteristics of developed muffins incorporated with different levels of BCP

Textural properties like Hardness, adhesiveness, resilience(%), cohesion (%), springiness, gumminess and chewiness were determined by means of texture profile analyser (CT3 Texture Analyzer; Brookfield Engineering Laboratories) as followed by Zhao et al., 2017.

5.11.3 Sensory evaluation of prepared muffins

The assessment of samples for various quality attributes was conducted by panelists using a 9-point hedonic scale, as detailed in the methodology by Kaur et al., (2015).

Performa for sensory evaluation

Name of Panelist: _______________________________ Date: _______

Treatments	Appearance	Taste	Flavour	Texture	Overall Acceptability

Sensory Evaluation (9-point hedonic scale)

9 - Extremely liked

8 - Very much liked

7 - Moderately liked

6 - Slightly liked

5 - Neither liked nor disliked

4 - Slightly disliked

3 - Moderately disliked

2 - Very much disliked

1 - Extremely disliked

The muffins, featuring varying percentages of incorporated baby corn powder, underwent evaluation by panelists for attributes such as appearance, taste, flavour, texture, and overall acceptability. On the score sheet, a scale ranging from a maximum score of 9 to a minimum score of 1 was utilized, with a lower score indicating a poorer rating.

5.11.4 Color characteristics of muffins

The color values of the developed muffins (crust and crumb) were analysed by the method already described in section 5.2.5

5.11.5 Cost economics of developed baby corn products

The estimation of the product's cost considered various factors including raw material costs, marketing expenses, taxes such as VAT, and other associated charges. It was presented as Rs. 1 per kilogram of the product (Darshane, 2021).

5.12 Data analysis

5.12.1 Analysis of sorption isotherm data

The moisture equilibrium content (Xeq) of baby corn powder at varying temperatures were plotted against the water activity (expressed as relative humidity/100) to generate sorption isotherms.Regression analysis was performed to fit the experimental data to seven different mathematical models, as listed in Table 7. The suitability of each model was assessed by examining (%RMSE), the minimum mean absolute percentage error (E), and the maximum coefficient of determination (R^2), calculated by using the equations provided below.

$$\%RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (Y_{i-} Y_i' \;/Y_i \;)^2 \quad \times 100}$$

$$E = \frac{100}{N} \sum_{i=1}^{N} (Y_{i-} Y_i' \;/Y_i \;)$$

$$R^2 = 1 - \frac{\sum_{i=1}^{N} W_i (Y_{i-} Y_i')^2 (N-1)}{\sum_{i=1}^{N} W_i (Y_{i-} Y'')^2 (N-M)}$$

Where, Y_i represents the actual experimental value, Y_i' represents the predicted value of equilibrium moisture content; Y_i'' denotes the mean value derived from the experimental data of equilibrium moisture content. The variable N signifies the total number of observations; F represents the degrees of freedom within the regression model. The weighting applied to each data point is denoted by W_i, which, in this analysis, was consistently set to unity. Moreover, M represents the number of coefficients within each equation.

Table 8: Models for moisture sorption isotherms applied to fit experimental data pertaining to baby corn powder.

Model name	Mathematical expression
GAB (1981)	$Xeq=X_m.C.K.a_w/[(1-K.a_w)(1-K.a_w+C.K.a_w)]$
BET (1993)	$Xeq = X_m.C.a_w /[(1-aw)+(C-1)\cdot(1-a_w)\cdot a_w]$
Oswin (1946)	$Xeq = a\cdot(a_w/1 - a_w)^b$
Caurie (1970)	$Xeq = \exp(a + b \cdot a_w)$
Smith (1947)	$Xeq = a + b \cdot \log(1 - a_w)$

Note: Xeq: moisture content (% dry basis); Xm: monolayer value (% dry basis);
a_w: water activity; T: temperature; C, K, a, b: constants.

5.12.2 Statistical analysis

Analytical determinations were conducted meticulously in triplicate to ensure data accuracy and reliability. The data collected from different treatments was meticulously recorded and subjected to rigorous statistical analysis. This entailed the application of one-way or two-way Analysis of Variance (ANOVA) and subsequent analysis using Duncan's Multiple Range Test (DMRT) with a significance level of $P \leq 0.05$.Furthermore, the most appropriate models were selected based on the values of R^2 (coefficient of determination), root mean square error (RMSE), and χ^2 (chi-squared statistic). These statistical assessments played a crucial role in identifying the best-fitting models for representing the observed data trends accurately.

CHAPTER 6

RESULTS AND DISCUSSION

CHAPTER 6- RESULTS AND DISCUSSION

The present investigation entitled **"Characterisation of Baby Corn and its Valorisation for Powder Development "**was conducted in the Department of Food Science and Nutrition, Lovely Professional University, Phagwara, Punjab. The results obtained during investigation are as given below:

Objective 1

To characterize baby corn varieties on the basis of physico-chemical, textural and functional properties

Classification of baby corn has been done on the basis of size i.e., long, short and medium. For this purpose, random samples were considered for measuring physical parameters like length and diameter using Vernier calliper which is represented in table 8.

6.1 Classification on basis of size

The physical parameter (size) based on the classification varied from short to long as shown in Fig 4 and Table 9. The change in the length and diameter from short to long predicts that increase in the size is due to the stages of maturity (Aggarwal and Kaur, 2010). Herein, the length and diameter for Syngenta 5417 and Sheeshu (Pusa HM 4 male sterile were found to be 88.61±3.05, 102.52±4.24, 133.34±7.23mm; 75.08±2.95, 110.92±5.30, 128.42±5.20 and diameter11.20±1.67, 15.23±1.21, 17.63±0.81; 16.07±5.84, 18.30±7.81, 20.3±8.68 for short, medium and long category respectively. As per the available literature, the desirable length of baby corn was observed 60-110 mm and diameter 10 to 15 mm by Dass et al., (2011). The classification was done based on the size, and highly dependent upon the population density, cropping season and variety. Similarly, in a study done by the Miles et al., (2002), the ideal size of ears have been reported to be 2-4 inches (76.2-101.6mm) in length and 1/3 -2/3 inch (8.47 -16.93mm) in diameter. Also, Singh et al., (2013) examined the physical parameters viz., length and diameter of baby corn with and without husk. They observed the length of babycorn (Syngenta G-5414) approximately 10.93 cm and the diameter at different points from tip, mid portion and end to be 1.60, 1.42 and 1.02 cm respectively.

Consequently, physical parameter of baby corn gets affected with maturity stage. With the advancement of maturity, the overall size of baby corn gets increased as reported by Aggarwal and Kaur, (2010). They have made the classification of variety Hybrid Prakash on the basis of harvesting days of silk emergence. The values for length and breadth on 2nd and 4^{th} day were found to be 8.16, 9.87 cm for length and 1.24, 1.59 cm for breadth respectively.

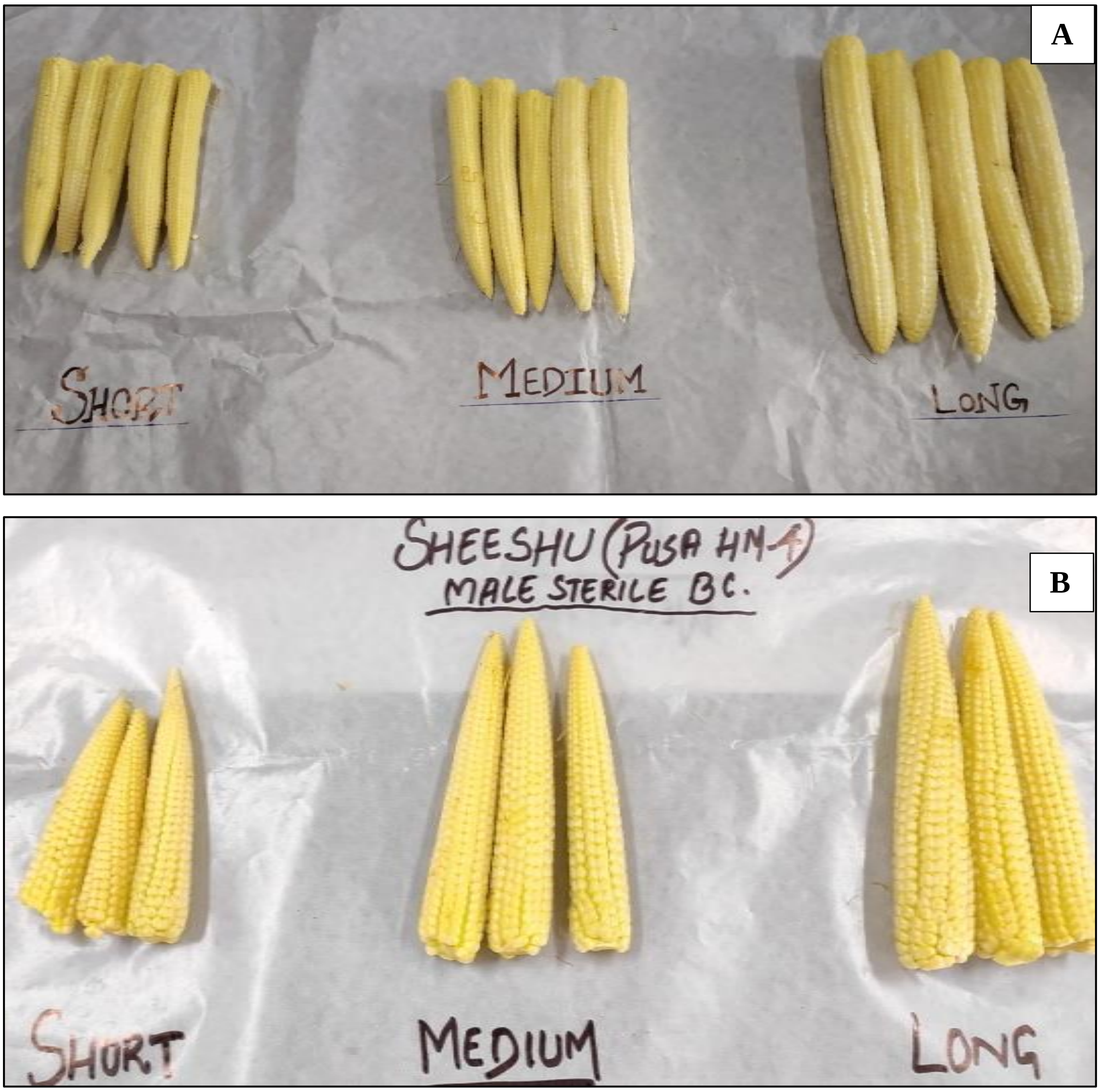


Figure 4. Classification on basis of size of baby corn varieties (A) Syngenta 5417, (B) Sheeshu (Pusa HM-4)

Table 9: Comparison on basis of physical classification

Syngenta 5417				**Sheeshu (Pusa HM 4 male sterile)**		
Parameters	Short	Medium	Long	Short	Medium	Long
Total yield (g)	35.53±5.00[a]	78.19±10.89[b]	133.43±28.27[c]	36.40±2.74[a]	57.85±10.59[b]	80.45±13.62[c]
Silk yield(g)	13.29±2.35[a]	21.07±1.10[b]	23.76±3.24 [b]	8.11± 0.50 [a]	8.91 ± 1.15 [a]	8.95 ± 0.15 [a]
Stalk yield(g)	16.77±2.28[a]	44.19±8.50[b]	80.99±21.17[c]	17.99 ±1 [a]	33.28±9.13[ab]	47.58±11.34[b]
Cob yield(g)	5.35±2.22[a]	12.89±3.26[b]	28.61±7.43[c]	9.38±1.65[a]	16.40±1.49[b]	23.92±1.89[c]
Length (mm)	88.61±3.05[a]	102.52±4.24 [b]	133.34±7.23[c]	75.08±2.95[a]	110.92±5.30[b]	128.42±5.20[c]
Diameter(mm)	11.20±1.67[a]	15.23±1.21[b]	17.63±0.82[c]	16.07±5.84[a]	18.30±7.81 [a]	20.3± 8.68 [a]
Density (g/cc)	0.94±0.16[a]	0.98±0.03[a]	0.99±0.02 [a]	0.97±0.12 [a]	1.02 ±0.03 [a]	1.08±0.02 [a]

The data is depicted as Mean ± Standard Deviation (n=3). Significant disparities among values within a row are denoted by different superscripts at a significance level of $P < 0.05$.

6.1.1 Yield on the basis of classification

Five random samples of baby corn (silk, stalk, cob and total weight) were taken for determination of weights based on their classification. However, the increasing trend in yield (Table 9 and fig. 5) is due to the two main factors including potentiality of genotypes and climatic conditions (Das et al., 2011). In this context, the cob, stalk, silk and total weight were measured to be 5.35±2.22, 12.89±3.26, 28.61±7.43 (g), 16.77±2.28, 44.19±8.50, 80.99±21.17 (g), 13.29±2.35, 21.07±1.18, 23.76±3.24 (g) and 35.53±5.00, 78.19±10.89, 133.43±28.27 (g) for short medium and long category, respectively for Syngenta 5417 and for Sheeshu , yield (cob, stalk, silk and total yield) was found to be 9.38±1.65, 16.40±1.49, 23.92±1.89 (g), 17.99 ±1, 33.28±9.13, 47.58±11.34 (g), 8.11± 0.50, 8.91 ± 1.15, 8.95 ± 0.15(g) and 36.40±2.74, 57.85±10.59, 80.45±13.62 (g) for short medium and long category, respectively.

Figure 5. Yield of different parts of baby corn on basis of classification of baby corn varieties (A) Syngenta 5417 (1: Short; 2: Medium ; 3: Long); (B) Sheeshu (Pusa HM-4) (4 Short;5: Medium ; 6: Long);

6.1.2 The true density (ρt). Five random samples (cobs) were choosed on basis of grading for calculating density (g/cm^2) as illustrated in Table 9. Density showed an increasing value from 0.94±0.16, 0.98±0.03, 0.99±0.03 (g/cm$^{2)}$ for Syngenta 5417 and for Sheeshu (Pusa HM4 male sterile) showed non-significant difference from 0.97±0.12, 1.02±0.03, 1.08 ±0.02 (g/cc$^{)}$ for short, medium and long respectively. However, the results from the studies by Singh et al., (2013) revealed the density of fresh end cut and whole baby corn to be 0.966 g/cc and 0.932 g/cc, respectively, which are shown to be slightly lower than our results. Similarly, Eboibi and Uguru (2018) worked on influence of maturity stage on beans. From this study, the increase in true density was observed which might be because of the on-going changes of cellular matrix.

6.1.3 Proximate analysis of raw materials

The proximate composition of raw material, Syngenta 5417 and Sheeshu is represented in Table no. 10 as outlined below on the basis of classification. It is observed from the analysis based on the grading (short, medium and long) that with increase in maturity stage there is no significant difference in moisture (87.8-86.2%); (88.40-87.13%), ash (0.47- 0.4%) ; (0.42- 0.40%) pH (5.35-5.21); (5.32-5.20), titratable acidity (0.40-0.40%);(0.40-0.40%) and fibre content (3.58-3.72%);(3.38-3.57%) of both varieties respectively . Also, TSS of short, medium and long category increased significantly from 8.5±0.06 to 9.80±0.5; 10±0.02 to 11±0.04 respectively which are probably due to starch hydrolysis to sugar with the advance in maturity (Moneruzzaman et al., 2008).

Scanty of literature is available on the proximate composition of this miracle crop based on the classification. Although, investigations done by Aggarwal and Kaur (2010) are in agreement with the results presented in Table 10. The results obtained for proximate composition are higher than the findings of Singh et al., (2020), Prasanti et al., (2017).

Table 10. Proximate composition on basis of classification of two varieties of baby corn

	Syngenta 5417			Sheeshu (Pusa HM 4 male sterile)		
Parameters	**Short**	**Medium**	**Long**	**Short**	**Medium**	**Long**
Moisture (%)	87.8±0.35 [a]	86.3±0.58 [a]	86.2±2.27 [a]	88.40 ±0.53[a]	87.33±0.42[a]	87.13±0.50[a]
Ash (%)	0.47±0.31 [a]	0.40±0.4 [a]	0.40±0.4 [a]	0.42±0.12 [a]	0.40±0.12 [a]	0.40±0.12 [a]
Protein (%)	2.92±0.36 [a]	3.33±0.36[b]	3.54±1.90 [b]	2.98±1.08 [a]	3.48±1.17 [a]	3.50±1.10 [a]
Fat (%)	0.92±0.5 [a]	0.94±0.29 [a]	0.94±0.29 [a]	0.91±0.5 [a]	0.94±0.29 [a]	0.94±0.29 [a]
Fiber (%)	3.58±0.58 [a]	3.72±0.58 [a]	3.72±0.63 [a]	3.38±0.58 [a]	3.56±0.58 [a]	3.57±0.63 [a]
Carbohydrates (%)	4.27±0.66 [a]	5.13±0.74 [a]	5.20±0.78 [a]	3.91±0.55 [a]	4.29±0.57 [a]	4.46±0.55 [a]
pH	5.35±0.04 [b]	5.21±0.01 [a]	5.21±0.03 [a]	5.32±0.02 [a]	5.20±0.03[b]	5.20±0.01 [b]
TSS (˚Brix)	8.5±0.06 [a]	9.33±0.58 [b]	9.80±0.5[b]	10±0.02 [a]	10.33±0.58 [a]	11±0.04 [b]
Trititable Acidity (%)	0.4±0.03[a]	0.4±0.02 [a]	0.40±0.04 [a]	0.40±0.01 [a]	0.40±0.03 [a]	0.40±0.01[a]

Values are presented as Mean±SD (n =3) ($p<0.05$). Significant differences between values in a row are indicated by distinct superscripts

6.1.4 Antioxidant activity on the basis of grading

The results obtained from the DPPH, FRAP, Flavonoids, and total phenol content are shown in Table 11. Where, it was clear that long graded corns were primary contributors in all tested parameters followed by short and medium. However, DPPH of short, medium, and long graded corns have weaker activity (37.23, 43.94, and 54.91 %, respectively) than other vegetables like carrot (69.04 %), cabbage (58.05 %), red chilli (78.66 %), and green chilli (52.4 %) (Ghasemzadeh et al., 2011). In addition, significant difference was observed in FRAP, flavonoid, and total phenol content for short medium, and long graded corns. Moreover, several authors have documented that, the polyphenolic content of fruits and vegetables is highly dependent upon their maturing stage. Also, Fuentes et al., 2013 estimated FRAP, DPPH, total phenolic content of green and red tomatoes. In their study, they observed that total phenolic content of red tomatoes 33.3 mg GAE/100 g was higher than green tomatoes 27.6 mg GAE/100 g.

Table11. Antioxidant activity on the basis of grading

	Syngenta 5417			Sheeshu (Pusa HM 4 male sterile)		
PARAMETERS	SHORT	MEDIUM	LONG	SHORT	MEDIUM	LONG
Ascorbic Acid (mg/100g)	21±5.20 [a]	18±0.00 [a]	15±5.2.25 [a]	28.5±5.20 [a]	19.5±5.20 [a]	18±7.79 [a]
DPPH (%)	36.99±0.28 [a]	37.11±0.37 [a]	37.90±0.42 [a]	37.23±7.39 [a]	43.94±5.59 [ab]	54.91±6.92[b]
FRAP((µg/ml)	113.99±9.59 [a]	123.40±3.27 [a]	123.93±1.14 [a]	113.99±9.59 [a]	134.39±6.53[b]	136.48±6.25 [b]
Flavonoid (mgQE/100g)	2.24±0.006 [a]	2.26±0.006 [ab]	2.37±0.05[b]	2.35±0.20 [a]	2.58±0.35 [ab]	2.97±0.19 [b]
Total phenol content(mg GAE/100 g)	47.02±1.20 [a]	48.98±0.03[b]	49.02±0.01[b]	48.02±0.14 [a]	48.08±0.04 [a]	49.93±0.09 [a]

Values are presented as Mean±SD (n =3) ($p<0.05$). Significant differences between values in a row are indicated by distinct superscripts

6.1.5 Textural properties of baby corn varieties

The textural analysis of two varieties of baby corn , Syngenta 5417 and Sheeshu (Pusa HM4), as depicted in Table 12 reveals subtle differences in their physical properties. Both varieties demonstrate comparable levels of hardness, resilience, and springiness, indicating similar responses to compression and deformation. However, Sheeshu displays slightly higher adhesiveness and cohesion compared to Syngenta 5417, suggesting it may adhere better and hold together more firmly upon compression. Despite these differences, both varieties exhibit remarkably high levels of guminess, implying a sticky or gummy texture when chewed. Chewiness levels between the two varieties are nearly identical. Overall, while there are slight variations in certain textural parameters, both Syngenta 5417 and Sheeshu share similar textural characteristics, with Sheeshu showing slightly superior adhesive and cohesive properties.

Table 12. Textural properties of baby corn varieties

Textural parameters	Syngenta 5417	Sheeshu(Pusa HM4)
Hardness(N)	81.629	82.629
Adhesiveness(g.s)	-200.999	-203.999
Resilience (%)	2.827	2.827
Cohesion (%)	20.714	22.714
Springiness(mm)	88.944	89.944
Guminess (N)	67945.001	67940.001
Chewiness(N)	60525.643	60520.643

6.1.6 Mineral composition of baby corn varieties on basis of grading

The mineral composition of two varieties of baby corn, Syngenta 5417 and Sheeshu (Pusa HM 4 male sterile), was analysed across short, medium, and long grading categories, measuring vital micronutrients essential for human health such as calcium, magnesium, zinc, phosphorus, and iron as represented in Table 13. Through statistical analysis, notable trends emerged, revealing progressive increases in mineral content in long-graded cobs, with Sheeshu often demonstrating slightly higher concentrations. However, differences in the composition of mineral between the varieties could be due to genetic factors and environmental variables like irrigation, soil composition, and fertilizer application (Ikram et al., 2010; Prasanthi et al., 2017). The phosphorus content in baby corn ranged from 163.636 to 232.727 mg/100 g for Syngenta 5417 and 161.818 to 247.273 mg/100 g for Sheeshu, significantly surpassing the phosphorus levels found in high value vegetables viz., brinjal, cabbage, spinach, cauliflower, bitter gourd, lettuce, French beans, and ladies' finger, which typically contain 44.00, 28.00, 26.00, 10.00, 47.00, 57.00, 28.00, and 56.00 mg/100g of phosphorus respectively (Hooda and Kawatra, 2013).

Table 13. Mineral composition of baby corn

Syngenta 5417				Sheeshu (Pusa HM 4 male sterile)		
Minerals	Short	Medium	Long	Short	Medium	Long
Calcium (mg/100g)	7.82±0.007[a]	7.92±0.004[b]	8.01±0.011[c]	7.76±0.002[a]	7.81±0.004[b]	8.1±0.008[c]
Magnesium (mg/100g)	37.424±0.01[a]	37.917±0.016[b]	38.213±0.006[c]	37.626±0.009[a]	37.808±0.004[b]	38.097±0.009[c]
Zinc (mg/100g)	1.023±0.007[a]	1.09±0.007[b]	1.113±0.005[c]	1.037±0.004[a]	1.105±0.004[b]	1.124±0.004[c]
Phosphorous (mg/100g)	163.636±5.455[a]	192.727±8.332[b]	232.727±11.355[b]	161.818±8.332[a]	174.545±10.91[a]	247.273±13.72[b]
Iron (mg/100g)	0.695±0.009[a]	0.746±0.005[b]	0.785±0.005[c]	0.685±0.004[a]	0.719±0.004[b]	0.753±0.004[c]

Values are presented as Mean±SD (n =3) ($p<0.05$). Significant differences between values in a row are indicated by distinct superscripts

6.1.7 Multivariate statistical analysis

Correlation analysis

Multivariate statistical analyses, specifically Pearson correlation (Figure 6), were conducted at a 95% confidence level to examine the complex relationships among multiple variables. The outcomes revealed significant associations across various factors. Zinc content (mg/100g) displayed robust positive correlations with Protein%, Fat%, Iron content (mg/100g), Total Phenol content (mg GAE/g), and FRAP Assay (µg/ml), while inversely correlated with Ph and Ash%. Likewise, Protein% showed positive correlations with Fat%, Magnesium content (mg/100g), Iron content (mg/100g), and FRAP Assay (µg/ml), while negatively correlated with Ph and Ash%. Fat% exhibited notable positive correlations with Iron content (mg/100g), and negative correlations with Ph, Ascorbic Acid content (mg/100g), and Moisture%. Magnesium content (mg/100g) displayed positive associations with Iron content (mg/100g), and negative correlations with Ph and Ash%. Phosphorus (mg/100g) was positively linked with Calcium content (mg/100g) and Total Phenol content (mg GAE/g). Carbohydrate% correlated positively with Fibre% and negatively with Moisture%. Fibre% demonstrated a negative correlation with Moisture%. Flavonoid content was positively correlated with DPPH % and FRAP Assay (µg/ml), while DPPH % was also positively correlated with FRAP Assay (µg/ml). Furthermore, the Length of Cob showed positive correlations with cob yield (g), Stalk yield (g), and Yield (g). Cob Yield correlated positively with Stalk yield (g) and Yield (g), while Stalk yield (g) exhibited a significant positive correlation with total yield (g). These findings underscore the intricate interplay and mutual influences among the diverse components and attributes within the analyzed context.

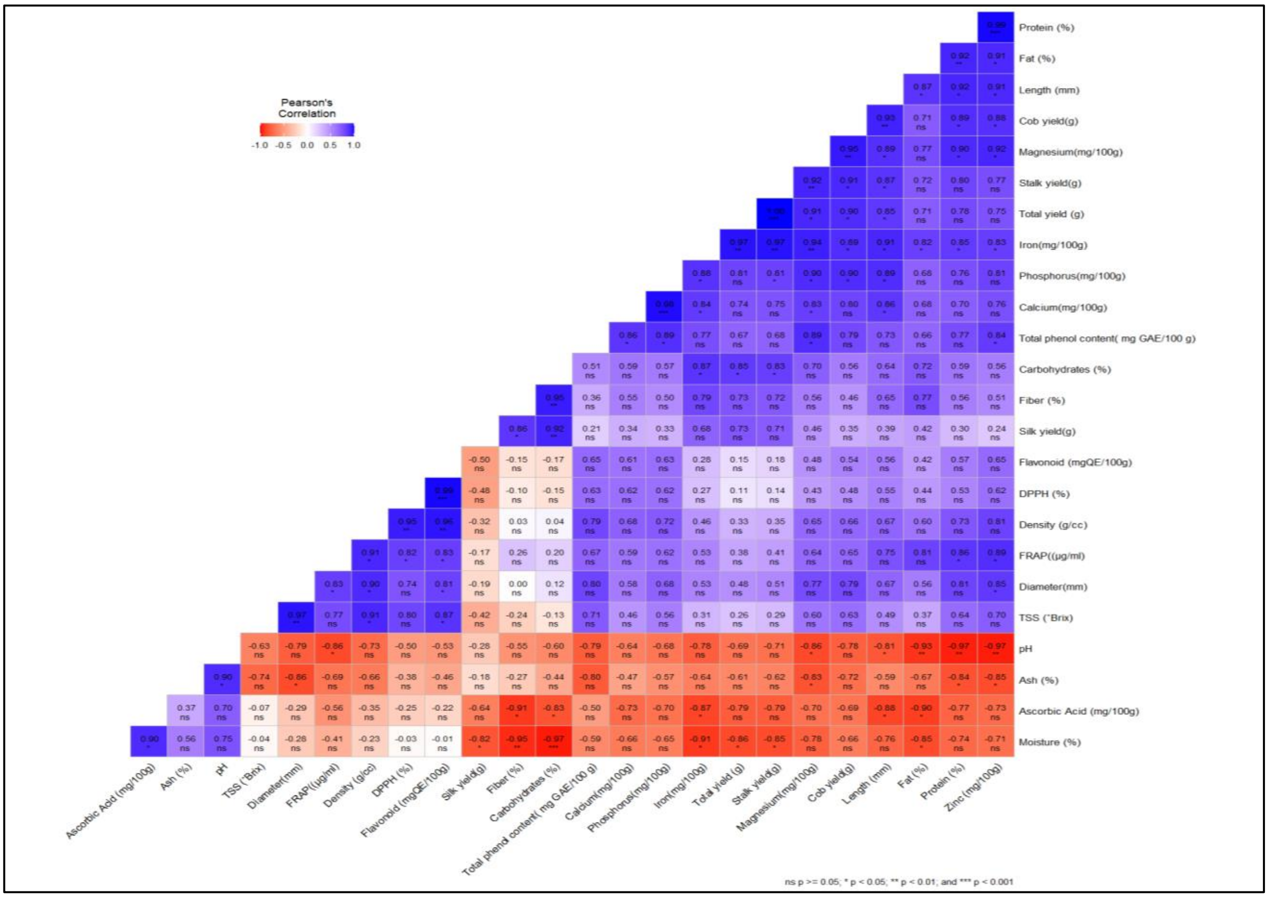


Figure 6. Pearson Correlation among varieties of baby corn

6.1.8 Principal component analysis (PCA)

Principal Component Analysis (PCA) was utilized to examine the variability among different baby corn varieties, specifically aiming to differentiate small, medium and long graded varieties based on their performance in determining quality traits. The PCA results were illustrated through a Scree plot, (Fig 7(a) delineating the percentage of explained variances or contributions of each principal component/dimension and elucidating the significance of individual parameters across diverse principal components/dimensions (Fig. 7(b)). Additionally, the Eigen values and cumulative variances (Table 14) of the studied traits were presented for both varieties under varying sowing conditions, as outlined in the accompanying table. Notably, the first two principal components accounted for the majority of the total variability, with PCA1, PCA2, and PCA3 collectively explaining a substantial portion of the variation. Visualization from PCA2 underscored the significance of moisture%, density, zinc, iron, carbohydrates, and silk yield as crucial factors influencing PCA2 (Figure 7c and 7d)

Table 14: Eigen values and cumulative variances

Dimensions	Eigenvalue	Variance percent	Cumulative variance percent
Dimension 1	1.66E+01	6.63E+01	66.25673
Dimension 2	5.61E+00	2.24E+01	88.69397
Dimension 3	1.20E+00	4.81E+00	93.50673
Dimension 4	1.14E+00	4.57E+00	98.07204
Dimension 5	4.82E-01	1.93E+00	100
Dimension 6	2.23E-28	8.91E-28	100

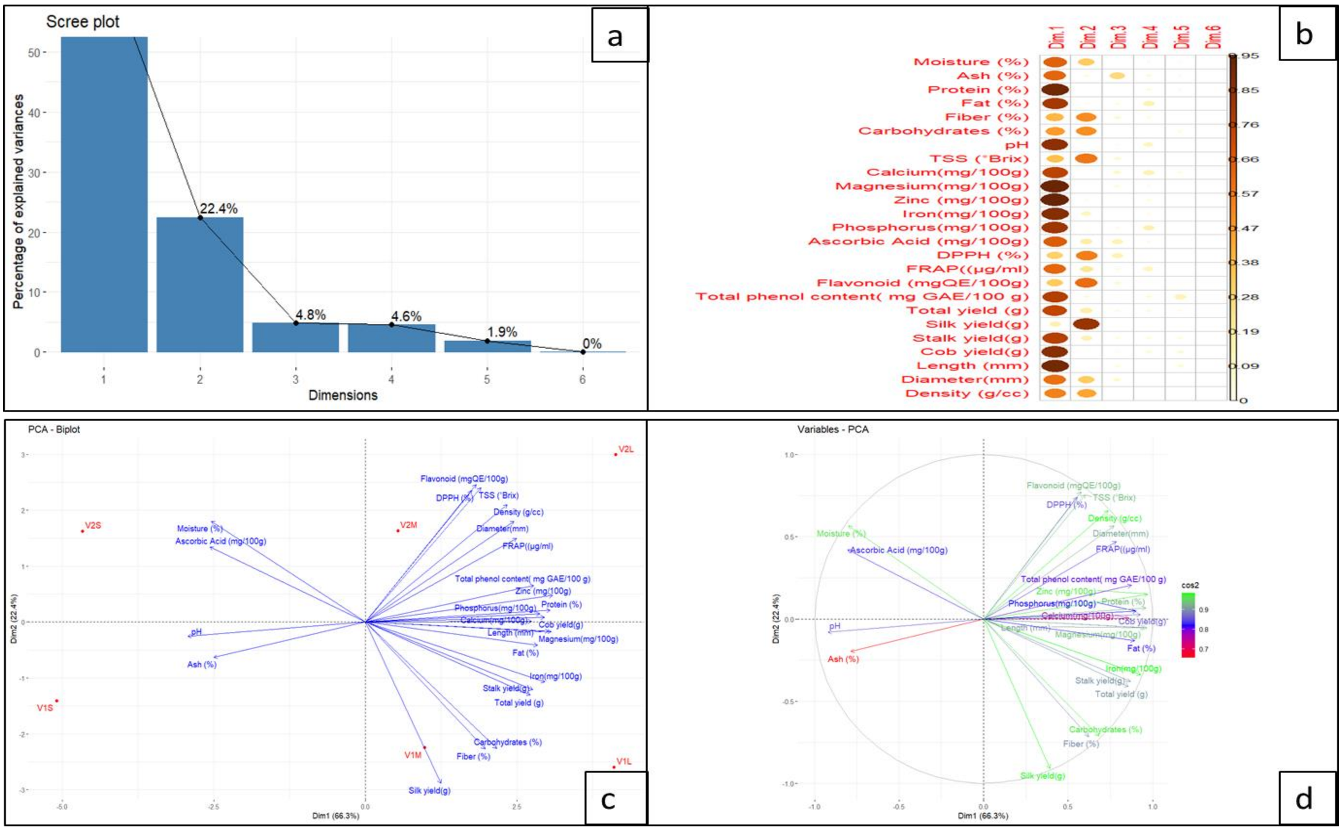


Figure 7. Principal component analysis of various parameters of two varieties of baby corn

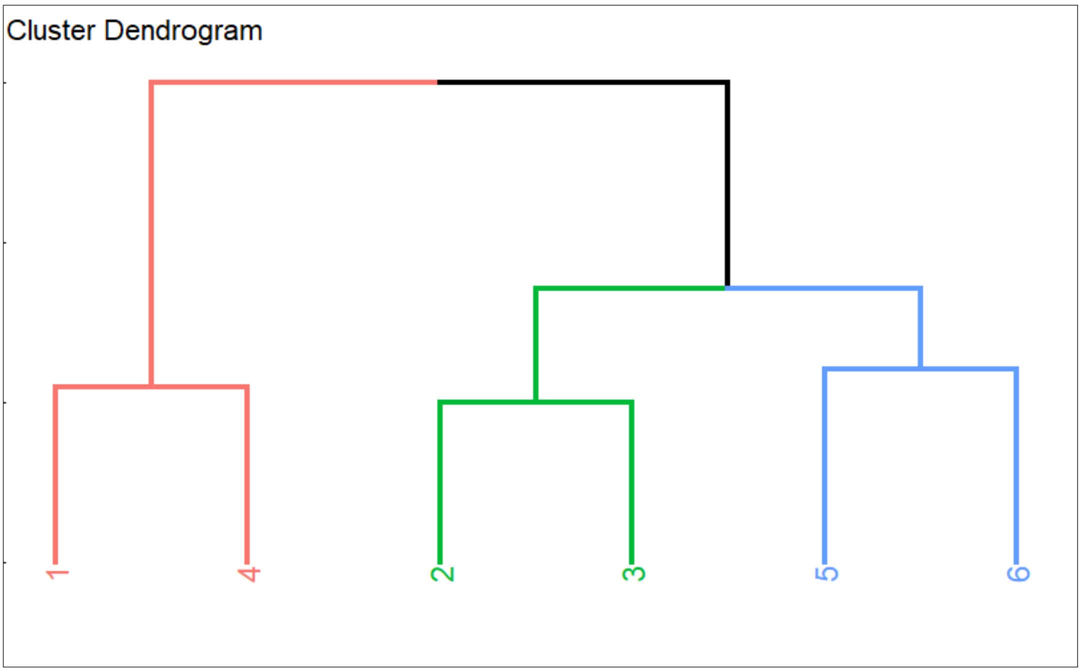


Figure 8. Clustering dendrogram constructed from morphological and proximate analyses

The clustering dendrogram constructed from morphological and proximate analyses (Fig 8) indicates the classification of baby corn varieties into three distinct clusters: Cluster 1 includes V2M and V2L; Cluster 2 encompasses V1M and V1L, while Cluster 3 comprises V1S and V2S. Notably, there is a close relationship between Clusters 1 and 2, suggesting similarities in their morphological and proximate characteristics. This clustering pattern offers valuable insights into the categorization and interrelationships among the different varieties of baby corn, providing a basis for further understanding their traits and composition.

The selection of variety for the further processing was done on basis of the overall yield and farmer's choice. Syngenta 5417 was selected for the same because of its higher yields than Sheeshu.

Objective 2: To optimize the process parameters for the development of baby corn powder.

Baby corn, characterized by its high water activity and elevated respiration rate, poses a formidable obstacle to prolonged storage under standard ambient conditions and necessitates specialized treatments for transportation to distant locations (Mehan et al., 2014).One of the primary postharvest challenges associated with baby corn is the occurrence of brown pigment formation at the apex of its immature ovules, cut surfaces and silk attached to the young ears (Attia et al.,2011).Browning is a common phenomenon in many fruits and vegetables and the underlying mechanisms for the same is either enzymatic or non-enzymatic (Moon et al., 2020). Moreover, quality attributes (nutrients, colour, texture and flavor) are highly affected by intercellular enzymes like peroxidase and polyphenol oxidase (PPO) after harvest (Wang et al., 2017). Therefore, prevention of enzymatic browning can be done by physical and chemical methods including blanching which can easily inhibit the enzymatic browning by denaturation of the enzymes and which ultimately leads to prevention of post-harvest losses.

For further studies the long graded cobs were selected on the basis of some criteria's (1) the food processing industries focuses more on the short graded cobs for edible purposes (2) long graded cobs are available in canned and freezed forms. (3) antioxidant activity after analysis was found to be maximum in case of long graded cob. Keeping that in view present study focused on long graded cobs for blanching pre-treatments in order to attain the maximum benefit of this high value vegetable. Different time temperature combinations influence the effectiveness of blanching. Various studies have been reported on blanching of vegetables and crops. But scanty of literature is available on addressing the impact of blanching techniques on the quality of baby corn. Therefore, the primary objective was to examine the influence of various blanching methods on the characteristics of this high value vegetable.

6.2 Blanching treatment

Blanching was meticulously carried out with the primary objective of inactivating the peroxidase enzyme, a widely recognized marker enzyme associated with the blanching process .The effect of the treatments was studied on various physico-chemical properties of baby corn. Sample (100g) meticulously sliced in circular pieces, each having a diameter of precisely 15.23mm and a thickness within the range of 0.1cm to 0.2cm, were subjected to various distinct blanching treatments viz. HWB at 70°C, 80°C, 90°C for 30, 60, 120 180 and 240 s, SB for 30, 60, 120 180 and 240 s and MWB at 360-900W for 30-300 s (Figure 9) . Treated samples were analysed in triplicates for shrinkage (%), mass of kernel (g), TSS, densities, color, enzyme inactivation and antioxidant assay.

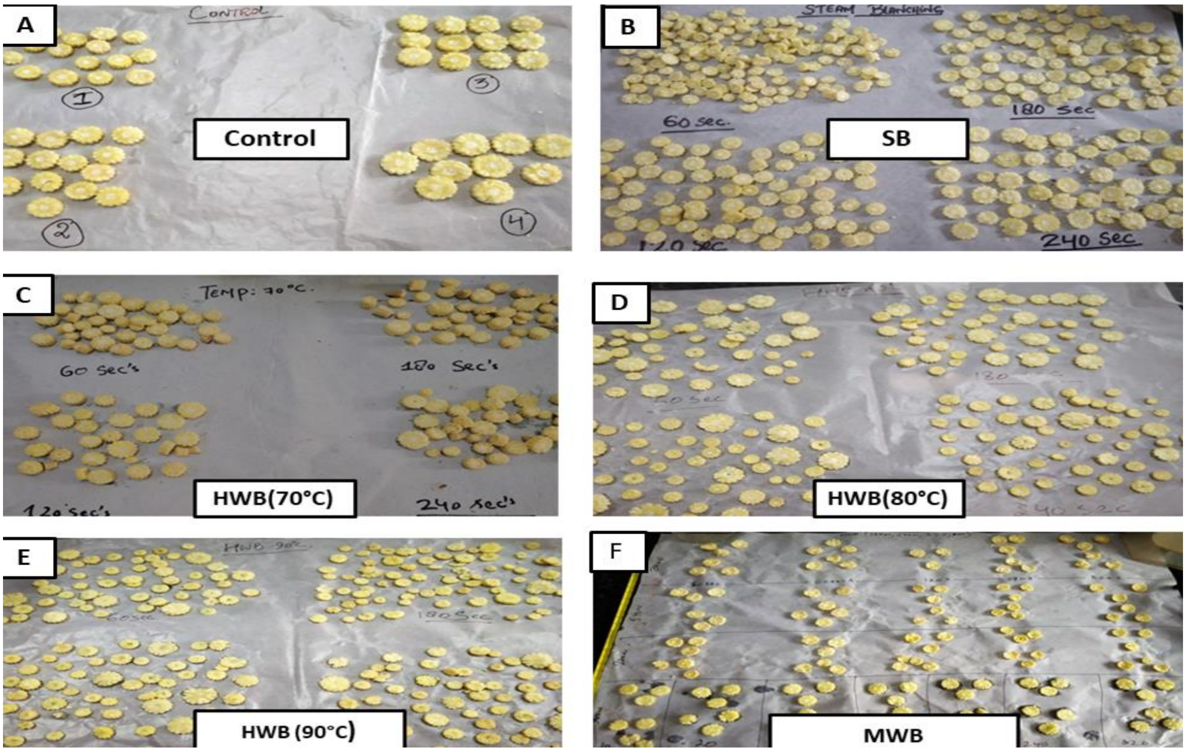


Figure 9. Blanching of baby corn roundals at different time, temperature and power conditions (A) Control; (B) Steam blanched (SB); (C) Hot water blanched (70°C) ; (D) Hot water blanched (80°C) ; (E) Hot water blanched (90 °C) and (F) Microwave blanched (360-900w for 30-300sec)

6.2.1 Effect of blanching treatments on shrinkage (%) and mass of roundels of treated samples

From the overall data, shrinkage (%) as represented in Table 15 increased after subjecting to blanching treatments which may be due to several changes occurring due to thermal processing in the cellular structures (shape and size) and internal structure like causing the gaps, cracks, and voids (Halder et al., 2011). Consequently, investigation conducted by Ciurzynska et al., (2021) freeze dried red beet roots also revealed the similar effect of blanching on the cellular structure. The maximum increase of mass was observed in case of the HWB roundels followed by SB roundels. The microwave blanching treatment causes the moisture loss due to heating of roundels hence the mass was observed to decrease with increasing time and power.

Table 15. Variation in shrinkage (%) after hot water (70-90°Cfor 60-240 sec), steam blanching 100°C for 30-240 sec) and microwave blanching (360-900w for 30-300 sec)

Temp (°C)	Time (sec)	Shrinkage (%)	Power (W)	Time (sec)	Shrinkage (%)
70	30	0.6±0.05^{o}	360	30	0.57±0.02^{j}
	60	0.66±0.02^{no}		60	0.58±0.05^{j}
	120	1.02±0.04^{jkl}		180	0.6±0.04^{j}
	180	1.17±0.03^{hij}		240	0.95±0.03^{g}
	240	1.4±0.01^{g}		300	1.02±0.04^{fg}
	300	1.43±0.01^{g}	540	30	0.58±0.04^{j}
80	30	0.8±0.02^{ml}		60	0.65±0.05^{ij}
	60	1.32±0.03^{gh}		180	0.97±0.03^{g}
	120	1.95±0.02^{f}		240	1.12±0.08^{fg}
	180	2.6±0.14^{d}		300	1.36±0.05^{de}
	240	2.64±0.01^{d}	720	30	0.66±0.03^{hij}
	300	5.06±0.12^{c}		60	0.73±0.03^{hi}
90	30	1.12±0.12^{ijk}		180	1.31±0.15^{e}
	60	1.23±0.06^{hi}		240	1.87±0.02^{c}
	120	2.33±0.05^{e}		300	2.17±0.1^{b}
	180	4.95±0.13^{c}	900	30	0.77±0.05^{h}
	240	6.02±0.03^{b}		60	1.04±0.03^{fg}
	300	6.47±0.04^{a}		180	1.43±0.07^{d}
100	30	0.59±0.03^{o}		240	1.95±0.08^{c}
	60	0.6±0.04^{o}		300	2.63±0.15^{a}
	120	0.73±0.08^{no}			
	180	0.93±0.03^{lm}			
	240	0.96±0.32^{kl}			
	300	1.02±0.04^{jkl}			

Values are presented as Mean±SD (n =3) ($p<0.05$). Significant differences between values in a column are indicated by distinct superscripts

6.2.2 Effect on bulk, true density and porosity of blanched baby corn

The bulk density of fresh baby corn roundels was determined to be 0.36 g/cc. Subsequently, various blanching treatments, including hot water, steam, and microwave blanching, were administered. It was observed that the bulk density exhibited a decreasing trend with an increase in temperature and time in case of hot water blanching and SB from 0.36g/cc to 0.31g/cc and 0.32g/cc (Table 16).The decrease in the bulk density after HWB and SB can be attributed to the absorption of moisture by roundels which leads to expansion (Popalia and Kumar 2021).Similar reduction was reported by

Kachhadiya et al. (2018) for sweet corn kernels whereas it increased in case of microwave blanching with increasing time and power, it increased from 0.36-0.47g/cc (Table 16). The rise in bulk density could be attributed to the decrease in dimensions due to microwave treatment which has led to more compact structure of treated roundels (Popaliya and Kumar 2022). The true density of fresh baby corn roundels was found to be 1.86g/cc which increased in case of HWB and SB to 2.71g/cc and 2.78g/cc respectively (Table 17) whereas it was found to decrease with increasing time and power in case and MWB 0.64g/cc (Table 17). The less effect on the overall dimensions of roundels resulted in decreasing true densities.

Table 16. Variation in bulk density (g/cc) after hot water (70-90°C for 60-240sec), steam blanching (100°C for 30-240sec)and microwave blanching (360-900w for 30-300sec)

HWB/SB			**MWB**		
Temp (°C)	**Time (sec)**	**Bulk density (g/cc)**	**Power (W)**	**Time (sec)**	**Bulk density (g/cc)**
Fresh	0	0.36 ± 0.02^{a}	360	0	0.36 ± 0.04^{f}
70	30	0.35 ± 0.01^{a}		30	0.36 ± 0.03^{e}
	60	0.34 ± 0.02^{b}		60	0.37 ± 0.02^{e}
	120	0.34 ± 0.03^{b}		120	0.39 ± 0.03^{d}
	180	0.32 ± 0.02^{d}		180	0.4 ± 0.03^{cd}
	240	0.32 ± 0.03^{d}		240	0.43 ± 0.04^{b}
80	30	0.35 ± 0.04^{a}		300	0.45 ± 0.03^{b}
	60	0.34 ± 0.04^{b}	540	30	0.36 ± 0.01^{e}
	120	0.34 ± 0.03^{b}		60	0.36 ± 0.02^{e}
	180	0.32 ± 0.07^{d}		120	0.37 ± 0.03^{cd}
	240	0.31 ± 0.03^{e}		180	0.39±0.02cd
90	30	0.35 ± 0.02^{a}		240	0.4 ± 0.03^{b}
	60	0.32 ± 0.03^{d}		300	0.43 ± 0.02^{b}
	120	0.32 ± 0.04^{c}	720	30	0.36 ± 0.03^{e}
	180	0.32 ± 0.05^{d}		60	0.38 ± 0.04^{de}
	240	0.31 ± 0.01^{e}		120	0.41 ± 0.02^{c}
100	30	0.37 ± 0.03^{a}		180	0.43 ± 0.01^{bc}
	60	0.36 ± 0.03^{a}		240	0.44 ± 0.02^{b}
	120	0.36 ± 0.03^{a}		300	0.46 ± 0.03^{a}
	180	0.34 ± 0.03^{b}	900	30	0.38 ± 0.03^{de}
	240	0.33 ± 0.01^{d}		60	0.39 ± 0.02^{d}
				120	0.42 ± 0.03^{c}
				180	0.44 ± 0.04^{b}

			240	0.46±0.02[a]
			300	0.48±0.01[a]

Values are expressed as Mean ± SD (n =3) ($p<0.05$). Significant differences between values in a column are indicated by distinct superscripts

Table 17. Variation in true density (%) after hot water (70-90°Cfor 60-240sec), steam blanching 100°C for 30-240sec) and microwave blanching (360-900w for 30-300sec).

HWB/SB			**MWB**		
Temp(°C)	**Time (sec)**	**True density (g/cc)**	**Power** (W)	**Time (sec)**	**True density (g/cc)**
Fresh	0	1.87±0.04[g]	360	0	1.87±0.04[a]
70	30	1.83±0.03[g]		30	1.16±0.1[b]
	60	1.89±0.07[h]		60	1.09±0.08[bc]
	120	1.96±0.03[g]		120	0.9±0.05[ef]
	180	2.23±0.07[e]		180	0.88±0.07[f]
	240	2.62±0.13[bc]		240	0.83±0.14[f]
80	30	1.83±0.03[g]		300	0.78±0.13[fg]
	60	1.89±0.04[h]	540	30	1.14±0.1[b]
	120	1.99±0.03[g]		60	1.06±0.1[d]
	180	2.5±0.07[d]		120	0.89±0.1[f]
	240	2.6±0.12[c]		180	0.87±0.08[f]
90	30	1.9±0.02[g]		240	0.79±0.13[f]
	60	1.93±0.03[gh]		300	0.76±0.1[g]
	120	1.99±0.04[g]	720	30	1.13±0.1[b]
	180	2.5±0.05[d]		60	1.02±0.11[d]
	240	2.71±0.1[b]		120	0.89±0.11[f]
100	30	1.96±0.03[f]		180	0.85±0.12[f]
	60	2±0.03[f]		240	0.8±0.11[f]
	120	2.08±0.03[f]		300	0.71±0.12[g]
	180	2.62±0.03[bc]		30	1.08±0.11[bc]
	240	2.78±0.08[a]		60	0.96±0.12[e]

		900	120	0.86±0.12[f]
			180	0.75±0.11[g]
			240	0.75±0.12[g]
			300	0.65±0.13[h]

Values are presented as Mean±SD (n =3) ($p<0.05$). Significant differences between values in a column are indicated by distinct superscripts

Initial porosity of baby corn roundel was about 80.95% which increased with increasing processing time and temperature from 80.95% to 88.72% and 88.89 (%) (Table 18).The more the void spaces, the more will be porosity of roundels in case of HWB and SB roundels. The same was found to decrease with increasing time and power to 26.82% (Table 18) which is due to compactness of roundels to microwave blanching treatment. This can be co related with the data obtained from shrinkage (%).

Table 18. Effect on Porosity (%) after hot water (70-90°C for 30-240 sec), steam blanching 100 °C for 30-240 sec) and microwave blanching (360-900 W for 30-300sec).

HWB/SB			MWB		
Temp(°C)	**Time (sec)**	**Porosity (%)**	**Power (W)**	**Time (sec)**	**Porosity (%)**
Fresh	0	80.96±0.71[h]	360	0	80.96±0.71[a]
70	30	81±0.31[g]		30	69.11±0.31[b]
	60	81.62±0.15[g]		60	66.09±0.15[bc]
	120	81.62±0.54[g]		120	57.39±0.11[d]
	180	82±1.05[f]		180	54.71±0.12[e]
	240	81.95±0.68[gh]		240	48.47±0.17[g]
80	30	81.25±0.32[b]		300	43.19±0.13[h]
	60	82.92±0.09[e]	540	30	68.72±0.32[b]
	120	83.17±0.94[e]		60	64.34±0.09[c]
	180	83.87±1.5[e]		120	55.45±0.13[e]
	240	82.98±1.51[f]		180	52.97±0.12[f]
	30	83.55±0.34[e]		240	45.06±0.15[h]

90	60	85.72 ± 0.22^{d}		300	40.77 ± 0.22^{i}
	120	87.31 ± 0.94^{b}	720	30	68.35 ± 0.34^{b}
	180	87.23 ± 1.5^{bc}		60	62.91 ± 0.22^{cd}
	240	87.05 ± 1.55^{bc}		120	54.79 ± 0.13^{f}
100	30	85.55 ± 0.26^{d}		180	50.27 ± 0.14^{fg}
	60	87.77 ± 0.05^{b}		240	44.64 ± 0.05^{h}
	120	88.19 ± 1.01^{a}		300	35.49 ± 0.16^{j}
	180	88.72 ± 1.52^{a}	900	30	65.3 ± 0.26^{c}
	240	88.89 ± 1.58^{a}		60	59.35 ± 0.05^{d}
				120	52.25 ± 0.18^{f}
				180	41.62 ± 0.2^{i}
				240	38.61 ± 0.2^{j}
				300	26.83 ± 0.18^{k}

Values are presented as Mean±SD (n =3) ($p<0.05$). Significant differences between values in a column are indicated by distinct superscripts

6.2.3 Influence of blanching treatments on moisture content

The determination of moisture content in baby corn was conducted for untreated and blanched samples at different time temperature/power combinations. The moisture content of unblanched samples was assessed using a classification method and it was found to be approximately 86.76 ± 1.06 (%) whereas the moisture content of hot water and steam blanched samples were found to increase from 86.76 ± 1.06 to 92 ± 0.43 and 89.5 ± 0.01 respectively. However, the same decreased to 84 ± 0.04 in case of microwave blanching. This significant increase in moisture content in during conventional blanching methods, such as hot water and steam blanching can be attributed to moisture absorption. In the context of microwave-blanching, it was observed that the moisture content decreased as the microwave power increased, owing to the heat treatment applied to the samples. Notably, the minimal alteration in moisture content during microwave blanching was consistent with findings reported by Kachhadiya et al., (2018).

6.2.4 Influence of blanching treatments on TSS and water activity

The TSS was determined for fresh and treated samples. It was observed that TSS decreased from 9.80 to 4.60, 6.90 and 7.47° Brix respectively in case of HWB, SB and MWB (Table 19). The TSS is due to the presence of sugars which are water soluble and hence gets leached out with hot water in case of HWB and SB (Adetoro et al., 2020).The decrease in Total Soluble Solids (TSS) observed in the case of microwave-treated samples is linked to the chemical reaction between reducing sugars and amino groups, a phenomenon supported by previous studies conducted by Kachhadiya et al., (2018).The minimum loss of TSS happened in MWB followed by SB and HWB respectively. The water activity of fresh sample was 0.979 that increased with increasing processing time and temperature to 0.999, 0.993 in case of HWB and SB treated roundels respectively. It decreased with increasing processing power and time to 0.970

Table 19. Effect on TSS (°Brix) after hot water (70-90°C for 30-240sec), steam blanching (100°C for 30-240sec) and microwave blanching (360-900 W for 30-300sec.

HWB/SB			**MWB**		
Temp(°C)	**Time (sec)**	**TSS (°Brix)**	**Power (W)**	**Time**	**TSS (°Brix)**
Fresh	0	9.8 ± 0.1^{a}		0	9.8 ± 0.1^{a}
	30	7.49 ± 0.33^{d}		30	9.77 ± 0.06^{a}
	60	7.47 ± 0.33^{d}		60	9.74 ± 0.16^{a}
70	120	6.97 ± 0.66^{f}	360	120	9.3 ± 0.2^{d}
	180	6.84 ± 0.06^{g}		180	8.67 ± 0.16^{e}
	240	6.67 ± 0.26^{g}		240	8.54 ± 0.62^{ef}
	30	7.02 ± 0.66^{e}		300	8.1 ± 0.63^{h}
80	60	7 ± 0.61^{e}	540	30	9.64 ± 0.16^{b}
	120	6.6 ± 0.4^{g}		60	9.44 ± 0.42^{c}
	180	6.4 ± 0.18^{g}		120	9.27 ± 0.76^{d}
	240	6.17 ± 0.16^{g}		180	8.4 ± 0.2^{f}
	30	6.66 ± 0.06^{g}		240	8.27 ± 0.26^{g}

90	60	6.64±0.26^{g}		300	7.84±0.06^{i}
	120	6.54±0.42^{g}	720	30	9.5±0.1^{c}
	180	5.8±0.1^{h}		60	9.4±0.82^{c}
	240	4.6±0.18^{i}		120	9.17±0.38^{d}
100	30	7.88±0.26^{b}		180	8.37±0.16^{f}
	60	7.84±0.16^{c}		240	8.04±0.16^{h}
	120	7.8±0.46^{c}		300	7.77±0.06^{j}
	180	6.97±0.29^{f}	900	30	9.47±0.64^{c}
	240	6.9±0.3^{f}		60	9.24±0.21^{d}
				120	8.94±0.06^{de}
				180	8.24±0.26^{g}
				240	7.87±0.16^{i}
				300	7.47±0.16^{k}

Values are represented as Mean ± SD (n =3) ($p<0.05$). Significant differences between values in a column are indicated by distinct superscripts

6.2.5 Influence of blanching on the ascorbic acid content

The blanched samples were air dried and analysed for ascorbic acid content, enzyme assay and antioxidant activity. The ascorbic content of the treated samples is visually represented in Table 20. An analysis of Table 20 suggests a notable decline in ascorbic acid content as the intensity of the blanching treatment, characterized by varying time-temperature combinations, increases. Furthermore, it is observed that an extended blanching time is associated with a greater loss in ascorbic acid content, primarily attributed to the leaching of water-soluble ascorbic acid into the blanching water. These observations align with research findings presented by Severini et al., (2015) in their study on broccoli.

Consequently, high-temperature thermal degradation during HWB pre-treatment was not found to be favourable for the withholding ascorbic acid content because of its sensitive nature towards heat during blanching process (Wang et al., 2020).Moreover, these findings are closely linked to the leaching of soluble solids in the water, a significant drawback associated with conventional blanching methods such as Hot

Water Blanching (HWB) (Latorre et al., 2013).However, it's worth noting that samples treated with steam blanching exhibited a notable upward trend in ascorbic acid content with prolonged treatment durations, as illustrated in Table. 20 These findings align with research conducted by Nayak et al., (2011) which indicated that steam blanching, when applied before the drying process, resulted in an increase in ascorbic acid content in dry flakes and raw potatoes. This phenomenon may be attributed to the structural openings caused by blanching, which potentially facilitate the rise in ascorbic acid content.

6.2.5.1 Ascorbic acid content of baby corn after microwave blanching

From Table 20, it is evident that microwave blanching effectively preserves ascorbic acid content, showcasing minimal leaching losses. This outcome is consistent with findings reported by Wang et al., (2017), which also observed a substantial increase in content due to the low leaching losses associated with this blanching method. The notable increase in ascorbic acid content can be attributed to the capability of thermal blanching to disrupt the cell wall, facilitating the release of antioxidants. The results depicted above are in accordance with the results revealed by several studies done by Oerlemans et al., (2006).The outcome of their studies revealed a significant increase in the extractability of chemicals from plant tissue after heat treatment, leading to a rise in the vitamin C content of the treated samples. In comparison to conventional methods, microwave blanching was found to yield higher retention of ascorbic acid. The %age of retained vitamin C was found to be 83.5, 94 and 94.15 % for HWB, SB AND MWB samples at 90 °C, 100°C and 540W and for 60, 60 and 30 sec, respectively. Furthermore, prolonged treatment can lead to the texture losses.

Table 20. Effect on ascorbic acid (mg/100g) after hot water (70-90 °C for 30-240 sec), steam blanching 100 °C for 30-240 sec) and microwave blanching (360-900 W for 30-300 sec)

HWB/SB			MWB		
Temp(°C)	**Time (sec)**	**Ascorbic acid (mg/100g)**	**Power (W)**	**Time**	**Ascorbic acid(mg/100g)**
Fresh	0	21.5±0.26^{d}	360	0	21.5±0.26^{e}
70	30	22.01±0.06^{c}		30	18±0.1^{h}
	60	22.5±0.06^{b}		60	21±0.01^{ef}
	120	21±0.06^{c}		120	21.89±0.03^{e}
	180	16.5±0.06^{g}		180	22.5±0.06^{d}
	240	15±0.06^{i}		240	24±0.06^{b}
80	30	22.5±0.26^{b}		300	25±0.06^{a}
	60	19.5±0.1^{e}	540	30	15±0.06^{k}
	120	18±0.06^{f}		60	16.5±0.06^{j}
	180	16.5±0.1^{g}		120	17.01±0.02^{i}
	240	15±0.06^{i}		180	18±0.1^{h}
90	30	19.5±0.06^{e}		240	22.5±0.1^{d}
	60	18±0.03^{f}		300	24±0.06^{b}
	120	16.5±0.06^{g}	720	30	16.5±0.03^{j}
	180	15±0.06^{h}		60	21.5±0.03^{e}
	240	13.5±0.01^{j}		120	21.7±0.03^{e}
100	30	16.5±0.6^{g}		180	22±0.01d^{e}
	60	18.24±0.1^{f}		240	23.2±0.06^{c}
	120	21±0.06^{c}		300	25±0.06^{a}
	180	22.5±0.03^{b}	900	30	13.5±0.1^{l}
	240	24±0.02^{a}		60	15±0.02^{k}
				120	17.01±0.01^{i}
				180	19.5±0.06^{g}

			240	21±0.02^{f}
			300	22.5±0.04^{d}

Values are presented as Mean±SD (n =3) (p<0.05). Significant differences between values in a column are indicated by distinct superscripts

6.2.6 Impact of blanching pre-treatments on the color characteristics of baby corn

The L*, a*, and b* values for fresh baby corn samples were measured at 75.17 ± 0.37, 4.53 ± 0.21, and 30.27 ± 0.22, respectively. Notably, the lightness (L*) value decreased, while the a* (redness) and b* (yellowness) values increased. The reduction in lightness was attributed to non-enzymatic browning (Chikpah et al., 2022) the yellowness (b*) value was found to increase due to the presence of the yellow pigments which increases ones the samples are blanched (Popalia and Kumar, 2021; Kacchadiya et al., 2018). ΔL values were found to be 161.03 ± 2.29, 187.41 ± 5.90 and 3.20 ± 1.24 respectively for HWB (90°C, 60s), SB (100°C, 60s) and MWB (540W, 30s) respectively. Similarly Δa, Δb for HWB (90°C, 60s), SB (100°C, 60s) and MWB (540W, 30s) were found to be (0.11±0.01, 0.004±0.01, 0.02 ±0.02) and (11.56±1.20, 67.73±1.22, 29.48±1.10) respectively. The ΔE was found to be 13.14, 15.97 and 5.72 for HWB, SB and MWB samples. The variations in color L*, a*, b* and ΔE were due to the different blanching treatments and temperature/power. The maximum retention of the color was found to be more in case of samples treated with microwave blanching (Table. 21).

6.2.7 Influence of various blanching treatments on the antioxidant activity of baby corn

Antioxidant activity of baby corn after steam blanching

The samples were exposed to steam blanching, and the treated samples were subsequently analyzed for their antioxidant activity. The time has positive effect on antioxidant activity (p≤0.05) (Table 21). 1Slight increase in the flavonoid, TPC and DPPH was witnessed with increase in time. The DPPH (%), Flavonoids (mgQE/100g), TPC (mg GAE/100 g) increased from 36.03±0.01 to 38.34±0.02 (%), 2.07±0.01to 2.17±0.02 (mgQE/100g) and 48.02±0.01 to 48.08±0.03 (mg GAE/100 g) respectively. Moreover study carried out by Brambilla et al., (2011) on frozen blueberry purees shows the same declining trend of steam blanched samples. The disadvantage with steam blanching is that prolonged steaming time can lead to the softness hence degrading the texture of treated samples (Xiao et al., 2017).

Table -21: ANOVA for various responses in steam blanched samples of baby corn

Steam blanching					
DPPH (%)					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	5.682	1	5.682	340.53	.000b
Residual	0.217	13	0.017		
Total	5.899	14			
Flavonoid((mgQE/100g)					
Regression	0.138	1	0.138	366.459	.000b
Residual	0.005	13	0		
Total	0.143	14			
Total phenol((mg GAE/100 g)					
Regression	0.004	1.000	0.004	90.177	.000b
Residual	0.001	13.000	0.000		
Total	0.005	14.000			
Colour L*					
Regression	103.382	1	103.382	19.269	.001b
Residual	69.749	13	5.365		
Total	173.130	14			
Colour a*					
Regression	2.538	1	2.538	50.930	.000b
Residual	0.648	13	0.050		
Total	3.186	14			
Colour b*					
Regression	189.141	1	189.141	2.268	.156b
Residual	1084.024	13	83.386		
Total	1273.165	14			

Antioxidant activity of baby corn after hot water blanching

The treated/ blanched samples were analysed for antioxidant activity which shows a declininig trend with increasing time and temperature combinations. The time temperature has negative effect on antioxidant activity, temperature showing more effect than time ($p \leq 0.05$) (Table. 22).The highest level of antioxidant activity was observed in the samples treated at 70°C for 30 seconds. As the blanching time and temperatures increased, a decrease in antioxidant activity was noted. This trend aligns with findings described by Wang et al., (2020), who studied blanched pepper, and is attributed to the leaching of these antioxidant components.

Antioxidant activity of baby corn after microwave blanching

Microwave blanching, an efficient blanching method was employed for blanching baby corn samples and effect of it was observed on the antioxidant activity viz., flavonoids (mgQE/100g), total phenols (mg GAE/100 g), DPPH (%).Numerous studies have investigated microwave blanching and its impact on antioxidant activity. These studies have consistently reported an increase in antioxidant activity with longer exposure times and higher power levels.The power and temperature has positive effect on antioxidants, power showing more effect than temperature ($p \leq 0.05$) (Table. 21). Antioxidants in vegetables exist in both free and bound forms. Heat treatment has the potential to release antioxidants from bound sites, leading to an increase in antioxidant activity, as noted in the study by Dibanda et al., (2020).

Different time and power combinations led to the increase in total flavonoid from 2.99 ± 0.002 to 3.41 ± 0.00 (mgQE/100g), total phenols from 48.94±0.02 to 49.17±0.03 (mg GAE/100g) and DPPH 40.05±0.01 to 47.01±0.01 (%). The enhanced antioxidant activity observed in the treated samples is a result of the cell wall's breakdown caused by thermal blanching, which leads to the release of antioxidants, as reported by Wang et al., (2017). Additionally, blanching has been found to create openings in the cell matrix, leading to an increase in polyphenols, which, in turn, contributes to the overall increase in antioxidants.

Process Kinetics during different blanching treatments of Baby Corn

Zero and first order kinetic models may be used for evaluating different responses for different treatments. The best fitted model can be determined by values of R^2, RMSE and χ^2. The model with higher R^2 values and lower RMSE and χ^2 values is considered to be the best-fitted model. From Table 23 it can be observed that first order model fitted well for shrinkage (%) and ascorbic acid content (mg/100g) whereas the zero-order models proved to be a good fit for antioxidant and peroxidase activity, but higher values of $\chi 2$ and RMSE limit the applicability of the model for estimating POD activity. Among the three blanching treatments given, the steam blanched samples showed higher R^2 and lower RMSE and χ^2 values.

Table 22. ANOVA for various responses in hot water and microwave blanched samples of baby corn

DPPH(%)HWB						DPPH(%)MWB				
Source of variation	SS	df	MS	F	P value	SS	df	MS	F	P value
Time	47.93	4	11.98	373.59	0.00	264.3	4	66.07	1982212.15	0.00
Temperature/Power	27.95	2	13.98	435.71	0.00	3.23	3	1.08	32263.07	0.00
Interaction	3.65	8	0.46	14.23	0.00	4.98	12	0.25	7436.86	0.00
Total	70751.48	45				11794.5	60			
Total flavonoid(mgQE/100g)HWB						**Total flavonoid(mgQE/100g)MWB**				
Time	0.04	4	0.01	259.9	0.00	0.91	4	0.23	6815.08	0.00
Temperature/Power	0.01	2	0.004	128.87	0.00	0.16	3	0.05	1547.53	0.00
Interaction	0.001	8	6.500×10^{5}	1.95	0.09	0.02	12	0.002	54.08	0.00
Total	355.15	45				609.23	60			
Total Phenol(GAE/100g)HWB						**Total Phenol(GAE/100g)HWB**				
Time	0.02	4	0.01	166.29	0.00	0.26	4	0.07	1968.83	0.00
Temperature/Power	0.001	2	0.001	17.15	0.00	0.04	3	0.01	374.53	0.00
Interaction	0	8	2.19×10^{5}	0.646	0.73	0.01	12	0.001	34.5	0.00
Total	28.93	44					60			

Colour L*(HWB)						Colour L*(MWB)				
Time	281.124	4	70.281	3.488	0.019	220.827	5	44.165	2.667	0.033
Temperature/Power	85.610	2	42.805	2.124	0.137	1002.968	3	334.32	20.190	0.000
Interaction	19.394	8	2.424	0.120	0.998	83.328	15	5.555	.335	0.988
Total	171735.95	45				357983.026	72			
Colour a*(HWB)						Colour a*(MWB)				
Time	7.411	4	1.853	16.92	0.000	23.050	5	4.61	30.02	0.00
Temperature/Power	0.758	2	0.379	3.459	0.044	4.634	3	1.545	10.058	0.00
Interaction	0.301	8	0.038	0.344	0.941	0.367	15	0.024	0.159	1.00
Total	420.85	45								
Colour b*(HWB)						Colour b*(MWB)				
Time	333.47	4	83.37	7.217	0.00	1015.11	5	203.022	16.49	0.00
Temperature/Power	171.76	2	85.88	7.434	0.002	304.08	3	101.36	8.23	0.00
Interaction	23.06	8	2.88	0.249	0.977	167.05	15	11.137	.904	.564
Total	102097.58	45								

Table 23. Coefficients and statistical parameters on various responses during different blanching treatments of baby corn kernels

Response	Zero Order						First Order					
	Coefficients			Statistical parameters			Coefficients			Statistical parameters		
	C_O	K_1	K_2	R^2	χ^2	RMSE	C_O	K_1	K_2	R^2	χ^2	RMSE
Shrinkage (%)												
HWB	-8.28	0.11	0.02	0.85	4.25	11.39	0.07	0.03	0.01	0.69	8.80	28.87
SB	0.35	0.00	0.01	0.95	0.97	3.59	-0.73	0.00	0.01	0.96	0.16	0.16
MWB	0.23	0.00	0.01	0.93	0.74	2.88	0.08	0.00	0.00	0.97	0.34	1.18
Ascorbic Acid (mg/100g)												
HWB	44.61	-0.02	-0.03	0.93	776.52	4032.72	4.19	-0.01	0.00	0.91	0.77	17.43
SB	30.19	0.00	0.02	0.99	776.51	4032.72	3.41	0.00	0.00	0.92	0.01	0.03
MWB	26.24	0.00	0.02	0.84	8940.26	20419.43	3.33	0.00	0.01	0.81	623.95	692.50
Moisture (%)												
HWB	86.01	0.05	0.01	0.92	0.01	0.58	4.46	0.00	0.00	0.92	24682.95	111239.81
SB	89.13	0.00	0.01	0.95	0.00	0.23	4.49	0.00	0.00	0.95	8141.13	36643.66
MWB	90.13	-0.01	-0.01	0.79	0.03	2.94	4.50	0.00	0.00	0.79	31000.72	138715.85
Flavanoid (mgQE/100)												
HWB	2.98	-0.01	0.00	0.33	0.00	0.01	1.10	0.00	0.00	0.33	45.53	46.73
SB	2.81	0.00	0.00	0.98	0.00	0.00	1.03	0.00	0.00	0.98	16.18	17.54
MWB	2.85	0.00	0.00	0.97	0.01	0.01	1.05	0.00	0.00	0.97	71.01	82.34
Phenol(mgQE/100)												
HWB	48.07	-0.00	-0.00	0.97	0.00	0.00	3.87	-2E-05	-5E-06	0.97	7540.3	29187.2

SB	48.01	0.00	0.00	0.97	1.16	5.58	3.87	0.00	4.5E-06	0.96	2519.03	9753.75
MWB	48.91	0.00	0.00	0.93	6.55	0.003	3.89	0.00	0.00	0.97	10480.11	40799.4
DPPH (%)												
HWB	49.00	-0.10	-0.01	0.93	0.05	2.01	3.94	0.00	0.00	0.94	5295.46	19514.94
SB	40.61	0.00	0.01	0.98	0.02	0.08	3.70	0.00	0.00	0.99	1926.86	7182.22
MWB	40.57	0.00	0.02	0.90	0.21	9.06	3.72	0.00	**0.00**	0.90	8619.69	8619.69
Peroxidase activity (%)												
HWB	32.60	0.63	-0.01	0.17	24.58	1958.88	3.73	0.01	0.0	0.16	20859.30	91678.45
SB	92.91	0.00	0.01	0.95	0.17	16.26	4.51	0.00	0.00	0.89	8811.33	40037.04
MWB	90.66	0.00	0.02	0.59	0.70	66.47	4.50	0.00	0.00	0.60	36037.68	164266.40

6.2.8 Influence of various blanching treatments on the peroxidase activity of baby corn.

The treated samples were analyzed for peroxidase activity to assess the efficacy of different blanching methods, including hot water (70-90 °C for 30-240 s), steam (100°C for 60-240 s), and microwave blanching (360-900W for 30 to 300 s). From the quantitative POD assay, it was found that the blanched samples (hot water, steam and microwave) showed the decreasing enzyme activity with increasing time, temperature/ power, the 90% inactivation of peroxidase enzyme was achieved at 540W, 90 °C and 100°C for 30, 60 and 60 s respectively (Table 24). Similar results for different blanching methods have been reported by Kacchadiya et al., (2018).Furthermore, a study conducted by Ndiaye et al., (2009) on steam blanching treatments revealed a similar pattern of decreasing enzyme activity with increasing blanching time

Table 24. Effect on Enzyme inactivation (EI) (%) after hot water (70-90 °C for 30-240 sec), steam blanching 100 °C for 30-240 sec) and microwave blanching (360-900 W for 30-300 sec)

HWB/SB			MWB		
Temp(°C)	**Time (sec)**	**EI (%)**	**Power (W)**	**Time**	**EI (%)**
70	30	70.78 ± 0.001^{i}	360	30	88.06 ± 0.01^{i}
	60	71.12 ± 0.001^{h}		60	93.89 ± 0.01^{g}
	120	77.5 ± 0.002^{g}		120	93.89 ± 0.01^{g}
	180	84.45 ± 0.001^{f}		240	94.17 ± 0.02^{f}
	240	92.78 ± 0.001^{d}		300	95 ± 0.01^{e}
	300	94.45 ± 0.001^{b}	540	30	90.84 ± 0.01^{h}
80	30	88.1 ± 0.01^{e}		60	93.89 ± 0^{g}
	60	89.17 ± 0.01^{e}		120	96.67 ± 0.01^{c}
	120	92.5 ± 0.01^{d}		240	97.78 ± 0.01^{b}
	180	92.78 ± 0.01^{d}		300	98.34 ± 0^{a}
	240	94.45 ± 0.01^{b}	720	30	91.39 ± 0.01^{h}
	300	94.73 ± 0.01^{b}		60	94.45 ± 0.01^{f}

90	30	89.62±0.01^{e}		120	97.23±0.02^{b}
	60	93.06±0.01^{c}		240	98.06±0.01^{a}
	120	93.34±0.02^{c}		300	98.34±0.02^{a}
	180	95±0.01^{b}	900	30	91.12±0.01^{h}
	240	95.56±0.01^{a}		60	95.84±0.01^{d}
	300	95.76±0.01^{a}		120	97.23±0.01^{b}
100	30	89.89±0.01^{e}		240	98.34±0.01^{a}
	60	93.34±0^{c}		300	98.34±0.02^{a}
	120	95.28±0.01^{b}			
	180	95.84±0.01^{a}			
	240	96.12±0.01^{a}			
	300	96.34±0.01^{a}			

Values are presented as Mean±SD (n =3) ($p<0.05$). Significant differences between values in a column are indicated by distinct superscripts

Results revealed that for microwave, hot water, and steam-blanched samples, a 90% inactivation of peroxidase enzyme was achieved at 540W, 90°C, and 100°C for 30, 60, and 60 seconds, respectively. Additionally, higher retention of ascorbic acid was observed in microwave-blanched samples when compared to conventional methods. The retention % of ascorbic acid was found to be 94.15%, 83.5%, and 94% for microwave, hot water, and steam-blanched samples, respectively. Similarly the flavonoids for 540W, 90 °C and 100°C for 30, 60 and 60 secs was found to be 3.01,1.99 and 2.10(mgQE/100g) , phenols 48.98, 47.99 and 48.03 (GAE/100g) and DPPH (%) 42.55,34.20 and 37.08 respectively. Hence in terms of overall parameters, the microwave blanched samples possess maximum antioxidant activity and ascorbic acid content. Higher time temperature/power combinations can lead to the physical chemical and texture losses.

6.3 Drying at different temperatures and tray loads

The baby corn roundals (Syngenta 5417) were tray dried before and after blanching at 50, 60 and 70^{0}C .The tray load under investigation 0.45, 0.40, 0.35, 0.30 g/cm^{2} was to study the effect of tray load on time as depicted in Figure 10.

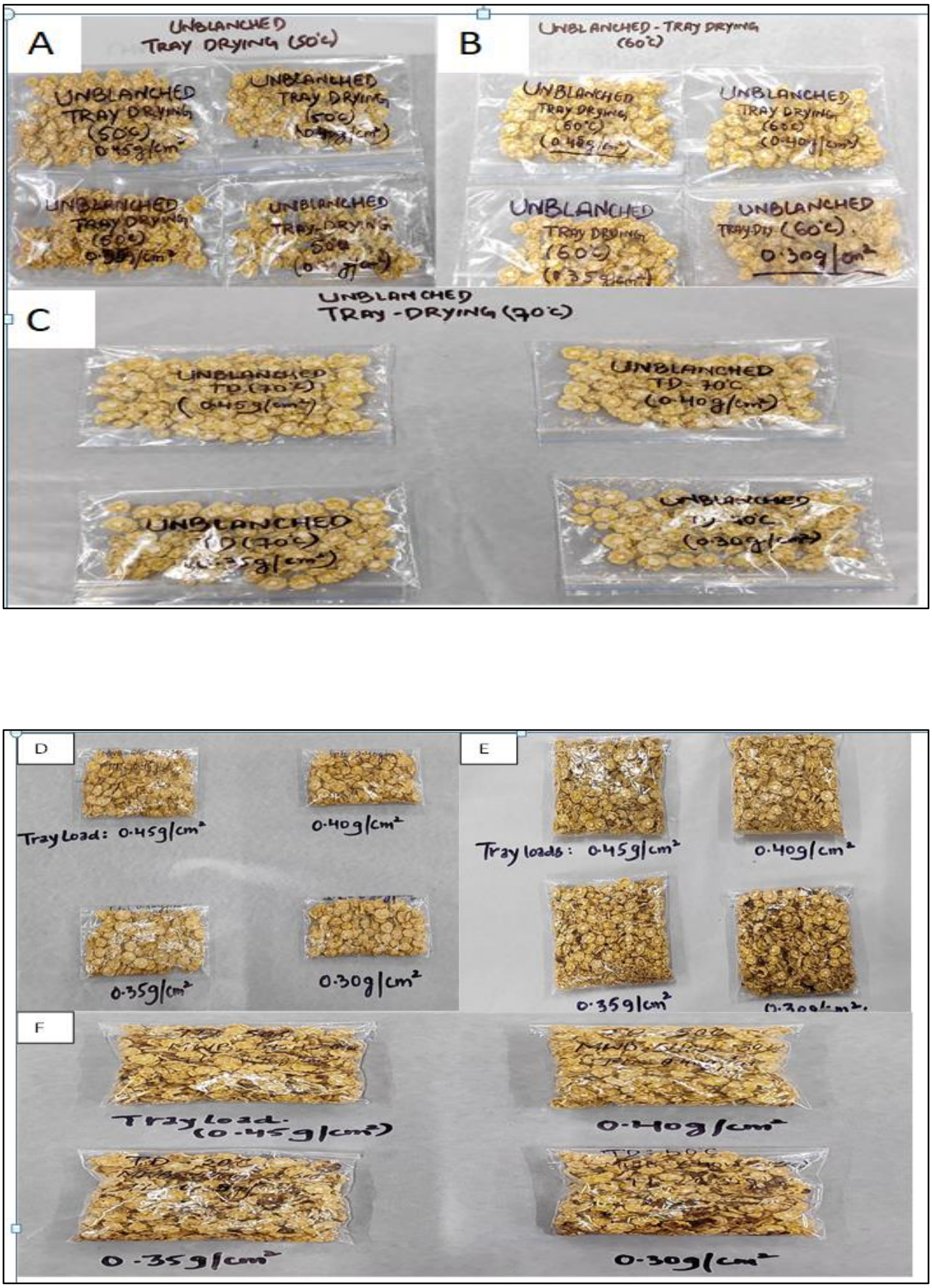


Figure 10. Tray drying of baby corn roundals before and after blanching with different tray loads (0.45, 0.40, 0.35 0.30 g/cm²) and temperatures (50, 60, 70°C)

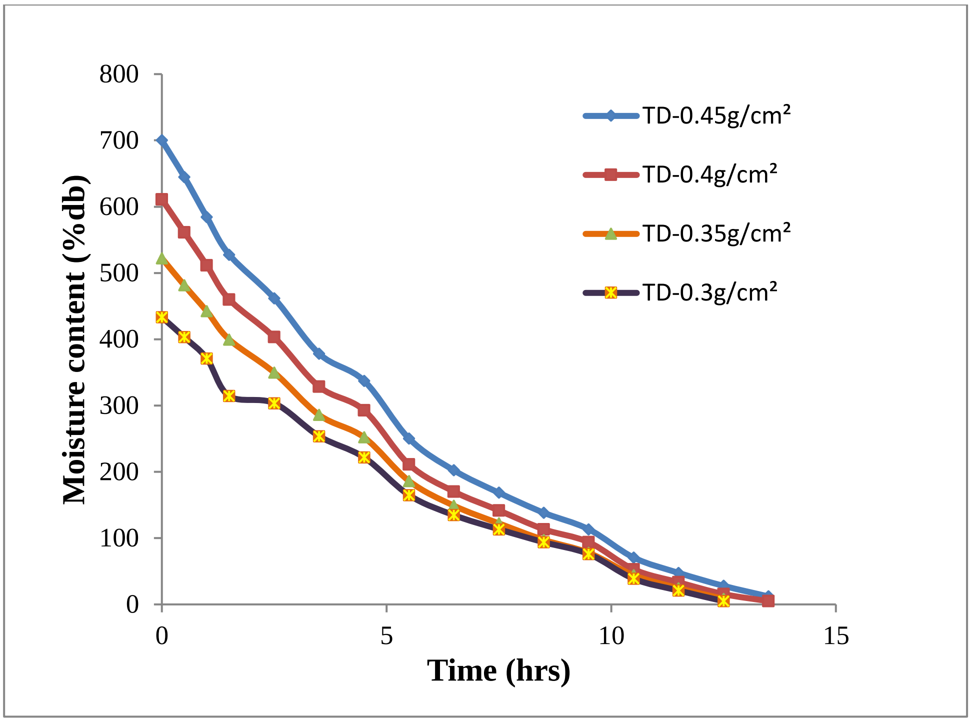


Figure 11. Variation in moisture content w.r.t time at 50 °C

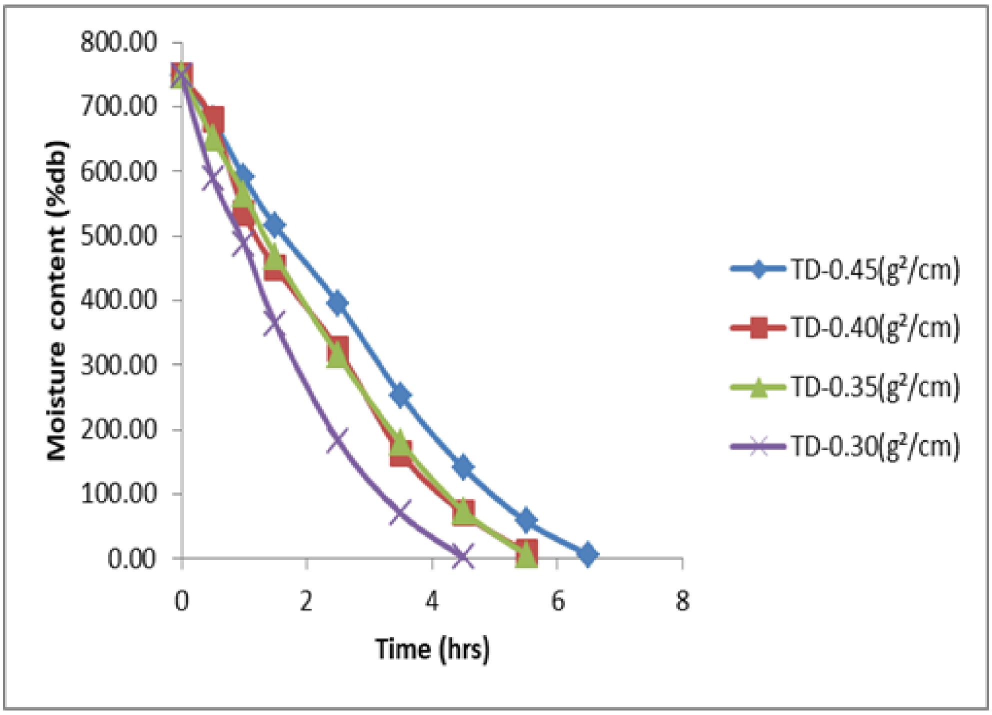


Figure 12. Variation in moisture content w.r.t time at 60 °C

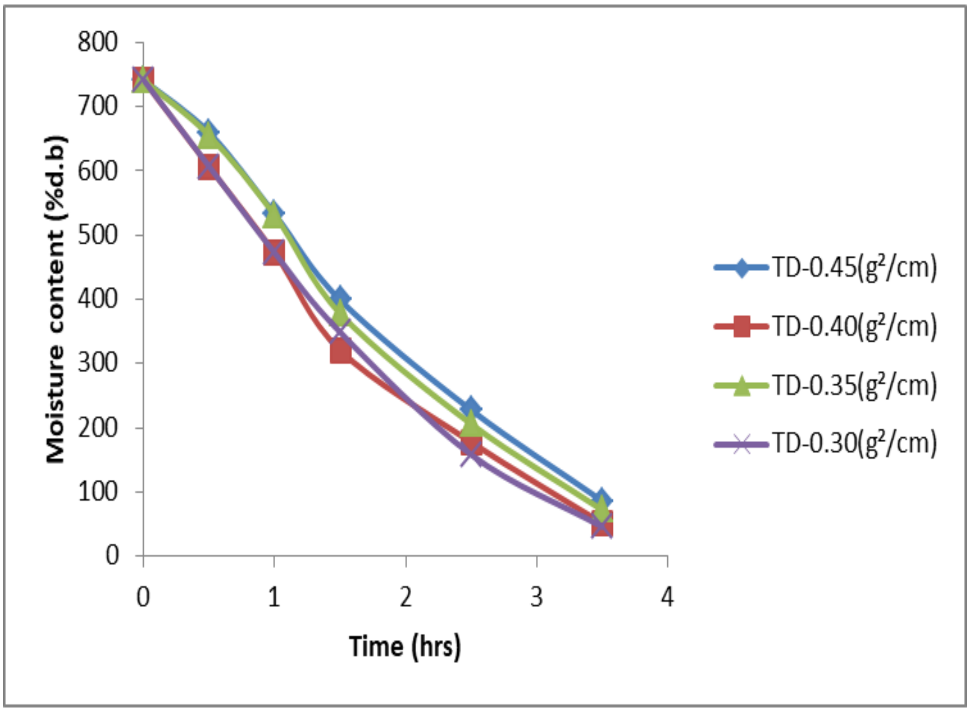


Figure 13. Variation in moisture content w.r.t time at 70 °C

From the figures (11, 12 and 13), plotted against moisture content (%db) and time (hrs), it can be observed that with increase in drying time there is decrease in moisture content(%db) in all the conditions of temperature and tray load, also drying rate increases with increase in temperature.. The drying time ranged from 210-930 min, depending upon the drying conditions viz., temperature and tray load. Moreover, the moisture loss at the initial phase of drying was found to be more as compared to the later phase of drying because of free moisture available which is in agreement to various investigations done on different fruits and vegetables as reported by Igbozulike et al., 2020; Jabeen et al.,2015; Borah et al., 2015 and Shalini et al., 2008. Furthermore overall drying rate ranged from 0.82 to 3.53 (%/min).

6.3.1 Effective moisture diffusivity and activation energy

For all the experiment variants, Table 24 shows the activation energy (E_a) and moisture diffusivity (D_{eff}) values. The D_{eff} for baby corn roundels at varying temperatures (50, 60 and 70°C) with varying tray loads (0.45,0.40, 0.35 and 0.30 g/cm²) ranged from 3.04×10^{-12} to 9.1×10^{-12}(m^2/s) respectively. The table 25 shows that as the drying temperature rises, the values of Deff also increase.This rise is attributed to the heightened heating energy, resulting in increased water molecule activity (Mghazli et al., 2017; Roberts et al., 2008) The Activation energy was calculated which ranged from 50848.42 to 39598.75 (J/mol) as depicted in Table 25. The decreasing trend of activation energy with increasing temperatures and decreasing tray loads was observed.

Table 25: Values of effective moisture diffusivity (D_{eff}) and activation energy (E_a)

Tray load (g/cm²)	Temp(°C)	Diffusivity(m²/sec)	Activation energy(J/mol)
0.45	50	3.04×10^{-12}	50848.424
	60	7.09×10^{-12}	
	70	9.12×10^{-12}	
0.40	50	3.04×10^{-12}	50855.906
	60	7.09×10^{-12}	
	70	9.1×10^{-12}	
0.35	50	3.14×10^{-12}	48246.14
	60	6.69×10^{-12}	
	70	8.92×10^{-12}	
0.30	50	3.65×10^{-12}	39598.75
	60	5.88×10^{-12}	
	70	8.62×10^{-12}	

Thin layer model drying

The results of statistical criteria for page model as observed are shown in table 18.The values of chi square (χ^2) ranged from 0.007 to 0.001,0.159 to 0.112 and 0.034 to 0.036 for page, Henderson and Lewis model respectively as shown in Table 26 .The best fitted model is determined by values of R^2, RMSE and χ^2. The higher values of R^2 and lower values RMSE and χ^2 is considered to be best fitted model. After analysing the models , the RMSE and χ^2 were found to be closest to zero for page model and R^2 values were found to be higher in case of page model ranging from 0.86 to 0.97. Hence the page model was found to be best fitted model.

Table 26. Model prediction evaluation

Page Model				
Temp(°C)	R^2	RMSE	Chi Square(χ^2)	RSS
50	0.86	0.079	0.007	0.106
60	0.97	0.047	0.002	0.037
70	0.96	0.043	0.001	0.018
Henderson-Pabis				
50	0.78	0.386	0.159	2.381
60	0.37	0.267	0.087	0.783
70	0.55	0.319	0.112	1.120
Lewis				
50	0.78	0.177	0.034	0.407
60	0.55	0.211	0.049	0.492
70	0.68	0.180	0.036	0.324
Logarithmic model				
50	0.74	0.286	0.017	0.136
60	0.73	0.249	0.019	0.132
70	0.79	0.232	0.021	0.018
Two term model				
50	0.65	0.398	0.035	0.110
60	0.70	0.362	0.041	0.042
70	0.73	0.347	0.046	0.033
Weibull model				
50	0.35	0.413	0.159	2.142
60	0.37	0.402	0.087	2.773
70	0.42	0.378	0.112	1.130
Midilli and Kucuk model				
50	0.54	0.289	0.134	1.347
60	0.55	0.273	0.097	1.332
70	0.68	0.262	0.036	1.354

The effect of different drying temperatures was observed on ascorbic acid which was found to be maximum at higher temperatures. The vitamin C content was maximum at 70°C and least at 50°C. The vitamin C content was found to be 12.2 ± 0.32, 12.9 ± 0.05 and 14.02 ± 0.04 (mg/100g) for 50, 60 and 70°C respectively. Among different temperatures, the samples dried at 70°C were found to retain maximum bioactive components.

Similarly, the microwave-blanched (540W for 30 secs) baby corn roundels were tray dried at different temperatures (50, 60 & 70°C) at different tray loads (0.45, 0.40, 0.35, 0.30 g/cm^2). The initial moisture content of microwave-blanched baby corn roundels was found to be 532.91 % on dry basis (db). The moisture content was reduced to 4-7% db. From Figure 14, 15, 16 and 17 plotted against moisture content (%db) and time (h), at different tray loads for different temperatures, it can be observed that the moisture content of the baby corn pieces decreased continuously with the increase in drying time demonstrating that the drying took place in falling rate period in all the treatments. Similar results have been reported by (Garba et al., 2015, Oberoi and Sogi, 2015) for black carrot and watermelon respectively. Also, the drying time decreases with every 10ºC increase in temperature and decrease in tray load. The tray load is directly proportional to the drying time as also reported by (Kumar et al., 2006). The dehydration characteristics are greatly influenced by tray load, henceforth, the time taken for drying was found to be more at tray loads 0.45g/cm^2 than at 0.30g/cm^2.

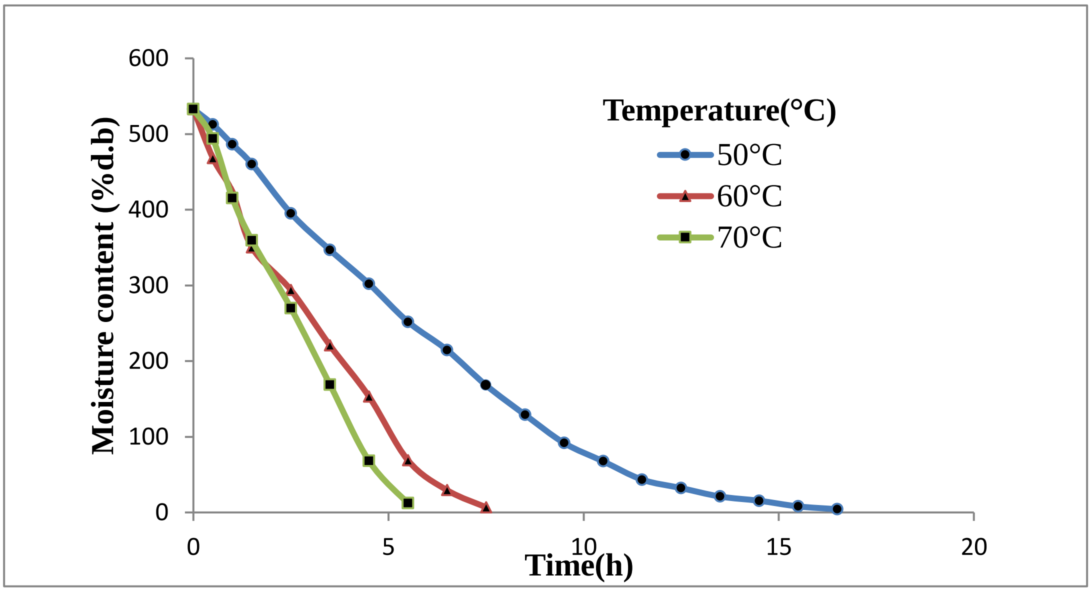


Figure 14. Variation in moisture content of microwave blanched baby corn roundals with respect to time at 50-70°C with tray loads 0.45g/cm

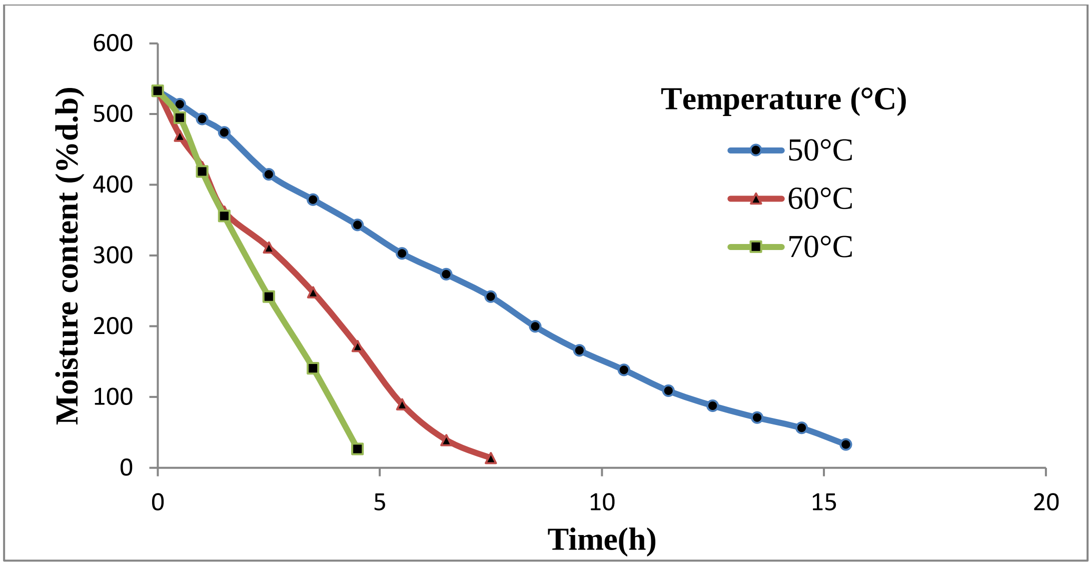


Figure 15. Variation in moisture content of microwave blanched baby corn roundals with respect to time at 50-70°C with tray load 0.40g/cm²

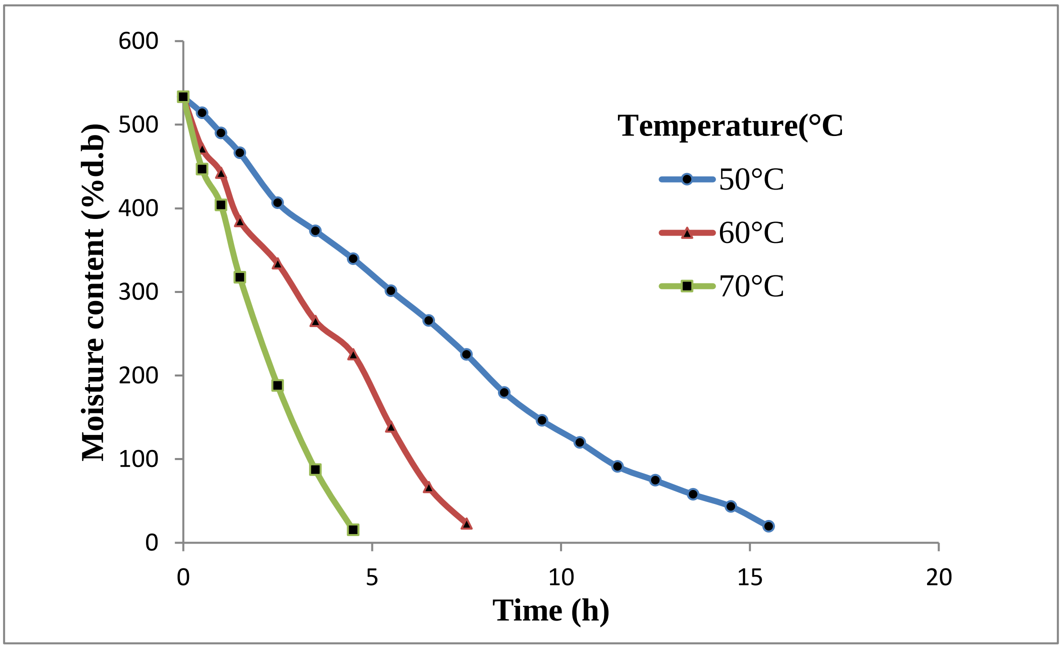


Figure 16. Variation in moisture content of microwave blanched baby corn roundals with respect to time at 50-70°C with tray load 0.35 g/cm²

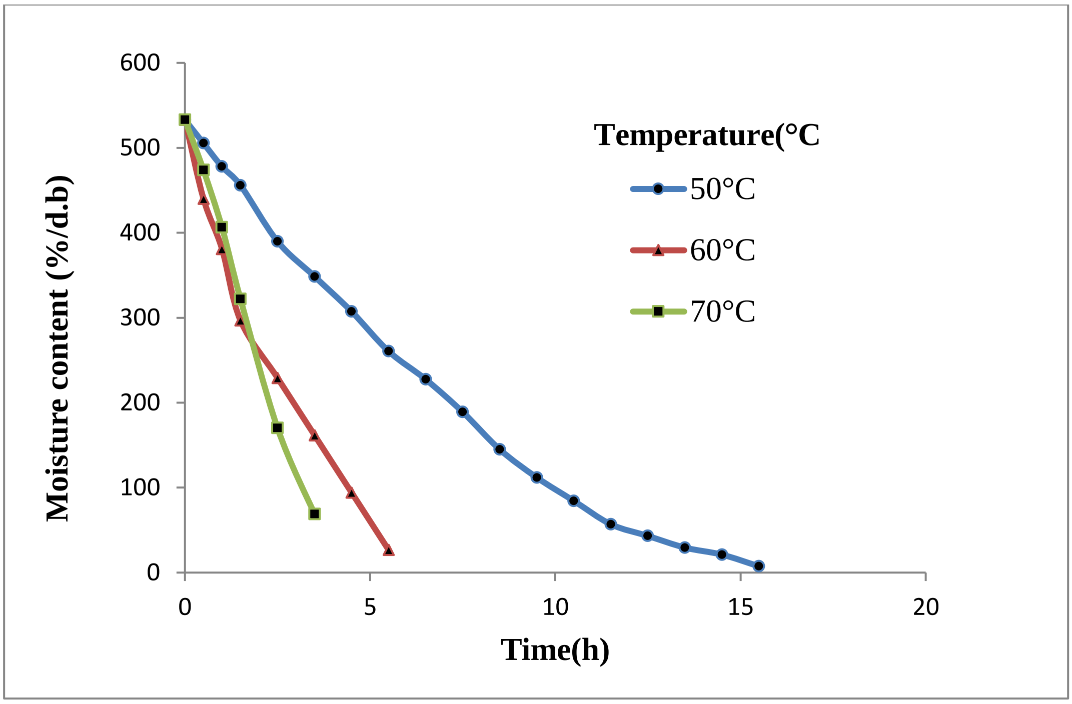


Figure 17. Variation in moisture content of microwave blanched baby corn roundals with respect to time at 50-70°C with tray load 0.30g/cm²

The increased drying rate at higher drying temperatures and less tray load led to higher moisture removal at the food and air interface. The higher rate of moisture evaporation leads to greater moisture diffusion from the interior of baby corn pieces to the surface, thereby increasing the diffusion coefficients. Similar patterns have been observed in various studies done on different fruits and vegetables as reported by (Igbozulike et al., 2020, Jabeen et al., 2015). The values of drying rate constants obtained from different models have been shown in table 19.

Table 27: Empirical constants of drying models and statistical results obtained using different models of thin-layer drying of baby corn

S.No.	Model	Tray load (g/cm^2)	Temp(°C)	R^2	χ^2	RMSE	Estimated Parameters				
							k	n	a	b	c
1.	Page	0.45	50	0.99	9.83×10^{-4}	0.031	0.068	1.33	-	-	
			60	0.99	3.02×10^{-4}	0.017	0.004	0.98	-	-	
			70	0.98	0.002	0.044	0.002	1.12	-	-	
		0.40	50	0.99	9.30×10^{-4}	0.030	0.060	1.69	-	-	
			60	0.98	0.001	0.035	0.001	1.17	-	-	
			70	0.99	5.66×10^{-4}	0.023	0.001	1.26	-	-	
		0.35	50	0.99	6.6×10^{-4}	0.025	0.081	1.35	-	-	
			60	0.97	0.003	0.057	0.208	1.28	-	-	
			70	0.98	0.001	0.043	0.003	1.13	-	-	
		0.30	50	0.99	8.02×10^{-4}	0.028	0.103	1.32	-	-	
			60	0.98	0.001	0.040	0.003	1.11	-	-	
			70	0.99	1.93×10^{-4}	0.013	0.301	1.58	-	-	
2.	Modified Page	0.45	50	0.85	0.003	0.061	0.141	0.014	-	-	
			60	0.84	3.066×10^{-4}	0.017	0.021	0.020	-	-	
			70	0.85	0.002	0.051	0.214	0.021	-	-	

		0.40	50	0.88	0.396	0.629	0.01	0.001	-	-	
			60	0.83	0.465	0.682	0.02	0.001	-	-	
			70	0.86	0.436	0.660	0.03	0.002	-	-	
		0.35	50	0.85	0.003	0.059	0.147	0.014	-	-	
			60	0.86	0.005	0.075	0.199	0.019	-	-	
			70	0.88	0.002	0.050	0.249	0.024	-	-	
		0.30	50	0.86	0.003	0.058	0.158	0.015	-	-	
			60	0.89	0.002	0.046	0.253	0.025	-	-	
			70	0.89	0.009	0.095	0.269	0.026	-	-	
3.	**Lewis Model**	0.45	50	0.96	0.003	0.059	0.002	-	-	-	
			60	0.99	2.83×10^{-4}	0.001	0.004	-	-	-	
			70	0.97	0.002	0.042	0.005	-	-	-	
		0.40	50	0.92	0.008	0.092	0.001	-	-	-	
			60	0.98	0.002	0.045	0.004	-	-	-	
			70	0.98	0.018	0.048	0.005	-	-	-	
		0.35	50	0.96	0.003	0.057	0.002	-	-	-	
			60	0.95	0.005	0.071	0.003	-	-	-	
			70	0.98	0.002	0.046	0.006	-	-	-	
			50	0.97	0.003	0.056	0.002	-	-	-	

		0.30	60	0.98	0.001	0.043	0.006	-	-	-	
			70	0.94	0.007	0.087	0.007	-	-	-	
4.	**Henderson and Pabis**	0.45	50	0.97	0.002	0.054	0.002	-	1.061	-	
			60	0.99	3.04×10^{-4}	0.017	0.004	-	0.996	-	
			70	0.97	0.002	0.050	0.004	-	0.004	-	
		0.40	50	0.94	0.007	0.084	0.002	-	1.092	-	
			60	0.98	0.002	0.046	0.004	-	1.025	-	
			70	0.98	0.001	0.042	0.005	-	1.055	-	
		0.35	50	0.97	0.002	0.051	0.002	-	1.060	-	
			60	0.95	0.005	0.073	0.004	-	1.0344	-	
			70	0.85	0.310	0.557	0.397	-	1.000	-	
		0.30	50	0.97	0.002	0.052	0.002	-	1.057	-	
			60	0.92	0.255	0.505	0.597	-	1.000	-	
			70	0.95	0.006	0.083	0.007	-	0.007	-	
5.	**Logarithmic**	0.45	50	0.92	0.033	0.579	101.20	2636.59	0.499	-	0.500
			60	0.98	0.254	0.504	79.22	2577.72	0.500	-	0.499
			70	0.98	0.351	0.593	90.21	2829.04	0.500	-	0.049
			50	0.96	0.404	0.636	108.58	2750.70	0.499	-	0.500
			60	0.95	0.370	0.608	92.37	2843.7	0.500	-	0.499

		0.40	70	0.98	0.465	0.682	100.29	3074.48	0.499	-	0.500
		0.35	50	0.97	0.131	0.363	3.33	2.11	0.235	-	0.023
			60	0.98	0.171	0.413	3.37	1.97	0.240	-	0.240
			70	0.94	0.209	0.457	3.33	2.16	0.219	-	0.219
		0.30	50	0.97	0.364	0.603	100.41	2721	0.499	-	0.500
			60	0.98	0.357	0.598	88.01	2970	0.500	-	0.499
			70	0.94	0.608	0.780	119.59	3699	0.498	-	0.501

Note: RMSE=root mean square error, $\chi 2$ =reduced chi square, k, n, a, b, c are constants

6.3.2 Evaluation of the drying models

The experimental data of moisture content recorded during drying experiments were represented in terms of moisture ratio (MR) and fitted in the eight drying models. The higher values of coefficient of determination (R^2) and lower values root mean square error (RMSE) and chi square (χ^2) were considered as the criteria for the best fitted model. Based on the statistical results of χ^2, R^2, root mean square (RMSE), Page, Lewis, Handerson and pabis were found to be the best-fitted model (Table 27) (Garba et al.,2015, Santos et al.,2017).

The moisture diffusivity and activation energy were estimated by Fick's law diffusion and Arrhenius model. Linearization of the equation allowed the determination of the effective moisture diffusivity (D_{eff}) for different tray load samples. The D_{eff} for baby corn roundels at different temperatures (50, 60, and 70°C) with varying tray loads (0.45, 0.40, 0.35, and 0.30 g/cm²) ranged from 2.40×10^{-11} to 7.11×10^{-12} (m²/s); 4.06×10^{-12} to 9.94×10^{-12} (m²/s); 2.94×10^{-12} to 6.80×10^{-12} (m²/s); 3.65×10^{-12} to 8.01×10^{-12} (m²/s) respectively. The data showed that with the rise in drying temperature, and reduction in tray load resulted in increased values of D_{eff}. This increase results from the increased heating energy which led to the increased diffusion of water molecules (Mghazli et al., 2017, Roberts et al., 2008). Also, blanching as pre-treatment prior to drying improves the cell membrane permeability which in turn increases the effective diffusivity (Xiao et al., 2017).

6.3.3 Effective moisture diffusivity and activation energy

Activation energy represents the minimum energy needed to start the moisture transfer process from the center of the food to its surface during drying. For most fruits and vegetables, this activation energy has been reported to range from 12.7 to 110 KJ/mol (Aral and Bese, 2016).In the present study, the activation energy was observed in the range of 57416.48 to 36499.29 (J/mol) for tray load 0.45 g/cm²-0.30 g/cm² respectively as shown in Table 28 which agrees with the mentioned range. A decrease in activation energy with increasing temperatures and decreasing tray loads was observed which is due to higher diffusivity.

Table 28. Values of effective moisture diffusivity (D_{eff}) and activation energy (E_a)

Tray load (g/cm²)	Temp(°C)	Diffusivity(m²/sec)	Activation energy(J/mol)
0.45	50	2.40×10^{-11}	57416.48
	60	6.19×10^{-12}	
	70	7.00×10^{-12}	
0.4	50	4.06×10^{-12}	41333.05
	60	6.9×10^{-12}	
	70	9.94×10^{-12}	
0.35	50	2.94×10^{-12}	38808.09
	60	5.88×10^{-12}	
	70	6.80×10^{-12}	
0.3	50	3.65×10^{-12}	36499.29
	60	7.61×10^{-12}	
	70	8.01×10^{-12}	

6.3.4 Effect of temperatures on bioactive components

The effect of different temperatures (50°C -70°C) at tray load 0.3 g/cm² was studied on various heat-labile components of baby corn and color values. As the heat treatment negatively affects the heat-sensitive nutrients as well as the color of the product the effect of different temperatures becomes important. It was observed that both microwave blanching and drying at different temperatures significantly affected nutrient degradation and color values. Ascorbic acid, a crucial dietary constituent found in nearly all fruits and vegetables, is sensitive to heat, pH, metal ions, and light, and can also be degraded by enzymes. This vitamin serves as a marker for assessing nutrient depletion during blanching and other heat treatments (Xiao et al., 2017). The main mechanism of vitamin C loss during steam, microwave and infra-red blanching could be action of ascorbic acid oxidase enzyme and thermal degradation while in hot water blanching it is through leaching (Xiao et al., 2017). In the study, a significant reduction in ascorbic acid at $p \leq 0.05$ was found during microwave blanching. The value was reduced from 21.05±0.15 mg/100 g to 15±0.06 mg/100 g. The effect of drying at different temperatures showed that higher temperatures short time resulted in better retention of ascorbic acid as recorded in Table 29. Low temperature and longer time facilitate the oxidation of ascorbic acid (Deng et al., 2018) The total phenol content and antioxidant activity were found to increase with increasing temperatures, (Kamiloglu et al., 2016) whereas the flavonoid content decreases with increasing temperatures; it is temperature dependent (Sonawane and Arya, 2015).Among different temperatures, the samples dried at 70°C were found to retain maximum bioactive components.

Table 29. Effect of Treatments on bioactive components of baby corn

Baby corn	Ascorbic Acid (mg/100g)	TFC (mg QE/100g)	TPC (mg GAE/100g)	DPPH (%)	FRAP (µg/ml)
FRESH	21.50±0.15^{c}	2.37±0.01^{d}	49.02±0.01^{c}	37.90±0.12^{b}	123.93±1.14^{c}
MWB	15 ±0.06^{b}	3.01±0.02^{e}	49.68±0.04^{d}	40.89±0.05c	124.01±0.06^{e}
50°C	14.81± 0.01^{a}	1.98± 0.01^{c}	48.03±0.01^{a}	34.00±0.02^{a}	118.63±0.01^{a}
60°C	14.98± 0.01^{b}	1.96±0.01^{b}	48.72± 0.02^{b}	38.00±0.57^{b}	120.63±0.02^{b}
70°C	15.02± 0.02^{b}	1.90± 0.03^{a}	49.02 ± 0.03^{c}	38.00±0.01^{b}	124.63±0.01^{d}

Note: Values are presented as Mean±SD (n =3) (p<0.05); a-d within column with different letters are significantly different. TFC: Total flavonoid content; Total phenolic content; DPPH: 1,1-diphenyl-2-picrylhydrazyl:FRAP: Ferric reducing antioxidant power.

6.3.5 Color values

The L*, a* & b* values for fresh baby corn samples were found to be 75.17± 0.37, 4.53 ± 0.21, and 30.27 ± 0.22 respectively which when microwave blanched were found to be 71.00 ± 0.32, 5.1 ±0.21 and 33.3± 0.33. The lightness (L*) value decreased whereas a*(redness) and b*(yellowness) values got increased. Higher L* values indicated the lighter color of the sample (Parmar et al.,2017).The darkness of the color during blanching might be due to non-enzymatic browning (Chikpah et al.,2022) which was further intensified significantly at p≤0.05 during drying at 50ºC and 60 ºC. The L* value (70.63±0.12) was minimally affected at 70ºC. The a* value significantly increased from 4.53±0.21 for fresh sample to 5.1±0.21 for microwave blanched and 5.6±0.01 for drying at 70ºC. The yellowness (b*) value was found to increase due to the presence of the yellow pigments which increases once the samples are blanched (Popalia et al., 2021). The treated samples after tray drying were observed for color values L* and b* values were found to decrease for different drying temperatures (Table 30). The L* values of dried samples at temperatures 50°C, 60°C & 70°C were found to be 57.87± 0.33, 55.67±0.45, 70.63 ± 0.12 respectively. The lightness value was better in the case of samples dried at 70°C which is because higher temperatures for a shorter time were found to retain color and carotenoid content than lower temperatures for a long time (Chikpah et al., 2022; Md Saleh et al., 2020). After drying, the overall a* & ΔE were found to increase. During the drying of fruits and vegetables browning reactions viz., (enzymatic and non-enzymatic) occurs, leading to an increase in the redness of dried samples (Xiao et al., 2014). Moreover, with the decrease in the moisture content redness increases. Consequently, the color difference was found to be minimum for the samples dried at 70°C than that at 50°C &60°C. ΔE was found to be 5.09 ± 0.12 for MWB, 24.44± 0.32, 29.02± 0.31, and 18.73±0.76 for dried samples at 50, 60, and 70 °C respectively. The ΔE increased with an increase in drying temperature; however, the higher temperature for a shorter time resulted in lower ΔE values as observed. Moreover, the samples dried at 50 & 60°C have higher values of ΔE since these are exposed for longer time periods hence thermal degradation and oxidation of pigments cause leads to more color difference (Chikpah et al., 2022, Argyropoulos and Muller, 2014).

Table 30. Effect of treatments on color characteristics

Baby corn	**Color values**		
	L*	**a***	**b***
FRESH	75.17± 0.37^{e}	4.53 ± 0.21^{a}	30.27±0.22^{a}
MWB	71.00 ± 0.32^{d}	5.1 ±0.21^{b}	33.3± 0.33^{b}
50°C	57.87± 0.33^{b}	5.3±0.03^{bc}	33.6±0.12^{c}
60°C	55.67±0.45^{a}	5.6±0.02^{d}	38.7±0.11^{d}
70°C	70.63 ± 0.12^{c}	5.6±0.01^{c}	39.8±0.31^{e}

Note: Values are presented as Mean±SD (n =3) (p<0.05); a-e within column with different letters are significantly different

6.3.6 Rehydration kinetics

The dehydrated baby corn roundals (70°C) were rehydrated at different temperatures (25, 40 and 80°C). The graph was plotted between the rehydration rate and time; it was observed (Fig 18) that the rehydration rate is higher at higher temperatures. Initially, the rehydration rate increased rapidly which further decreased till it reached equilibrium. This can be attributed to the osmotic pressure that is produced when the material is moistened which leads to the dissolution of soluble components, as solubility changes with temperature, the rate of water absorption rises as the temperature rises due to an increase in the osmotic pressure. Furthermore, the rehydration rate or rehydration capacity depends mainly on the cell wall, composition, capillary structure, porosity, and nature of the sample (Aravindakshan et al., 2021, Gornicki et al., 2013). The major water-retaining factors include the starchy nature of the material. Also, the swelling of material results due to the imbibition of water (Lewicki, 1998). Among the different temperatures under observation, the rehydration rate was more rapid at 80°C than that for the samples rehydrated at 25 and 40°C. Similar behaviour has also been reported by several researchers on different matrices including beans (Aravindakshan et al., 2021; and carrot (Falade and Abbo,2007).

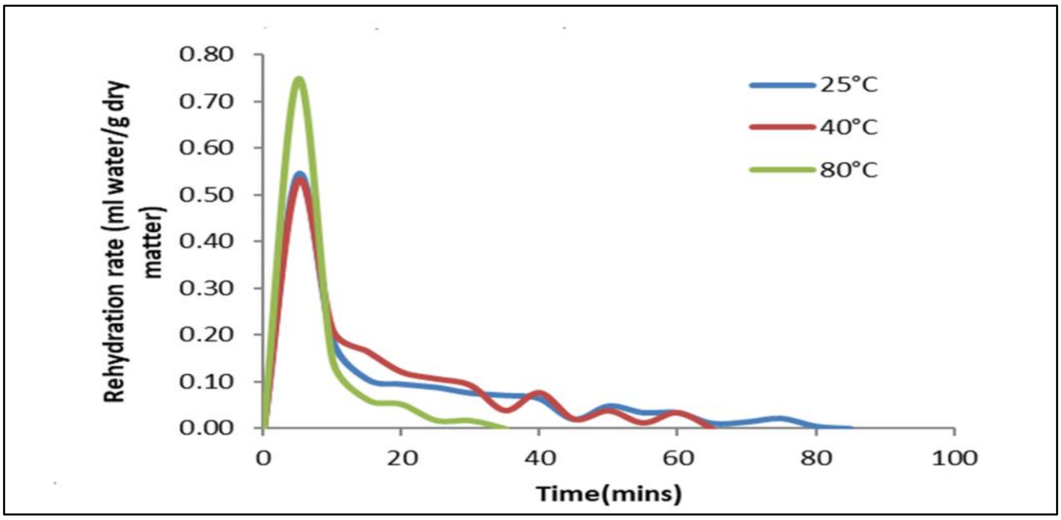


Figure 18. Variation in rehydration rate of baby corn with respect to temperature at 25, 40 and 80°C

6.4 Drying methods

The samples were also vaccum dried and sun dried as shown in figure 19 comparison between three drying methods was made on the basis of proximate and antioxidants

Figure 19. Sun drying and Vaccum drying of baby corn roundels

Vitamin C levels serve as a benchmark for assessing the retention of nutrients in dehydrated food products due to its remarkable sensitivity to heat, making it prone to rapid evaporation. Consequently, when vitamin C remains intact throughout the drying procedure, it is likely that other essential nutrients have also been effectively conserved (Ali et al.,2016).The data for vitamin C and antioxidants as shown in Table 31. From the data it can be revealed that overall vaccum drying shows better retention of bioactive components than that of tray dried and sun dried samples. But in some parameters like flavanoids better retention was observed in case of tray dried samples. The least retention of ascorbic acid and antioxidants were found in samples which were sun dried as there use to be lot of fluctuations during the sun drying that leads to degradation.

Table 31. Effect of different drying methods on ascorbic acid and bioactive components

Treatments	**Ascorbic acid((mg/100g)**	**Flavanoid (µg/ml)**	**TPC (mg GAE/100 g)**	**DPPH (%)**	**FRAP (µg/ml)**
Fresh	21.50±0.15[a]	2.37±0.01[a]	49.02±0.02[a]	37.90±0.01[bc]	123.93±1.14[b]
TD(50°C)	14.81±0.01[h]	1.98±0.01[b]	48.03±0.01[d]	34.00±0.02[e]	118.63±0.01[f]
TD(60°C)	14.98±0.01[g]	1.96±0.02[c]	48.72±0.02[b]	37.66±0.57[bc]	120.63±0.02[d]
TD (70°C)	15.02±0.02[f]	1.90±0.03[d]	49.0± 0.03[a]	38.01±0.02[b]	124.63±0.03[a]
VD (50°C)	15.88±0.03[c]	1.86±0.01[e]	48.55±0.02[c]	37.52±0.03[de]	120.33±0.02[e]
VD (60°C)	16.01±9.02[b]	1.90±0.02[d]	49.00±0.01[a]	39.53±0.03[a]	124.65±0.01[a]
VD (70°C)	15.53±0.01[d]	1.76±0.02[f]	49.00±0.02[a]	37.22±0.02[d]	121.34±0.03[c]
SD	15.34±0.02[e]	1.71±0.01[g]	45.82±0.03[e]	33.21±0.03[f]	118.15±0.01[g]

The data is presented as Mean ±SD(n=3).Different alphabets in a column indicate significant differences ($p < 0.05$) for each assay. TD: Tray Drying, SD: Sun drying, VD: Vaccum drying.

Similarly a comparison was made on the basis of drying time and final moisture content of samples subjected to different drying methods (tray, vaccum and sun drying).

Table 32. Effect of different drying methods on total drying time and moisture content

Treatments	**Total Drying time (h)**	**Moisture content(%)**
Fresh	-	86.2
TD (50°C)	15	12.22
TD (60°C)	8.5	11.35

TD (70°C)	8	10.75
VD (50°C)	4.5	11.94
VD (60°C)	4	11.4
VD (70°C)	3.5	11.07
SD	15	11.40

Note: VD: Vaccum drying; TD: Tray drying; SD: Sun drying

The Table 32, presents the results of varied drying methods, elucidating the relationship between overall drying duration and moisture content for baby corn. Tray drying treatments, (TD) executed at varying temperatures (50°C, 60°C, and 70°C) showcase a notable decrease in total drying time with increasing temperature. This phenomenon stems from the fundamental principle of elevated temperatures expediting the evaporation process, thereby hastening moisture removal from the material. Consequently, higher temperatures necessitate less time to achieve the desired moisture content. Likewise, vacuum drying (VD) treatments at increasing temperatures manifest a decline in total drying time. Vacuum drying operates within reduced pressure environments, thereby lowering the boiling point of water and facilitating swifter moisture removal Ghnimi et al., (2019). Consequently, higher temperatures in vacuum drying lead to abbreviated drying times compared to lower temperatures. Conversely, solar drying (SD) exhibits a prolonged total drying time relative to tray and vacuum drying methodologies. This discrepancy likely arises from the reliance on natural solar energy, which may not consistently provide the requisite intensity of heat throughout the drying process, thereby prolonging the duration needed to attain the desired moisture content Ong et al., (2017). Overall, the data underscores the substantial influence of drying method and temperature on both total drying time and moisture content, underscoring the fundamental principles of heat transfer and moisture removal mechanisms.

6.4.1 Effect of drying methods on the color values

Color plays an essential role in processing, Increased L* (lightness) and decreased b* (yellowness), a*/b*, and ΔE* values are preferable for the subsequent processing of fruits and vegetables.

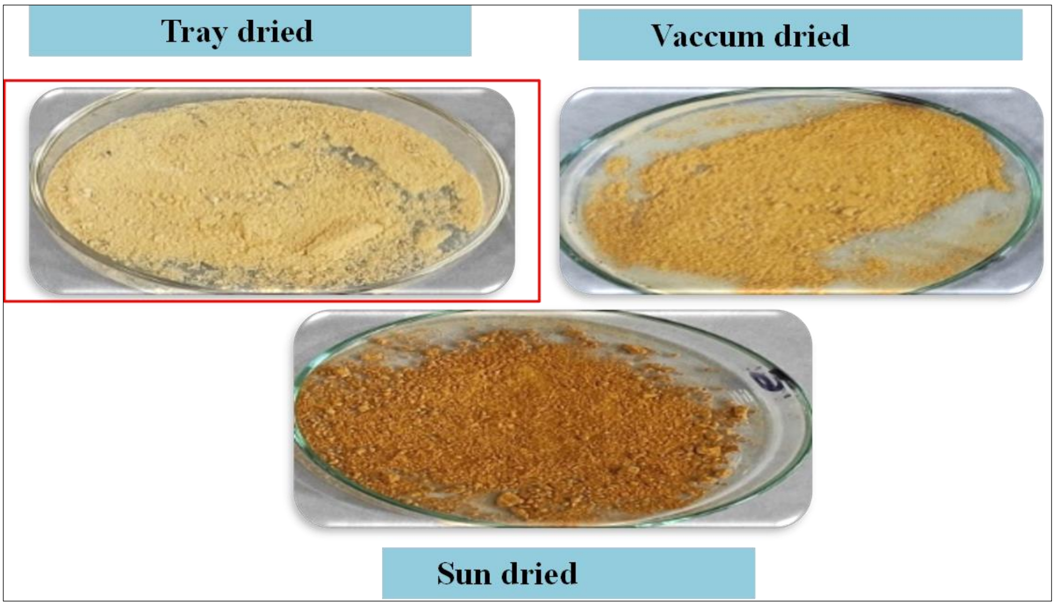


Figure 20. Effect of drying methods on the color of baby corn powder

The Table 33 provides data on the L*, a*, and b* values of baby corn subjected to different drying treatments, including thermal drying (TD) at temperatures of 50°C, 60°C, and 70°C, vacuum drying (VD) at the same temperature range, and solar drying (SD). The L* values, which represent lightness, it's noticeable that the fresh baby corn has the highest L* value of 75.17, indicating its lighter color compared to dried samples. Among the drying methods, TD at 70°C resulted in a higher L* value of 70.63, suggesting a relatively lighter color compared to other drying temperatures and methods. The a* values, representing the red-green color axis, vary across the treatments. TD at 60°C and 70°C, as well as VD at 50°C, exhibit similar a* values, indicating comparable levels of redness or greenness in the samples. Notably, VD at 60°C and 70°C shows significantly higher a* values, suggesting a more pronounced red or green coloration. Regarding the b* values, which indicate the yellow-blue color axis, there's a noticeable decrease in values with increasing drying temperatures for both TD and VD methods. This suggests a shift towards less yellow or more blue coloration in the dried baby corn samples. Additionally, VD at 60°C and 70°C shows considerably lower b* values compared to other treatments, indicating a more pronounced blue coloration.

These results are consistent with prior studies suggesting that drying methods and temperatures can significantly impact the color attributes of dried agricultural products. For instance, a study by Zhang et al., (2019) on the color changes of dried apple slices during hot air drying demonstrated that higher drying temperatures led to decreased L* and b* values, indicating darker and less yellow products. Similarly, Alibas, (2017) studied the effects of different drying methods on the color of dried apricots and found that vacuum drying resulted in products with lower L* and higher a* values compared to other drying methods, indicating darker and more reddish products. Overall, the data from the table suggest that drying treatments influence the color characteristics of baby corn, with higher temperatures generally leading to darker and more intensely colored products.

Table 33. Effect of different drying methods on Color values (L, a*, b*)

Treatments	**L**	**a***	**b***
Fresh	75.17 ± 0.37^{a}	4.53 ± 0.21^{b}	30.27 ± 0.22^{bc}
TD(50°C)	57.87 ± 0.33^{c}	5.3 ± 0.03^{b}	33.6 ± 0.12^{b}
TD(60°C)	55.67 ± 0.45^{c}	5.6 ± 0.02^{b}	38.7 ± 0.11^{a}
TD (70°C)	70.63 ± 0.12^{b}	5.43 ± 0.01^{b}	39.8 ± 0.31^{a}
VD (50°C)	57.43 ± 2.80^{c}	5.03 ± 0.70^{b}	32.9 ± 1.01^{b}
VD (60°C)	44.4 ± 2.06^{e}	11.73 ± 2.30^{a}	29.1 ± 2.58^{d}
VD (70°C)	33.03 ± 1.85^{f}	10.56±1.43a	25.76 ± 1.52^{d}

SD	48.2±0.80^{d}	5.50±1.08^{b}	33.0± 4.66^{b}

Note: The data is presented as Mean ±SD(n=3). Different alphabets in a column indicate significant differences (p< 0.05). TD: Tray Drying, SD: Sun drying, VD: Vaccum drying.

6.5 Impact of Particle Size on the Physical Properties, Techno-Functional Traits, Antioxidant Capacity, mineral composition and morphological structure of Baby Corn Powder

The obtained powder was classified by particle size using sieve shaker with sieve sizes of >500, 500, 420, 300, 150, 75, and 53 µm. The sieving process lasted for around 30 minutes at medium speed. The resulting powders of various particle sizes were then sealed in ziplock pouches and stored under refrigerated conditions for further analysis.

6.5.1 Proximate and nutritional composition of baby corn powder

The tray-dried samples underwent a proximate composition analysis, revealing specific nutritional components. The moisture content was determined to be 10.75 ± 0.22 (%). Ash content, representing inorganic residue after combustion, was found to be 1.13± 0.07 (%). Protein, fat, and fibre content stood at 15.7 ± 0.67 (%), 2.17 ± 0.41 (%), and 21.33 ± 0.14(%), respectively. Carbohydrate content, encompassing sugars and starches, was measured at 47.98 ± 0.29(%). It is noteworthy that similar results have been reported by (Kaur et al., 2021). The obtained powder was sieved, and it was observed that the The proximate composition of the baby corn flour was subtly affected by the particle size. As presented in Table 34 it was revealed that as particle size decreases, there is a consistent decline in moisture, fat, fibre and carbohydrate content. Conversely, protein content and TSS (Total soluble sugar) increase with smaller particle sizes. Ash content exhibits a significant increase when comparing particles >500 µm to 53 µm. These findings suggest that particle size significantly influences the composition of the baby corn powder, impacting its nutritional and physical characteristics. Hence, any determination regarding the selection of particle size should consider its ability to be incorporated into the specific food matrix to which the flour is intended to be added (Lucas et al., 2017).

Table 34: Proximate Composition of baby corn powder at different particle size

Particle size(µm)	Moisture (%)	Ash (%)	Fat (%)	Fibre (%)	Protein (%)	Carbohydrates (%)	Total Soluble Sugar (%)
>500	11.833±0.074[g]	1.03±0.007[a]	2.413±0.03[g]	20.6±0.213[e]	13.97±0.046[a]	50.73±0.095[g]	18±0.29[a]
500	10.983±0.054[f]	1.064±0.004[ab]	2.093±0.036[f]	19.78±0.125[d]	14.33±0.036[b]	50.04±0.098[f]	18.2±0.15[ab]
420	10.683±0.108[e]	1.11±0.008[b]	1.867±0.046[e]	18.63±0.257[c]	14.46±0.028[b]	49.49±0.144[e]	19±0.52[b]
300	9.783±0.[074d]	2.64±0.033[c]	1.273±0.022[d]	17.57±0.408[b]	14.81±0.022[c]	48.6±0.17[d]	21.33±0.3[c]
150	8.85±0.035[c]	2.877±0.043[d]	1.107±0.03[c]	17.48±0.054[b]	15.62±0.071[d]	45.64±0.072[c]	22±0.29[c]
75	8.383±0.054[b]	2.903±0.015[de]	1±0.014[b]	16.53±0.355[a]	16.35±0.085[e]	44.09±0.191[b]	23.87±0.22[d]
53	7.867±0.089[a]	2.94±0.014[e]	0.9±0.038[a]	16.75±0.309[a]	17.99±0.083[f]	42.89±0.269[a]	23.87±0.22[d]
CV %	1.1	1.5	3.0	2.1	0.5	0.5	2.3
LSD	0.1813	0.05518	0.07906	0.6715	0.1442	0.3988	0.848

The data is represented as Mean ±Standard Error (n=3). Significant differences between values in a column are indicated by distinct superscripts at a significance level of P <0.05.

6.5.2 Mineral composition of baby corn

The mineral composition of baby corn powder, as illustrated in Table 35, exhibits variations in calcium, magnesium, zinc, phosphorus, and iron across varying particle sizes. Notably, there is a discernible rise in calcium (73.83±0.271 to 106±0.177), magnesium (284.9±0.611 to 345.8±1.277), zinc (5.547±0.009 to 7.113±0.013), phosphorus (760.6±9.848 to 903±9.849), and iron (6.927±0.005 to 7.475±0.007) as particle size decreases from >500 to 53 µm. This trend suggests that finer particles tend to harbour elevated mineral concentrations. Furthermore, the results indicate significant variations ($p < 0.05$) in mineral content based on particle sizes, with the 53 µm particle size displaying the highest mineral contents. The study also reveals a noteworthy correlation between particle size and ash content, with finer particle powders exhibiting higher ash content compared to larger particle-size powders. This aligns with prior research (Deli et al., 2020; Becker et al., 2016) emphasizing that higher total ash content in finer particles implies heightened mineral concentrations. These findings hold implications for the nutritional value and bioavailability of the substance, particularly in food applications where mineral content plays a crucial role in dietary intake and health benefits.

Table 35. Mineral composition of baby corn powder at various particle sizes

Particle size(µm)	**Calcium (mg/100g)**	**Magnesium (mg/100g)**	**Zinc (mg/100g)**	**Phosphorous (mg/100g)**	**Iron (mg/100g)**
>500	73.83±0.271[a]	284.9±0.611[a]	5.547±0.009[a]	760.6±9.848[a]	6.927±0.005[b]
500	78.67±0.446[b]	290±0.816[b]	5.608±0.007[b]	763.6±12.895[a]	7.12±0.004[d]
420	84.5±0.177[c]	300.6±0.684[c]	5.668±0.018[c]	815.2±9.849[b]	6.69±0.004[a]
300	90.92±0.271[d]	325.8±4.364[d]	5.983±0.038[d]	860.6±13.421[c]	7.025±0.004[c]
150	96.5±0.813[e]	327.8±0.178[d]	6.097±0.02[e]	872.7±12.895[cd]	7.233±0.005[e]
75	100.08±0.892[f]	342.5±0.954[e]	6.46±0.022[f]	890.9±6.448[de]	7.352±0.005[f]
53	106±0.177[g]	345.8±1.277[e]	7.113±0.013[g]	903±9.849[e]	7.475±0.007[g]
CV %	0.8	0.8	0.5	1.8	0.1
LSD	1.275	4.488	0.05084	27.13	0.01238

The data is presented as Mean ±Standard Error(n=3). Significant differences between values in a column are indicated by distinct superscripts (P <0.05).

6.5.3 Physico-chemical properties of baby corn powder

6.5.3.1 Granulometric study

The British Standard Sieve Series (BSS), established by the British Standards Institution (BSI), defines a standardized set of sieve sizes for particle size analysis.Sieving through sizes >30, 30, 36, 52, 100, 200, and 300 BSS produced particles of different sizes: >500, 500, 420, 300, 150, 75, and 53 µm, respectively. The weight (%) of each particle size was calculated, revealing that the highest weight (%) for powdered baby corn was 39.4% at a particle size of 150 µm.These larger particles are indicative of undissociated or partially dissociated powder particles. This occurrence may be attributed to components that are challenging to grind, such as the fibrous portion of the food (Nabil et al., 2020). Furthermore, the minimum weight was found to be 2 % at 53 µm particle sizes, as depicted in Figure 21 (A). The smaller particles mainly consisted of suspended granules.

The data clearly indicates that finer particles are minimal in the baby corn powder.. However, the inclusion of these granulometric fractions as additives in various products could be justified if they possess a significant quantity of bioactive compounds and exhibit favourable functional properties.

6.5.3.2 The average particle size of baby corn powder

Particle size is essential for assessing the stability of powder particles and their potential applications (Singh et al., 2022; Zhu et al., 2019). The baby corn powder (BCP) exhibited an average particle size of 208.8 nm, a polydispersity index (PDI) of 0.133, and a zeta potential of -20 mV (Fig. 21B). The significance of these results lies in their implications for the utilization of the powder in food formulations. A Polydispersity Index (PDI) value less than 0.5 indicates a relatively narrow particle size distribution. This narrow distribution is crucial for achieving uniformity in the size of particles within the powder. Additionally, the zeta potential value, falling within the limits of -15 mV to 30 mV, confirms the stability of the powder. A stable powder is vital for its successful incorporation into food formulations, ensuring consistent quality and performance. These findings offer insightful knowledge into the suitability of the powder for use in various food products, emphasizing its stability and potential for uniform dispersion (Rao et al., 2011).

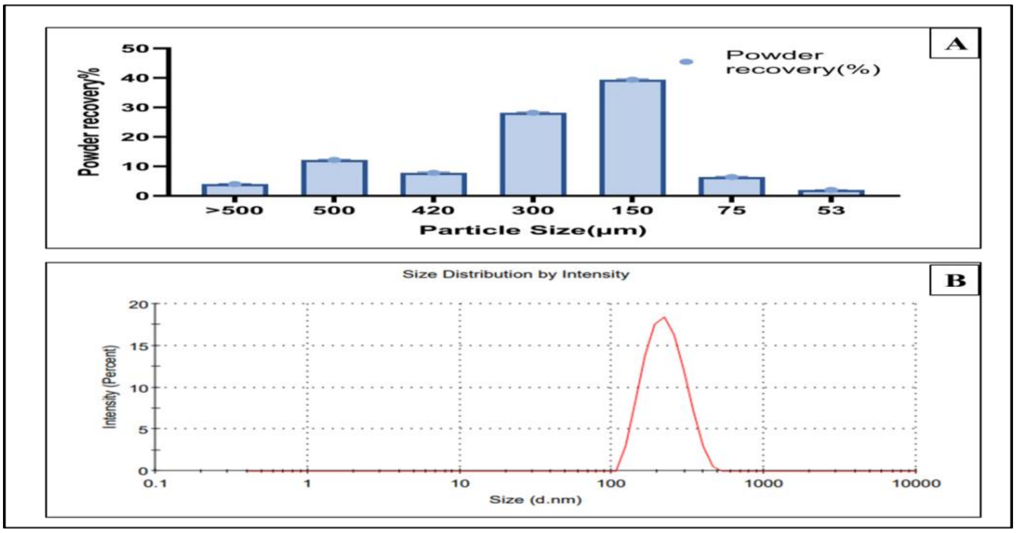


Figure 21: (A) Recovery % of baby corn powder passed through different sieves.
(B) Average particle size of baby corn powder.

6.5.3.3 Bulk and true density

Bulk density (BD) is a critical parameter for characterizing powders, influencing their storage, packaging, processing, and distribution. It is measured prior to compression. As shown in Table 36, there was an inverse relationship between sieve size and BD. The highest BD was observed in baby corn powder sieved through >30 BSS (0.577±0.01 g/cm³) with a particle size of 500 µm, while the lowest BD was found in powder sieved through 300 BSS (0.238±0.01 g/cm³) with a particle size of 53 µm.The observed shift in bulk density from coarser to finer particles is attributed to a combination of factors, primarily the influence of high ash content and low protein content. Finer particles, characterized by higher ash content, introduce mineral components that impede tight packing, resulting in increased volume for given flour mass and subsequently lowering bulk density. Additionally, the lower protein content in finer particles diminishes interparticle cohesion, limiting binding forces that contribute to tight packing. This collaborative effect of high ash content and low protein content in finer particles significantly influences the overall bulk density variation (Mirza et al., 2022; Ahmed et al., 2015). No significant differences were observed initially, but a significant difference ($p \leq 0.05$) was noted from 150 µm (0.356±0.03 g/cm³) to 53 µm (0.238±0.02 g/cm³). Similar findings have been reported by Bala et al., (2020) for grass pea flour and Sun et al., (2019) for kidney bean powder.

Similarly, both bulk density and true/tapped density showed a noticeable decline from 0.602±0.19 g/cm³ to 0.343±0.08 g/cm³ as particle size reduced from >500 µm to 53 µm. This reduction is attributed to particle stickiness during drying and subsequent agglomeration. Initially, there was only a minor difference until 300 µm, but a significant change was observed from 150 µm to 53 µm ($p \leq 0.05$). Additionally, tapped densities were higher than the corresponding bulk densities. Finer particles settle more quickly upon tapping compared to coarser ones due to their greater compactness (Bala et al., 2020). The varying densities suggest different applications for powders, with reduced densities being preferable for developing supplementary foods with a uniform and dense texture (Singh et al., 2022; Bala et al., 2020).

6.5.3.4 Carr index and Hausner ratio

Powder properties like flowability and cohesiveness significantly influenced by particle size distribution (Savlak et al., 2016). The Carr index and Hausner ratio are used to evaluate these characteristics. A lower Hausner ratio indicates better flowability of the powder. The Carr index reflects the powder's compactness and is inversely related to its compatibility. Powders with a Hausner ratio between 1.0 and 1.1 are considered free-flowing, 1.1 to 1.25 as moderately flowing, 1.25 to 1.4 as difficult flowing, and above 1.4 as very difficult flowing (Sotelo et al., 2023). According to the classification, powdered baby corn with particle sizes up to 300 µm, as shown in Table 35, exhibits better flowability compared to finer particles. Powders with sizes between 150 and 53 µm have poorer flowability. Additionally, Carr's index (CI) values ranging from 5 to 15% are considered indicative of excellent flowability and low compressibility (Savlak et al., 2016). For particle sizes from 500 µm to 300 µm, CI values ranged from 8.30% to 15.80% (Table 36), suggesting excellent flowability compared to the finer particle sizes of 150 to 53 µm. The majority of the powder samples fell within this range, indicating that baby corn powder generally has good flowability properties.

6.5.3.5 Angle of repose

The concept of the angle of repose is regarded as a straightforward approach for estimating the fluidity or flowability of powders. This defining angle serves as an indicator of the intrinsic flow characteristics and cohesive tendencies exhibited by food powders, offering valuable insights into how these powders can be managed and processed, enriching our understanding of their behaviour in practical applications (Al-Hashemi et al., 2018).The values observed (Table 36) were as follows: 45.00° (>500 µm), 44.85° (500 µm), 42.51° (420 µm), 40.05° (300 µm), 38.63° (150 µm), 37.83° (75 µm), and 34.48° (53 µm). Notably, a significant difference ($p \leq 0.05$) was discerned in baby corn powder samples, with a decreasing trend observed from coarser to finer particle sizes (Zhao et al., 2015; Singh et al., 2022). This trend aligns with findings from previous studies on ginger powder (Zhao et al., 2015) and corn silk powder (Singh et al., 2022).

Table 36: Physical properties of baby corn powder at different particle sizes

Particle size(µm)	Bulk density(gcm^{-3})	True density (gcm^{-3})	Hausner Ratio (%)	Carr Index (%)	Angle of repose (°)
>500	0.552±0.01^{e}	0.602±0.02^{f}	1.09±0.02^{a}	8.3±0.22^{a}	45.01±0.09^{e}
500	0.510±0.04^{de}	0.569±0.03^{ef}	1.12±0.02^{ab}	10.36±0.22^{b}	44.85±0.13^{e}
420	0.465±0.01^{cd}	0.535±0.02^{de}	1.15±0.03^{bc}	13.08±0.32^{c}	42.51±0.08^{d}
300	0.421±0.02^{c}	0.500±0.01^{cd}	1.19±0.03^{c}	15.8±0.08^{d}	40.05±0.13^{c}
150	0.356±0.02^{b}	0.480±0.02^{c}	1.35±0.03^{d}	25.78±0.32^{e}	38.63±0.73^{b}
75	0.318±0.01^{b}	0.432±0.02^{b}	1.36±0.03^{d}	26.4±0.36^{f}	37.83±0.52^{b}
53	0.238±0.01^{a}	0.343±0.06^{a}	1.44±0.03^{e}	30.48±0.29^{g}	34.49±0.86^{a}
CV %	8.2	5.1	2.4	0.7	1.7
LSD	0.058	0.044	0.052	0.218	1.235

The data is presented as Mean ±Standard Error (n=3).Significant differences between values in a column are indicated by distinct superscripts at a significance level of P <0.05.

6.6 Techno-functional properties of baby corn powder

6.6.1 Water absorption capacity (WAC)

The water absorption capacity (WAC) of powdered baby corn significantly increased ($p \leq 0.05$) from 2.36±0.10 g/g for coarser particles to 8.51±0.01 g/g for finer particles, as shown in Table 37. This notable rise in WAC is likely due to the increased surface area and smaller pore spaces between particles (Ahmed et al., 2015). Additionally, WAC is affected by the presence of carbohydrates and protein structures which are hydrophilic groups present in the powder (Martinez et al., 2022). Similar observations have been made by Singh et al., (2022) on silk of corn and Martinez et al.,2022 on peach peel flour.

6.6.2 Oil absorption capacity (OAC)

Protein, a key component affecting oil absorption capacity (OAC), contains both hydrophilic and hydrophobic regions. Hydrophobic interactions can occur between the non-polar segments of amino acid chains and the hydrocarbon chains of lipids (Chandra et al., 2015). Additionally, OAC depends on the structural geometry of the flour and significantly impacts flavor retention, texture, and shelf life (Coelho et al., 2017). The OAC of powdered baby corn significantly decreased ($p \leq 0.05$) from >500 µm to 500 µm (4.70±0.00 to 4.22±0.01 g/g), then increased significantly from 420 µm to 300 µm. Subsequently, OAC decreased markedly from particle sizes of 150 µm to 53 µm, as shown in Table 37. Ahmed et al. (2015) reported similar results, noting a reduction in OAC for particle sizes ranging from 210 µm to 105 µm.

6.6.3 Foaming capacity (%) and foam stability (%)

A foamy texture is a desirable characteristic in many culinary products, essential for maintaining their optimal texture and structural integrity during production and storage. The formation of foam largely relies on the flexibility of protein molecules, especially surface proteins (Ohizua et al., 2017). Proteins are crucial in forming a continuous, cohesive film around the air bubbles within the foam (Chandra et al., 2015). Additionally, the stability of the foam is influenced by the electrostatic forces between polypeptide and protein molecules. Non-polar residues in proteins enhance the durability of the foam film, whereas polar residues tend to reduce stability (Jitngarmkusol et al., 2008). In this study, the highest foam capacity (FC) was observed in particles sized at 300 µm, with a value of 17.65±0.01% (Table 37). In contrast, the lowest foaming capacity (FC) was observed in particles measuring 53 µm, at 9.8±0.02%. It was found that foam stability significantly decreased ($p \leq 0.05$) with smaller particle sizes. This reduction in stability was consistent across all particle sizes, with values ranging from 17.74±0.01% for larger particles to 10.51±0.02% for smaller ones.

6.6.4 Emulsifying activity (mLg^{-1}) and emulsion stability (%)

Techno-functional properties related to the ability to lower the interfacial tension between oil and water in an emulsion. According to Martinez et al., (2022), these properties are influenced by factors such as the protein and fat composition of the samples, the intensity of the mixing process, the type of oil used, and the emulsification system employed. The data presented in Table 37 shows a significant reduction ($p \leq 0.05$) in both EA and ES as particle sizes decreased from >500 µm to 53 µm.This outcome underscores a significant correlation between particle size and emulsification efficiency, aligning with the findings of Martinez et al., (2022) on peach palm peel flour.

Table 37: Techno-functional properties of baby corn powder at different particle size

Particle size(µm)	**Water absorption capacity (gg^{-1})**	**Oil absorption capacity(gg^{-1})**	**Foaming capacity (%)**	**Foaming stability (%)**	**Emulsifying activity (mLg^{-1})**	**Stability of emulsion (%)**
>500	2.36±0.1[a]	4.70±0.01[g]	11.75±0.01[b]	17.74±0.01	68.41±0.01[f]	57.88±0.02[f]
500	2.42±0.01[a]	4.23±0.02[c]	13.72±0.02[c]	16.4±0.01	68.41±0.01[f]	47.37±0.01[e]
420	3.35±0.01[b]	4.41±0.01[e]	15.69±0.01[d]	16.39±0.01	52.64±0.02[e]	42.11±0.01[d]
300	4.20±0.1[c]	4.48±0.01[f]	17.65±0.01[e]	15±0.01	48.42±0.01[d]	42.11±0.01[d]
150	6.34±0.02[d]	4.19±0.02[b]	11.76±0.02[b]	13.56±0.02	47.37±0.01[c]	38.95±0.02[c]
75	7.96±0.02[e]	4.26±0.01[d]	9.8±0.01[a]	12.07±0.01	42.11±0.02[b]	37.89±0.02[b]
53	8.51±0.01[f]	4.05±0.02[a]	9.8±0.02[a]	10.51±0.02	38.95±0.02[a]	36.84±0.01[a]
CV %	1.1	0.3	0.1	0.1	0.0	0.0
LSD	0.100	0.023	0.018	0.02	0.022	0.029

The data is presented as Mean ±Standard Error (n=3). Significant differences between values in a column are indicated by distinct superscripts (P <0.05).

6.6.5 Bioactive components and Antioxidant activity

Particle size greatly influences antioxidant activity, demonstrated by a notable and statistically significant enhancement ($p \leq 0.05$) in free radical scavenging activity (FRSA)as particle size decreases, as shown in Table 38. The FRSA (%) was lowest for particles larger than 500 µm (38.01±0.01%) and highest for particles measuring 53 µm (38.68±0.02%). Coarser particles had a lower total phenolic content (TPC), whereas finer particles demonstrated an increased ability to extract phenolic compounds. TPC and tannins saw a notable increase, rising from 49.02±0.02 to 50.96±0.04 mg GAE/100 g and from 307.8±4.93 to 410±4.74 mg/100 g, respectively, as particle size decreased from >500 µm to 53 µm (p≤0.05) (Tao et al., 2014; Zhu et al., 2015). Additionally, the decrease in particle size for baby corn powder presented a significant difference (p≤0.05) in FRAP, with values ranging from 124.63±0.03 to 127.03±0.02 µg/mL, as shown in Table 36. The increased FRAP and TPC can be attributed to the finer particles' greater surface area, which enhances the release of bioactive components and boosts overall antioxidant activity (Singh et al., 2020; Botella-Martinez et al., 2021).

Table 38. Bioactive components and antioxidant activity of baby corn powder at various particle sizes

Particle size(µm)	**Flavanoid Content (mgQE/100g)**	**Total Phenol Content (mg GAE/100 g)**	**DPPH (%)**	**FRAP (µg/ml)**	**Tannin Content (mg/100g)**
>500	1.91±0.01[a]	49.02±0.02[a]	38.01±0.01[a]	124.6±0.03[a]	307.8±4.93[a]
500	2±0.01[b]	49.57±0.26[b]	38.27±0.03[b]	125±0.01[b]	316.7±2.37[a]
420	2.07±0.03[c]	49.94±0.03[c]	38.41±0.01[c]	125.1±0.02[c]	315.6±3.62[a]
300	2.22±0.04[d]	50.23±0.02[d]	38.46±0.01[d]	125.2±0.03[d]	342.2±5.96[b]
150	2.35±0.02[e]	50.48±0.03[e]	38.54±0.02[e]	126.1±0.02[e]	373.3±4.74[c]
75	2.42±0.01[f]	50.77±0.02[f]	38.62±0.01[f]	126.4±0.01[f]	396.7±6.26[d]
53	2.55±0.01[g]	50.96±0.03[f]	38.68±0.02[g]	127±0.02[g]	410±4.74[e]
CV %	1.3	0.3	0.1	0.00	1.9
LSD	0.05170	0.2501	0.03705	0.04221	11.88

The data is presented as Mean ±Standard Error derived for triplicate experiments (n=3). Significant differences between values in a column are indicated by distinct superscripts (P <0.05).

6.6.6 PCA & Correlation Analysis:

The primary principal component (PC) accounted for the highest proportion of total variation at 90.1%, while the second PC contributed 5.4% (Fig. 22A). The identified baby corn powder particles were categorized into three distinct clusters: Group I (>500µm, 500µm, 420µm), Group II (300µm), and Group III (150µm, 75µm, 53µm) based on their biochemical and techno-functional characteristics (Fig. 22B). Notably, Group II exhibited isolation from the other groups, potentially attributed to variations in biochemical and techno-functional components, as well as geographical locations. The analysis of PCA variables indicated that phenol content played a major role in the total variation, followed by FRAP, total flavonoid content, and DPPH scavenging activity (Fig. 22B). Correlation analysis (Figure 23) revealed a positive correlation between antioxidant activities (DPPH and FRAP) and phenol (correlation values +0.99 and +0.92; p < 0.01, p < 0.001), flavonoid (correlation values + 0.93 and + 0.97; p < 0.01, p < 0.001), and a negative correlation with carbohydrates (correlation values -0.89 and -0.99; p < 0.01, p < 0.001). Additionally, techno-functional properties (FS) showed a positive correlation with OAC (correlation value +0.78; p < 0.05). Furthermore, (BD and TD) exhibited positive correlations with AOR (correlation values +0.97 and +0.94; p < 0.001, p < 0.01) and negative correlations with CI and HR (correlation values -0.98 and -0.94, p < 0.001, p < 0.01; -0.98 and -0.95; p < 0.001, p < 0.01) respectively, as depicted in the correlation analysis.

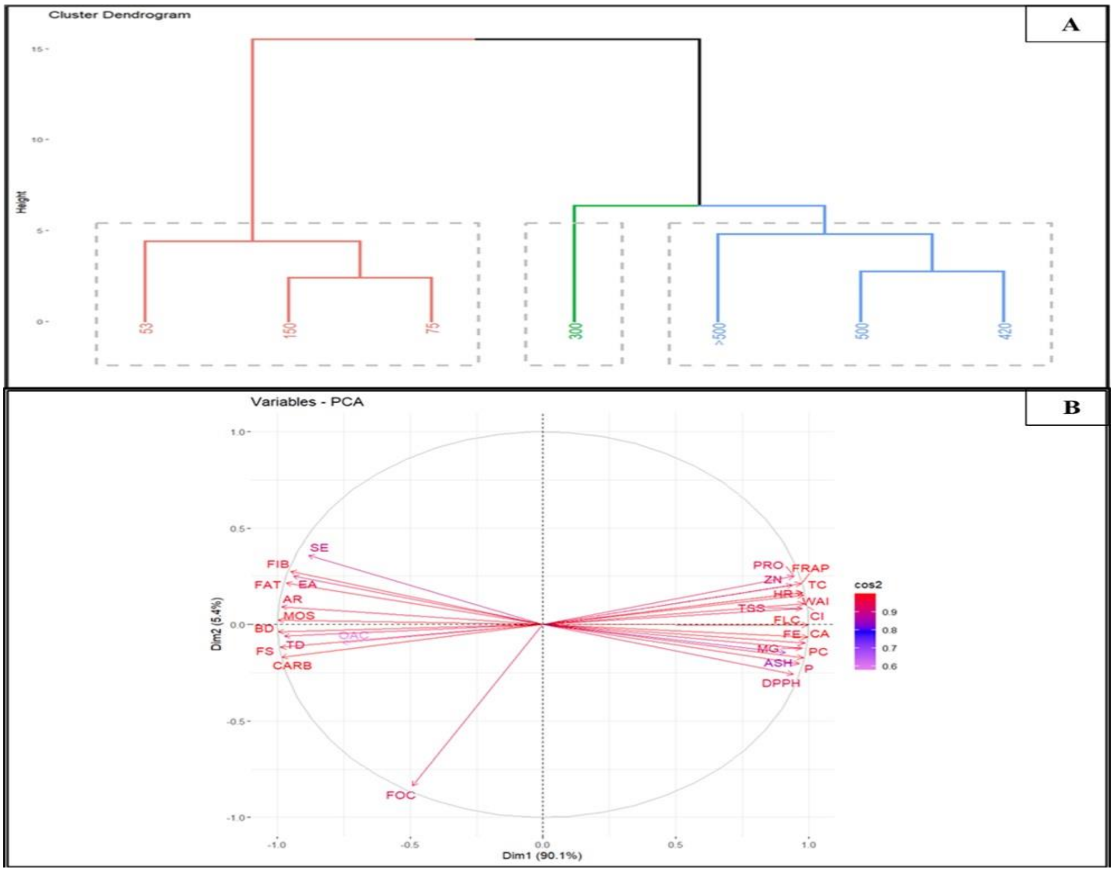


Figure 22: The PCA study of Different particle-sized powders of baby corn. **A).** Cluster Dendrogram of Different particle-sized powders of baby corn where each particle size formed a group based on Physical, Techno-functional, Proximate, mineral

and Antioxidative characteristics. **B).** Variable PCA study of Different particle-sized powders of baby corn with the contribution of different traits based on their mean values. {**BD**: Bulk density(g/cc); **TD**: True density (g/cc); **HR**: Hausner Ratio(%);**CI**: Carr Index (%);**AR**: Angle of Repose(°);**OAC**: Oil absorption capacity(gg^{-1}); **WAI**: Water Absorption index(gg^{-1}); **FOC**: Foaming capacity(%);**FS**: Foaming stability(%);**EA**: Emulsifying activity(mLg^{-1}); **SE**: Stability of emulsion (%);**FC**: Flavonoid content(mgQE/100g); **PC**: Phenol content(mg GAE/100 g); **DPPH**: DPPH(%);**FRAP**: FRAP (µg/ml); **TSS**: Total soluble sugars (g/100g); **TC**: Tannin Content(mg/100g); CA: Ca(mg/100g); **MG**: Mg(mg/100g); **ZN**: Zinc(mg/100g); **FE**: Fe(mg/100g); **P**: P(mg/100g); **PRO**: Protein%; **MOS**: Moisture%; **ASH**: Ash%; **FAT**: Fat %; **CARB**: Carbohydrate%; **FIB**: Fibre%.

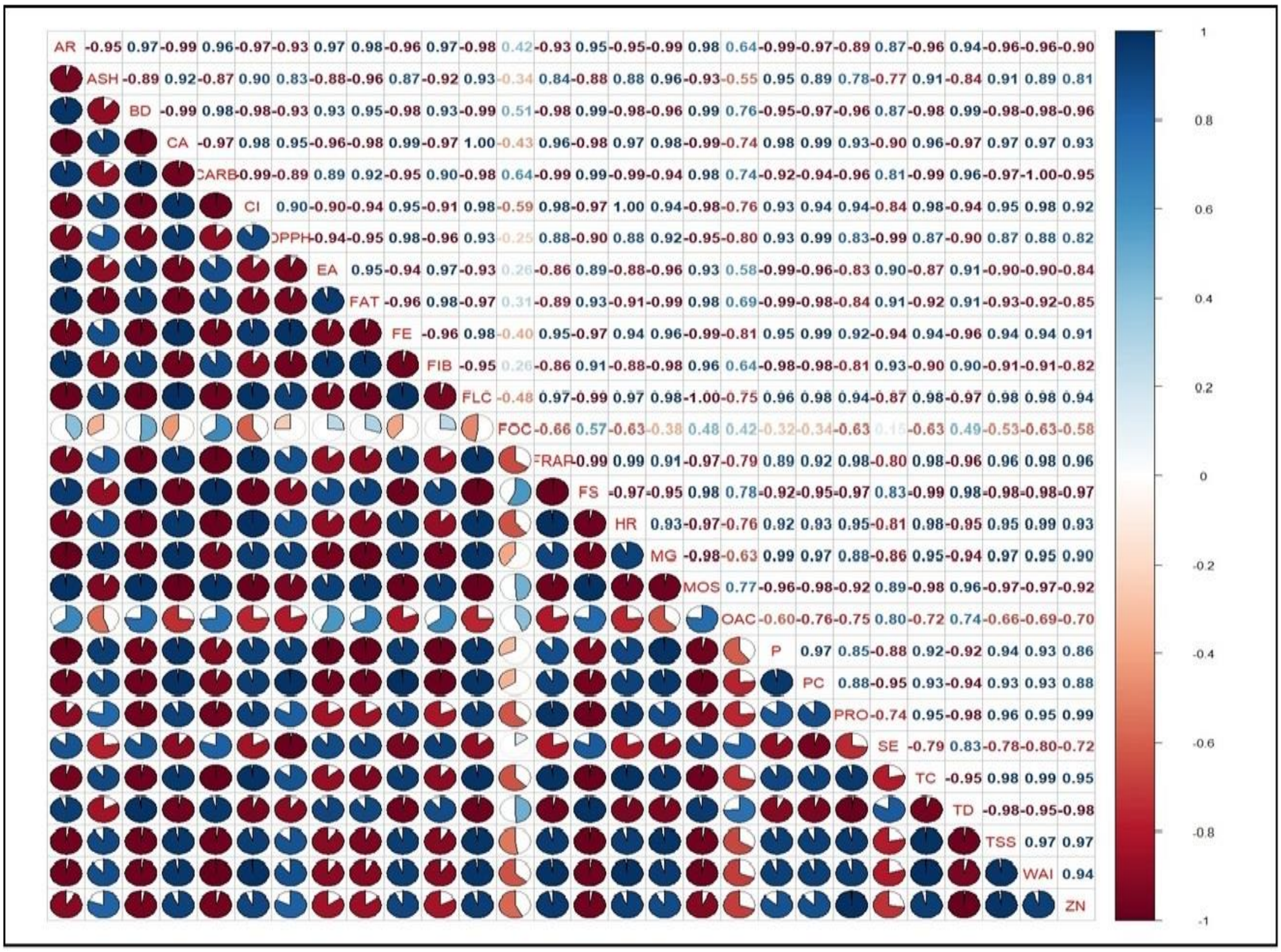


Figure 23: Correlation table of different Physical, Techno-functional, and biochemical Parameters of different particle-sized baby corn powder{ **BD** : Bulk density (g/cc) ; **TD** : True density (g/cc) ; **HR** : Hausner Ratio (%) ; **CI** : Carr Index (%) ; **AR** : Angle of Repose (°) ; **OAC** : Oil absorption capacity (gg^{-1}) ; **WAI** : Water Absorption index (gg^{-1}) ; **FOC** : Foaming capacity (%) ; **FS** : Foaming stability (%) ; **EA** : Emulsifying activity (mLg^{-1}) ; **SE** : Stability of emulsion (%) ; **FLC** : Flavonoid content (mgQE/100g) ; **PC** : Phenol content (mg GAE/100 g) ; **DPPH** : DPPH (%) ; **FRAP** : FRAP (µg/ml) ; **TSS** : Total soluble sugars (g/100g) ; **TC**

: Tannin Content (mg/100g) ; **CA** : Ca(mg/100g) ; **MG** : Mg(mg/100g) ; **ZN** : Zinc(mg/100g) ; **FE** : Fe (mg/100g) ; **P** : P(mg/100g) ; **PRO** : Protein % ; **MOS** : Moisture % ; **ASH** : Ash % ; **FAT** : Fat % ; **CARB** : Carbohydrate % ; **FIB** : Fibre %}.

6.6.7 Scanning electron microscopy (SEM)

The morphological characteristics of baby corn powder across different particle sizes, as examined through Field Emission Scanning Electron Microscopy (FESEM), are illustrated in figure 24. The analysis reveals that the baby corn powder displays an irregular shape with rough granule surfaces. The particles exhibit a close proximity to each other, lacking a distinct pattern. This irregularity in the powder's shape may influence its flow properties (Zhao et al., 2010). Thus, comprehending these properties becomes crucial for selecting applications based on the material's surface characteristics. Moreover, (Fig. 24) illustrates the variation in particle size within the powder samples, including unsieved, 500 µm, 420 µm, 300 µm, and 150 µm. Notably, a substantial difference is observed between the 500 µm and 150 µm particles, suggesting a potentially significant impact on the physical and chemical properties of the powder. Understanding these variations is essential for a comprehensive assessment of the material and its potential applications.

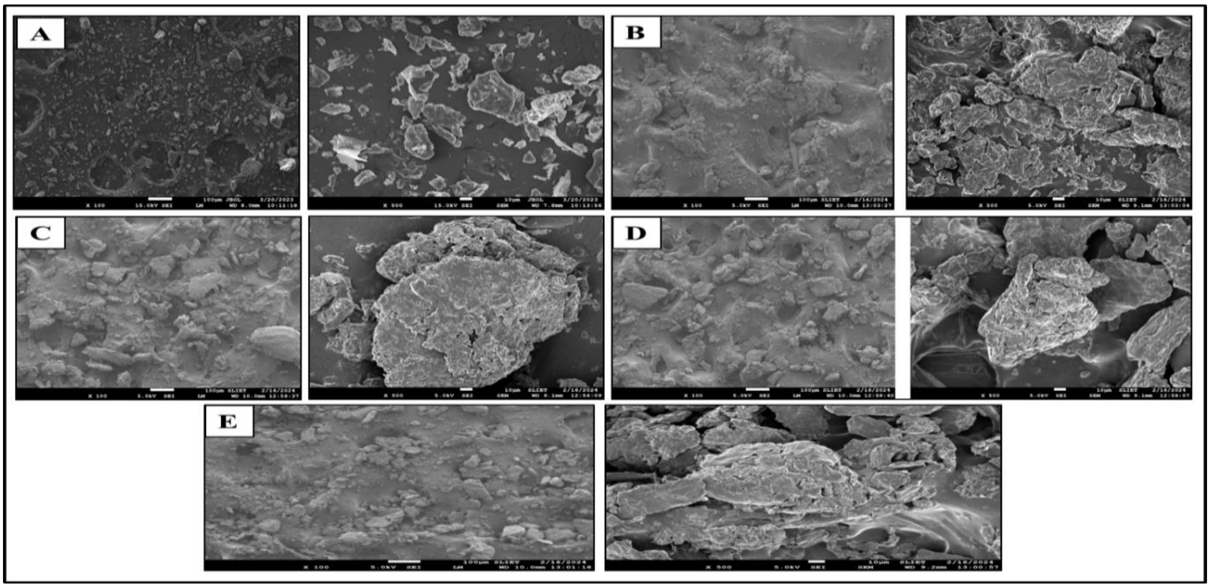


Figure 24. Scanning Electron Micrographs of Baby Corn Powder at 100X and 500X. A).Unseived, **B).** 500 (µm) **C).** 420 (µm) **D).** 300 (µm) **E).**150 (µm) of Baby corn Powder.

Objective 3: To investigate the effect of storage conditions and packaging materials on the quality of baby corn powder.

The microwave blanched (540 W, 30 secs), tray dried (70° C) samples were powdered in the grinder, packaged in three packing materials (LDPE, PP and AL) and stored at room temperature (30°-35°C, RH-72%) and at accelerated conditions (50°C ,RH-80-90%) as presented in Figure 25 and 26. The samples were analysed for proximate, powder, color and microbiological analysis initially at 7 days interval for two weeks and then analysed after every 15 days interval till 104 days.

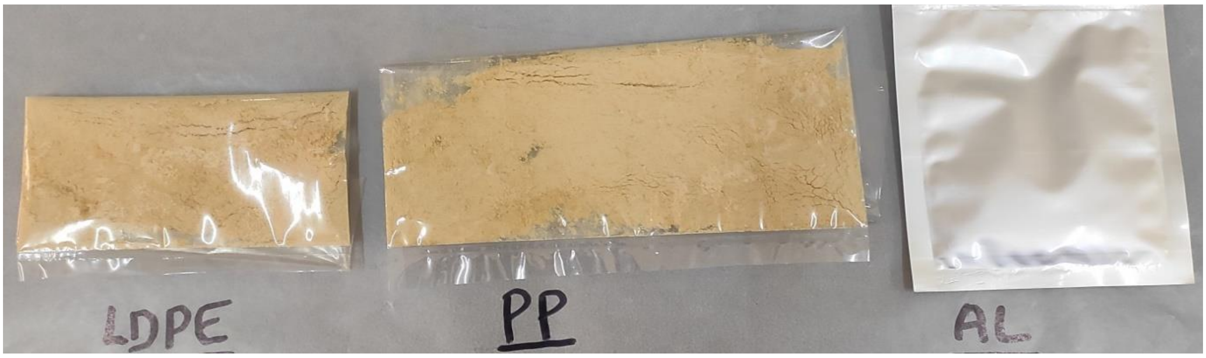


Figure 25. Storage of baby corn powder in LDPE (Low density plyethylene), PP (Polypropylene) and AL (Aluminium laminate)

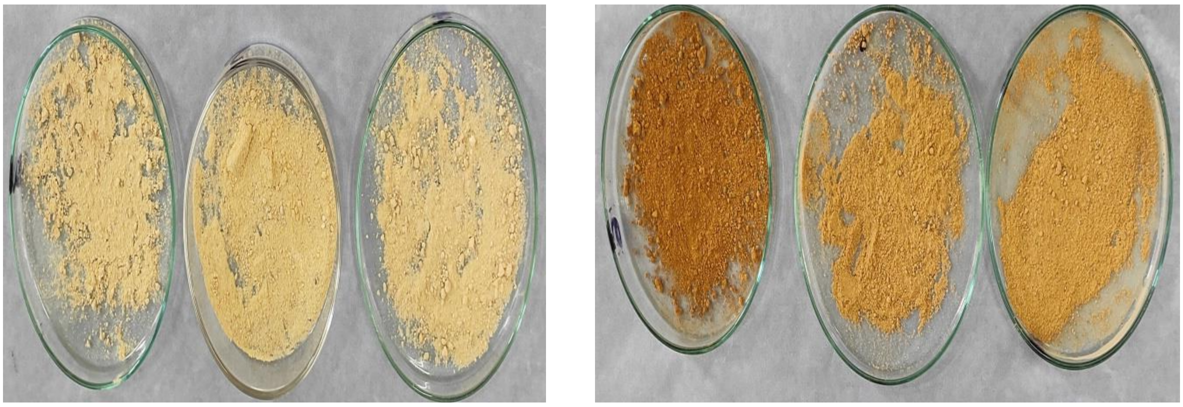


Figure 26. BCP stored at room conditions and accelerated conditions

6.7 Sorption isotherm of baby corn powder

The moisture sorption behavior of baby corn powder at 30 °C, 40 °C, and 50 °C demonstrates a clear temperature-dependent trend. As shown in Figure 27, the isotherms exhibit a sigmoidal curve, characteristic of a Type II sorption isotherm. This type of isotherm consists of three distinct phases: (i) the initial region (water activity 0–0.2), where moisture is tightly bound to the food matrix; (ii) the intermediate region (0.2–0.8 water activity), where moisture uptake occurs due to interactions with food components; and (iii) the final region (above 0.8 water activity), where capillary condensation leads to a sharp increase in moisture content (Arslan-Tontul, 2021).The isotherm features noticeable inflection points around water activity levels of 0.4 and 0.7–0.8, indicating changes in the moisture adsorption mechanism. At a low water activity of 0.21, the equilibrium moisture content (EMC) declines significantly as temperature increases, dropping from 23.25% at 30°C to 15.41% at 40°C and further to 9.80% at 50°C. This reduction suggests that higher temperatures limit the moisture absorption capacity of baby corn powder at the same water activity. However, at higher water activities (0.40, 0.66, 0.75, and 0.82), EMC shows an increasing trend, reinforcing the influence of temperature on moisture adsorption. Similar behavior has been observed in other food powders, including onion powder (Alam and Islam, 2015), tomato pulp powder (Goula et al., 2008), and orange juice powder (Sormoli and Langrish, 2015).

This trend can be attributed to the hydrophilic nature of carbohydrates and proteins in baby corn powder, which enhances water retention at elevated water activity levels (Labuza and Altunakar, 2020). Conversely, as temperature rises at a fixed water activity, EMC decreases due to a reduction in active water-binding sites, likely caused by structural and chemical modifications in the food matrix. Increased temperatures provide water molecules with higher kinetic energy, making them less likely to adhere to binding sites, thus leading to lower EMC values (Labuza and Altunakar, 2020). This behavior indicates that baby corn powder has lower hygroscopicity at higher temperatures (Betiol et al., 2020).Regions II and III of the isotherm are particularly significant in determining storage stability. In these regions, moisture is less tightly bound and primarily retained through capillary forces and the dissolution of soluble components. These factors directly impact the stability and shelf life of baby corn powder (Majid et al., 2019).

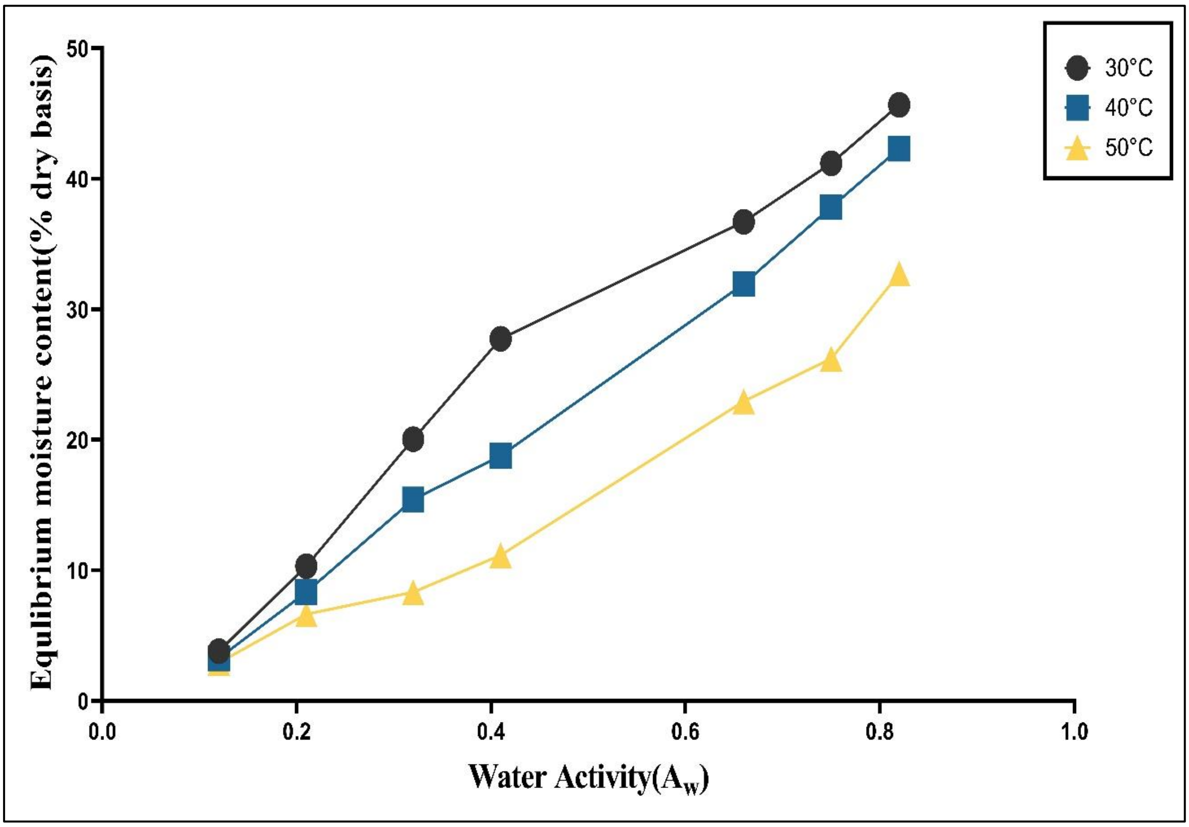


Figure 27. The moisture sorption isotherms of baby corn powder at 30 °C, 40 °C, and 50 °C

Table 39: Estimated coefficients and statistical parameters used to assess the accuracy of isotherm models for baby corn powder at various temperatures

Model	**Parameter**	**30 °C**	**40 °C**	**50 °C**
GAB	Xm	20.11	13.44	9.79
	C	1.819×10^{-43}	1.674×10^{-44}	-2.743×10^{-45}
	K	0.68	0.84	0.90
	R^2	0.99	0.98	0.97
	%RMSE	0.236	2.27	2.29
BET	Xm	9.97	8.80	7.40

	C	-1.96×10^{-46}	1.97×10^{-45}	-8.01×10^{-43}
	R^2	0.99	0.95	0.90
	%RMSE	11.65	6.715	4.04
Oswin	a	83.50	51.38	35.80
	b	-0.28	-0.011	0.123
	%RMSE	5.15	3.08	1.77
	R^2	0.93	0.94	0.98
Caurie	a	2.42	2.36	2.26
	b	2.41	2.30	2.23
	%RMSE	18.99	12.26	8.10
	R^2	0.83	0.80	0.82
Smith	a	1	1	1
	b	1.3	1	1.5
	R^2	0.73	0.70	0.65
	%RMSE	40.28	40.11	33.51

Xeq equilibrium moisture content; **Xm** monolayer moisture content; **C, K** model constants related to the monolayer properties; **a, b** model parameters; **%RMSE** percent root mean squared error; $\mathbf{R^2}$ coefficient of determination

The Table 39 evaluates the performance of five models—GAB, BET, Oswin, Caurie, and Smith, across temperatures of 30°C, 40°C, and 50°C, using R^2 and %RMSE as criteria. At 30°C, the GAB model shows the best fit, with an R^2 of 0.99 and a %RMSE of 0.236. At 40°C, GAB remains the best fitted model, with an R^2 of 0.98 and a %RMSE of 2.27, although the Oswin model is also well fitted with an R^2 of 0.94 and a %RMSE of 3.08. At 50°C, the Oswin model performs the best, achieving an R^2 of 0.98 and the lowest %RMSE of 1.77, surpassing the GAB model, which has an R^2 of 0.97 and a %RMSE of 2.29. Thus, GAB is the most suitable model at lower temperatures, whereas Oswin is the best fit at higher temperatures (Sobowale et al.,2017)

6.8 The effect of storage conditions and packaging materials on Moisture, color and TPC of baby corn powder

The comparison between the room conditions and accelerated conditions tables unveils a consistent trend in the moisture dynamics of the vegetable powder across varying storage scenarios and durations. LDPE consistently presents the highest moisture content among the packaging materials, trailed by PP and AL, indicating LDPE's relatively weaker moisture barrier properties. Both sets of data demonstrate a progressive increase in moisture content over time for all packaging materials, suggesting inevitable moisture permeation through the packaging during storage (Table 40). Notably, the accelerated conditions exhibit slightly higher moisture content compared to room conditions, hinting at an accelerated pace of moisture absorption. These findings underscore the paramount importance of meticulous selection of packaging materials and implementation of effective storage practices to mitigate moisture ingress and uphold the quality and shelf life of the vegetable powder, regardless of storage conditions.

Effect on color values

Color is a crucial factor that catches a consumer's eye when judging food products. As storage time increased, there was a noticeable decline in L* and b* values along with an increase in a* value across all three packaging materials. Among them, LDPE and PP showed more significant color changes compared to AL (Table 40). This shift in color is attributed to the Maillard reaction occurring in the powder samples. The minimal color changes observed in AL-packed powders can be attributed to AL's impermeable nature, which prevents moisture and air from affecting color-changing reactions (Ishrat et al., 2019). This phenomenon aligns with findings from Rai and Chauhan, 2008 on papaya flakes. Statistical analysis (ANOVA) revealed that both storage time and packaging material have a significant ($P<0.05$) impact on the L, a, and b values of baby corn powder.

Effect on Total plate count

The results indicate that the Total Plate Count (TPC) values remained within safe limits throughout the 104-day storage period, demonstrating the microbiological safety of the baby corn powder treatments under both room and accelerated conditions. Moreover, there was a consistent increase in TPC with the progression of storage days from 0 to

104 days, highlighting the potential for microbial growth over time (Table 40). The table illustrates how TPC in vegetable powder varies based on storage duration and conditions. The cryoprotective benefits against nutrients in fruits and vegetables in their dry and powdered forms are advantageous in low-temperature storage when compared to high-temperature storage (Obadina et al., 2018).Higher temperatures and humidity levels, such as 50°C with 80-90% relative humidity, corresponded to higher TPC values compared to milder conditions, like 30°-35°C with 72% relative humidity. Additionally, the choice of packaging material influenced TPC, with Aluminum (AL) packaging maintaining lower values than Low-Density Polyethylene (LDPE) and Polypropylene (PP) packaging, particularly at elevated temperatures. This suggests that AL's barrier properties against moisture and air may inhibit microbial growth more effectively. In conclusion, storage conditions and packaging material significantly impact the microbial quality of vegetable powder, with AL packaging offering superior preservation of product quality over time compared to LDPE and PP.

6.9 The effect of storage conditions and packaging materials on physical properties of baby corn powder

The moisture content plays a pivotal role in determining the quality characteristics of powdered products, influencing aspects such as flowability and storage stability. The densities, encompassing both bulk and true densities, of a food powder are intricately tied to factors like particle size and its distribution (Barbosa-Canovas et al., 2005). It's generally unfavourable for a product to exhibit lower bulk densities, as this necessitates a larger volume of packaging. Moreover, lower bulk densities lead to higher levels of occluded air within the powders, which can increase the likelihood of product oxidation, consequently diminishing storage stability (Goula and Adamopoulos, 2008, Kurozawa et al., 2009).Observatons as depicted in table (41) indicate an increase in bulk density over the storage time. This increase in BD may be attributed to the augmented moisture content of the powder during storage, potentially stemming from increased water absorption from the surrounding environment through the packaging material. Consequently, this can induce the formation of agglomerates or lumps within the powder, contributing to an increase in density and porosity. Higher bulk densities of flours imply their suitability for use in food preparations, whereas lower bulk densities might be advantageous in formulating complementary foods (Suresh and Samsher, 2013).

Similarly, table (41) shows a decline in true density during storage can be ascribed to various underlying factors. Primarily, the degradation or decomposition of materials over time may cause the breakdown of molecular structures or the loss of components, leading to a reduction in mass and subsequently true density (Oginni, 2014). Additionally, the uptake of moisture from the surrounding environment, particularly by polymers like LDPE, PP, and AL, can result in an expansion of volume without a commensurate increase in mass, thereby diminishing true density. Additionally, it was noted that the angle of repose increased with storage. The angle of repose (AOR), denoted as α, serves as a valuable indicator for assessing the flowability of food powders. Powders exhibiting α values falling within the range of 45° to 55° are typically categorized as 'cohesive' (Woldemariam et al., 2021). These properties hold significance in various commercial applications, particularly in the design and operation of systems for handling, processing, storage, and transportation. Ensuring an appropriate angle of repose helps mitigate potential issues such as sticking and agglomeration (Owolarafe et al., 2007; Kashaninejad et al., 2006).

6.10 The effect of storage conditions and packaging materials on powder or technofunctional properties of baby corn powder

Throughout the storage period, vegetable powders undergo dynamic changes in moisture content, a phenomenon influenced by the ambient humidity levels (Tehrany and Sonneveld, 2010). The Table 42 offers a detailed exploration of the technofunctional attributes of baby corn powder under diverse storage circumstances and with various packaging materials. Over the different storage durations and environmental settings, fluctuations are evident in properties such as foaming capacity, foaming stability, emulsifying activity, and stability of emulsion, indicating their sensitivity to environmental variables (Barbosa-Canovas et al., 2005). Particularly noteworthy is the trend toward diminished properties at elevated temperatures and humidity levels, hinting at potential alterations or degradation of the powder over time (Goula and Adamopoulos, 2008). Moreover, the choice of packaging material seems to influence the magnitude of these fluctuations, with LDPE and PP demonstrating more pronounced declines compared to AL. Nevertheless, attributes such as oil absorption capacity and water absorption index exhibit relatively consistent levels, highlighting their resilience to variations in storage conditions and packaging materials (Woldemariam et al., 2021). Overall, these insights emphasize the critical importance of meticulously managing storage conditions and carefully selecting packaging materials to preserve the desired technofunctional qualities of baby corn powder across diverse applications within the food industry (Owolarafe et al., 2007).

Table 40: The effect of storage conditions and packaging materials on Moisture, color and TPC of baby corn powder

Storage days	Temperature of storage	Packaging material	Moisture (%)	Color (L*)	Color (a*)	Color (b*)	TPC (10^5 g/CFU)
0th day	30°-35°C, RH-72%	AL	10.5±0.2	70.63±0.057	5.6±0.01	39.8±0.05	25±2
		LDPE	10.5±0.2	70.63±0.057	5.6±0.02	39.8±0.06	25±2
		PP	10.5±0.2	70.63±0.057	5.6±0.01	39.8±0.02	25±1
	50°C ,RH-80-90%	AL	10.5±0.3	70.63±0.05	5.6±0.01	39.8±0.02	25±2
		LDPE	10.5±0.3	70.63±0.06	5.6±0.02	39.8±0.01	25±2
		PP	10.5±0.3	70.63±0.05	5.6±0.01	39.8±0.02	25±1
7th day	30°-35°C, RH-72%	AL	10.5±1	67.9±0.05	5.83±0.06	32.8±0.01	28±2
		LDPE	11.02±0.08	66.97±0.05	5.73±0.05	36.13±0.06	28±2
		PP	10.8±0.05	67.67±0.03	5.66±0.06	34.9±0.01	28±3
	50°C ,RH-80-90%	AL	10.5±0.3	65.13±0.05	5.73±0.05	32.57±0.06	28±1
		LDPE	11.2±0.4	62.33±0.06	5.86±0.04	36.03±0.05	35±3
		PP	11.03±0.45	63.03±0.06	5.77±0.05	33.93±0.06	31±2
14th day	30°-35°C, RH-72%	AL	12.6±0.2	66.46±0.05	5.86±0.05	30.9±0.01	25±2
		LDPE	14.5±0.3	62.2±0.01	5.8±0.01	35.8±0.1	30±3
		PP	13.9±0.4	62.93±0.05	5.77±0.05	33.53±0.05	27±1
	50°C ,RH-80-90%	AL	11±0.5	64.53±0.05	5.93±0.05	30.16±0.05	29±2
		LDPE	11.7±0.2	55.73±0.05	6.4±0.01	34.2±0.01	37±1
		PP	11.4±0.4	57.9±0.01	6±0.02	32.13±0.05	33±3
29th day	30°-35°C, RH-72%	AL	11±0.5	64.4±0.02	6.4±0.01	28.46±0.05	27±3

		LDPE	11.9±0.6	61.1±0.01	5.83±0.05	33.03±0.06	36±2
		PP	11.4±0.2	61.7±0.01	6±0.01	30.46±0.05	29±4
	50°C ,RH-80-90%	AL	11.4±0.2	56.53±0.06	6.33±0.05	25.56±0.06	33±2
		LDPE	12.03±0.45	48.76±0.06	6.9±0.01	29.17±0.06	47±3
		PP	11.7±0.2	54.3±0.01	6.66±0.06	27.8±0.01	38±3
44th day	30°-35°C, RH-72%	AL	11.2±0.2	64.26±0.05	6.8±0.01	28.2±0.01	28±2
		LDPE	12.3±0.1	59.76±0.06	6.17±0.06	33.3±0.02	38±2
		PP	11.8±0.4	60.7±0.02	6.53±0.06	29.23±0.05	30±3
	50°C ,RH-80-90%	AL	11.7±0.3	56.3±0.02	6.53±0.05	23.23±0.06	46±1
		LDPE	12.7±0.19	47.83±0.06	6.93±0.06	26.3±0.01	50±2
		PP	12.3±0.2	48.83±0.05	6.77±0.04	25.16±0.05	52±2
59th day	30°-35°C, RH-72%	AL	11.4±0.25	61.36±0.05	6.77±0.05	25.33±0.06	45±2
		LDPE	12.7±0.2	55.8±0.01	6.23±0.05	29.3±0.01	53±4
		PP	12.22±0.23	60.36±0.05	6.66±0.06	27.03±0.05	49±4
	50°C ,RH-80-90%	AL	12±0.3	54.2±0.01	6.73±0.05	22.03±0.06	48±4
		LDPE	13±0.3	46.23±0.05	7.2±0.01	22.96±0.05	58±3
		PP	12.8±0.2	47.3±0.01	6.96±0.06	22.86±0.05	51±3
74th day	30°-35°C, RH-72%	AL	11.73±0.25	57.97±0.05	6.93±0.06	24.66±0.06	48±3
		LDPE	13.33±0.06	53.8±0.01	6.76±0.05	28.1±0.01	59±2
		PP	12.5±0.2	57.36±0.06	6.85±0.05	25.8±0.02	53±4
	50°C ,RH-80-90%	AL	12.4±0.2	52.53±0.06	6.96±0.05	23.9±0.03	52±2
		LDPE	13.66±0.25	32.4±0.01	7.46±0.04	22.6±0.02	62±2

		PP	13.2±0.4	46.26±0.05	7.53±0.05	21.56±0.05	57±4
89th day	30°-35°C, RH-72%	AL	12.03±0.15	52.53±0.05	6.96±0.05	23.9±2	52±2
		LDPE	13.8±0.5	50.26±0.06	6.86±0.06	26.77±0.06	64±3
		PP	13±0.3	51.23±0.25	6.9±0.05	24.26±0.05	58±4
	50°C ,RH-80-90%	AL	13±0.1	46.4±0.01	7.23±0.05	20.77±0.05	55±2
		LDPE	14.3±0.3	32.4±0.02	7.6±0.01	22±0.01	70±3
		PP	13.66±0.25	46.26±0.05	7.43±0.04	21.96±0.05	63±2
104th day	30°-35°C, RH-72%	AL	12.6±0.2	48.56±0.05	7.03±0.05	23.03±0.06	57±3
		LDPE	14.5±0.3	41.86±0.06	6.8±0.1	26.13±0.05	75±3
		PP	13.9±0.4	45.8±0.01	6.96±0.06	23.86±0.06	65±2
	50°C ,RH-80-90%	AL	13.5±0.1	43.63±0.06	7.4±0.01	20.03±0.05	60±2
		LDPE	14.9±0.5	28.2±0.01	7.76±0.06	21.86±0.05	78±3
		PP	14.2±0.4	43.4±0.02	7.53±0.04	21.56±0.06	70±3

Table 41. The effect of storage conditions and packaging materials on the physical properties of baby corn powder

	Bulk density			**True Density**		**Angle of Repose**	
DAYS	**Packaging material**	**Room conditions**	**Acc. Conditions**	**Room conditions**	**Acc. Conditions**	**Room conditions**	**Acc. Conditions**
0	**LDPE**	0.552	0.552	0.602	0.602	39.85	39.85
0	**PP**	0.552	0.552	0.602	0.602	39.85	39.85
0	**AL**	0.552	0.552	0.602	0.602	39.85	39.85
7	**LDPE**	0.545	0.545	0.600	0.588	39.92	40.01
7	**PP**	0.545	0.545	0.600	0.588	39.89	39.95

7	**AL**	0.545	0.545	0.601	0.600	39.87	39.90
14	**LDPE**	0.528	0.513	0.571	0.556	39.98	40.53
14	**PP**	0.531	0.529	0.576	0.566	39.91	40.32
14	**AL**	0.541	0.538	0.588	0.577	39.90	40.03
29	**LDPE**	0.462	0.441	0.545	0.517	40.16	41.28
29	**PP**	0.476	0.462	0.556	0.526	39.98	40.72
29	**AL**	0.492	0.484	0.577	0.556	39.93	40.21
44	**LDPE**	0.429	0.395	0.540	0.501	40.45	42.79
44	**PP**	0.441	0.406	0.542	0.510	40.02	41.05
44	**AL**	0.462	0.441	0.568	0.545	39.99	40.83
59	**LDPE**	0.411	0.380	0.500	0.484	40.52	43.60
59	**PP**	0.423	0.390	0.517	0.500	40.18	41.98
59	**AL**	0.441	0.435	0.566	0.517	40.06	41.11
74	**LDPE**	0.400	0.366	0.476	0.455	40.89	44.16
74	**PP**	0.411	0.375	0.492	0.476	40.32	42.13
74	**AL**	0.429	0.429	0.545	0.500	40.16	41.85
89	**LDPE**	0.385	0.353	0.448	0.435	41.12	45.03
89	**PP**	0.400	0.366	0.476	0.455	40.52	43.16
89	**AL**	0.411	0.400	0.536	0.484	40.26	42.23
104	**LDPE**	0.337	0.333	0.417	0.400	41.83	46.54
104	**PP**	0.353	0.345	0.455	0.435	40.89	45.82
104	**AL**	0.361	0.356	0.517	0.469	40.41	42.65

Table 42. The effect of storage conditions and packaging materials on the technofunctional properties of baby corn powder

Storage days	Temperature of storage	Packaging material	Oil absorption capacity(gg^{-1})	Water Absorption index (gg^{-1})	Foaming capacity (%)	Foaming stability (%)	Emulsifying activity(mLg^{-1})	Stability of emulsion (%)
0th day	30°-35°C, RH-72%	AL	0.552±0.001	0.602±0.005	17.65±0.005	17.74±0.02	47.37±0.03	38.95±0.02
		LDPE	0.552±0.001	0.602±0.001	17.65±0.001	17.74±0.01	47.37±0.02	38.95±0.03
		PP	0.552±0.002	0.602±0.002	17.65±0.001	17.74±0.02	47.37±0.01	38.95±0.04
	50°C , RH-80-90%	AL	0.552±0.004	0.602±0.004	17.65±0.03	17.74±0.01	47.37±0.02	38.95±0.03
		LDPE	0.552±0.003	0.602±0.003	17.65±0.02	17.74±0.02	47.37±0.05	38.95±0.01
		PP	0.552±0.001	0.602±0.004	17.65±0.03	17.74±0.03	47.37±0.03	38.95±0.03
7th day	30°-35°C, RH-72%	AL	0.544±0.001	0.6±0.001	18.52±0.02	17.92±0.02	47.32±0.04	35.33±0.04
		LDPE	0.544±0.002	0.601±0.004	17.77±0.02	17.8±0.03	47.03±0.03	30.06±0.03
		PP	0.544±0.002	0.599±0.001	17.86±0.02	17.87±0.01	47.22±0.03	32.11±0.04
	50°C , RH-80-90%	AL	0.545±0.002	0.602±0.002	18.42±0.03	17.86±0.03	47.21±0.04	34.18±0.05
		LDPE	0.545±0.003	0.587±0.002	17.58±0.02	17.78±0.02	46.95±0.02	28.53±0.04
		PP	0.544±0.001	0.587±0.004	17.8±0.01	17.83±0.02	47.01±0.05	31.34±0.04
14th day	30°-35°C, RH-72%	AL	0.541±0.003	0.576±0.003	19.04±0.03	17.98±0.01	47.01±0.04	33.12±0.01
		LDPE	0.528±0.001	0.606±0.002	17.99±0.03	17.87±0.02	45.57±0.01	25.66±0.03
		PP	0.53±0.002	0.571±0.003	18.11±0.01	17.92±0.01	47±0.03	28.16±0.3
	50°C ,	AL	0.538±0.001	0.576±0.002	18.98±0.01	17.92±0.05	46.94±0.05	33.47±0.03

	RH-80-90%							
		LDPE	0.513±0.003	0.556±0.003	17.95±0.03	17.83±0.01	46.05±0.04	27.13±0.04
		PP	0.529±0.003	0.566±0.004	18.01±0.02	17.86±0.03	46.74±0.03	30.06±0.01
29th day	30°-35°C, RH-72%	AL	0.491±0.001	0.556±0.002	16.32±0.02	16.67±0.02	46.81±0.04	30.37±0.05
		LDPE	0.461±0.001	0.588±0.001	15.15±0.03	14.33±0.03	45.84±0.02	23.75±0.03
		PP	0.475±0.002	0.545±0.002	15.76±0.02	15.87±0.03	46.53±0.04	26.47±0.04
	50°C , RH-80-90%	AL	0.484±0.004	0.555±0.003	16±0.03	16.33±0.04	46.62±0.03	25.43±0.4
		LDPE	0.441±0.004	0.516±0.005	14.98±0.01	13.98±0.04	45.53±0.01	17.77±0.04
		PP	0.462±0.005	0.526±0.003	15.13±0.01	15.04±0.03	46.17±0.02	20.04±0.04
44th day	30°-35°C, RH-72%	AL	0.462±0.004	0.542±0.001	15.85±0.04	15.97±0.01	40.32±0.05	26.53±0.01
		LDPE	0.429±0.002	0.577±0.001	14.32±0.03	13.98±0.02	33.1±0.02	13.56±0.04
		PP	0.441±0.005	0.54±0.004	14.82±0.01	15.08±0.03	36.71±0.05	19.32±0.01
	50°C , RH-80-90%	AL	0.441±0.003	0.544±0.001	15.73±0.02	15.83±0.05	40.11±0.04	23.65±0.02
		LDPE	0.395±0.003	0.501±0.001	14.01±0.02	13.02±0.04	30.03±0.06	12.2±0.03
		PP	0.406±0.002	0.509±0.003	14.53±0.03	14.62±0.04	32.34±0.04	15±0.02
59th day	30°-35°C, RH-72%	AL	0.44±0.002	0.516±0.002	15.12±0	15.53±0.04	28.45±0.03	24.65±0.03
		LDPE	0.411±0.005	0.567±0.002	13.88±0.02	13.11±0.02	16.83±0.02	10.74±0.03
		PP	0.423±0.003	0.5±0.003	14.12±0.03	14.62±0.04	20.11±0.04	17.48±0.04
	50°C , RH-80-90%	AL	0.436±0.003	0.516±0.003	14.93±0.04	15.37±0.02	26.32±0.04	22.35±0.03
		LDPE	0.38±0.004	0.483±0.003	13.32±0.03	12.53±0.01	15.78±0.05	10.38±0.04
		PP	0.39±0.003	0.5±0.003	13.73±0.01	13.79±0.03	20.03±0.05	13.46±0.04

74th day	30°-35°C, RH-72%	AL	0.429±0.002	0.429±0.003	14.65±0.03	14.98±0.01	20.33±0.03	22.22±0.03
		LDPE	0.4±0.005	0.566±0.003	13.11±0.02	12.73±0.04	14.28±0.04	9.05±0.03
		PP	0.411±0.001	0.475±0.003	13.72±0.03	14.1±0.03	15.79±0.03	15.78±0.05
	50°C , RH-80-90%	AL	0.429±0.003	0.5±0.003	14.33±0.03	14.88±0.02	22.21±0.02	21.07±0.03
		LDPE	0.366±0.002	0.455±0.002	12.72±0.02	12.01±0.04	12.63±0.05	9.8±0.03
		PP	0.374±0.002	0.475±0.004	13.08±0.02	13.12±0.03	16.18±0.03	10.48±0.04
89th day	30°-35°C, RH-72%	AL	0.411±0.002	0.476±0.003	14.01±0.25	14.36±0.03	17.79±0.04	17.78±0.04
		LDPE	0.385±0.003	0.545±0.003	12.85±0.001	12.07±0.02	11.43±0.03	6.83±0.06
		PP	0.4±0.001	0.448±0.001	12.89±0.15	13.62±0.02	12.2±0.02	11.11±0.01
	50°C , RH-80-90%	AL	0..400±0.002	0.483±0.002	13.98±0.03	14.23±0.02	20.43±0.03	15.88±0.04
		LDPE	0.353±0.003	0.435±0.004	12.03±0.02	11.3±0.02	10±0.03	6.11±0.04
		PP	0.366±0.001	0.455±0.004	12.54±0.02	12.43±0.01	14.28±0.04	11.02±0.02
104th day	30°-35°C, RH-72%	AL	0.361±0.003	0.455±0.002	13.54±0.02	14.02±0.01	15.3±0.04	15.78±0.03
		LDPE	0.337±0.001	0.535±0.001	11.02±0.015	10.71±0.01	6.66±0.02	4.83±0.04
		PP	0.352±0.004	0.416±0.004	12.01±0.025	12.73±0.02	9.8±0.04	9.52±0.1
	50°C , RH-80-90%	AL	0.355±0.002	0.469±0.001	13.52±0.03	13.86±0.02	15±0.06	14.02±0.03
		LDPE	0.333±0.003	0.4±0.006	10.03±0.02	10.01±0.02	4.9±0.03	4.72±0.02
		PP	0.344±0.1	0.435±0.004	11.96±0.1	11.53±0.04	9.5±0.04	8.43±0.04

Objective 4: To incorporate the developed powder in a food model.

6.11 Characterisation of baby corn powder

Average particle size of baby corn powder : Refer to 6.5.3.2

Differential Scanning Calorimeter (DSC)

The Differential Scanning Calorimeter (DSC) serves as a sophisticated thermal analysis instrument, quantifying alterations in the physical characteristics of a specimen over time, in tandem with temperature variations. In essence, this apparatus meticulously assesses temperature and the associated heat transfer throughout material phase transitions, considering both time and temperature as key parameters. While tracking temperature fluctuations, DSC gauges the thermal energy exchange, characterized by heat emission or absorption, differentiating between the sample and a reference material, based on their respective temperature differentials (Gill et al., 2010).Figure 28 summarise the DSC parameters obtained for endothermic reaction at onset temperature (29.55°C) and end temperature 100.31°C.

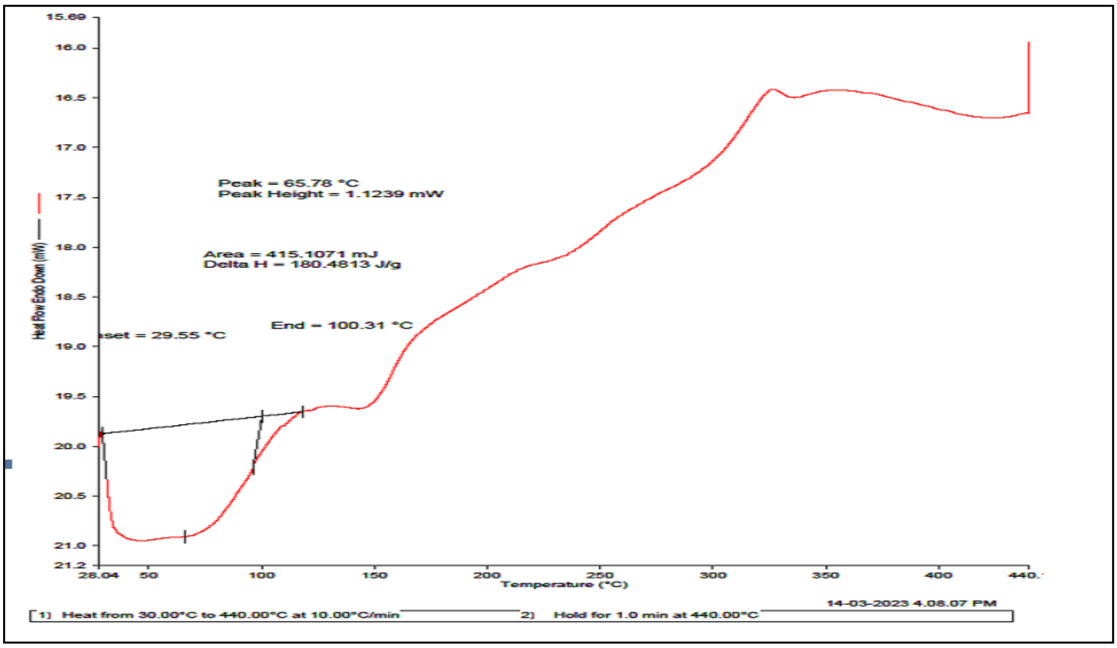


Figure 28. DSC thermograph of baby corn powder

Thermogravimetric analysis (TGA)

Thermogravimetric analysis (TGA) is a thermal analytical technique that monitors variations in a sample's mass over time while subjecting it to changing temperatures. Its primary purpose is to assess the thermal stability of the material under examination (Palanisamy et al., 2020). A plot derived from the TGA curve, referred to as the Differential Thermogravimetric (DTG) curve, elucidates the rate at which mass alterations transpire and presents the relationship between temperature and the rate of mass loss. Changes in sample mass can be attributed to various processes, encompassing evaporation, desiccation, desorption, adsorption, sublimation, and thermal decomposition as depicted in figure 29, the total loss was found to be 98.07%.

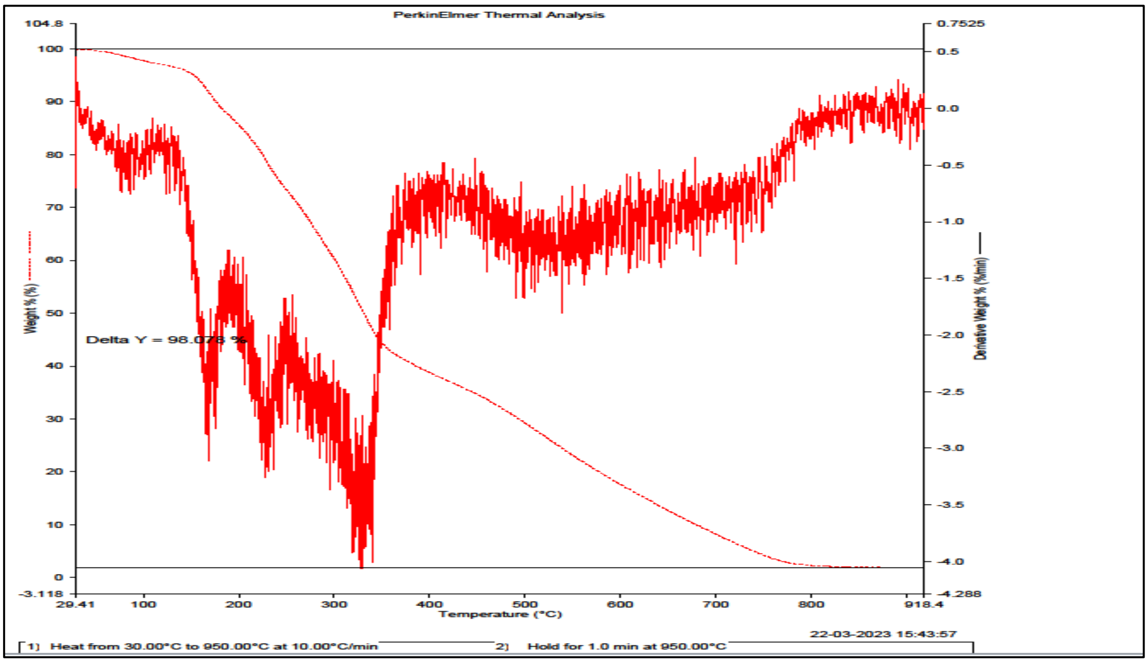


Figure 29 . Thermogravimetric analysis (TGA) curve for the baby corn powder

Morphological structure of powder

Scanning electron microscopy (SEM) was employed to examine the cellular structures of baby corn powder, revealing intricate granular formations. This technique plays a crucial role in elucidating the detailed morphology of powders. The particles of baby corn powder were found to be closely packed ogether, devoid of any discernible shape, as illustrated in Figure 30

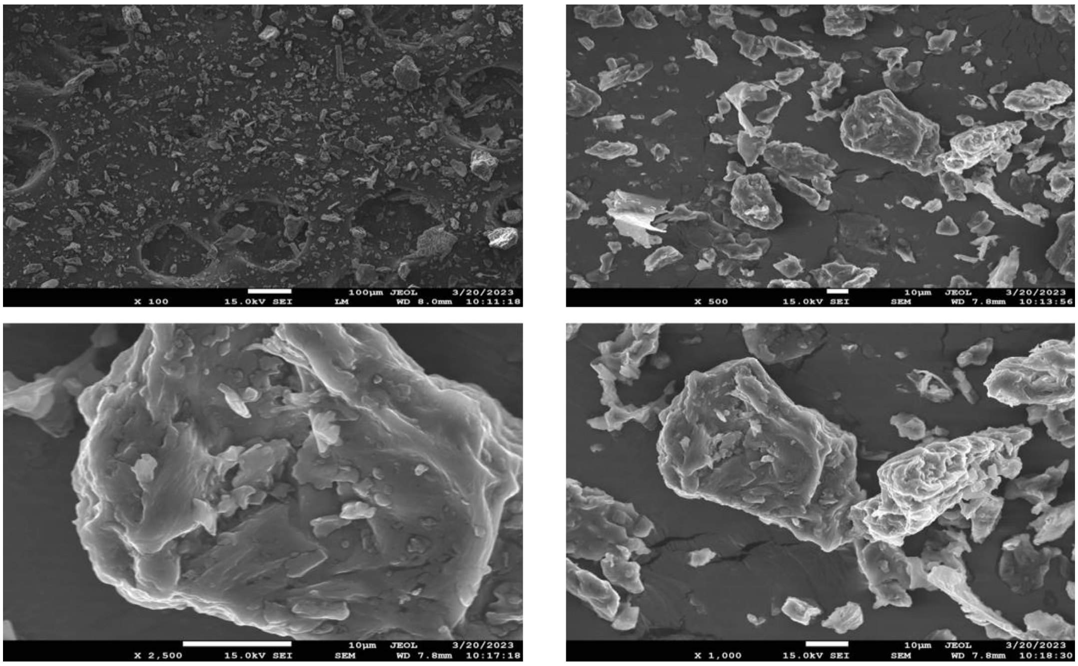


Figure 30. Morphological structure of baby corn powder.

6.12. Development of muffins incorporated with baby corn powder

The baby corn powder acquired was integrated into muffin formulation (figure 31) to elevate its nutritional content, particularly in terms of dietary fiber. Variations of 0%, 10%, 20%, and 30% of baby corn powder were meticulously incorporated. The resulting muffins underwent a comprehensive evaluation encompassing measurements of moisture content, total ash, fat levels, overall dietary fiber, protein, textural characteristics, and sensory analysis. Expert panelists employed a precise 9-point hedonic scale to assess the developed product across various quality attributes (Suparat, 2009).

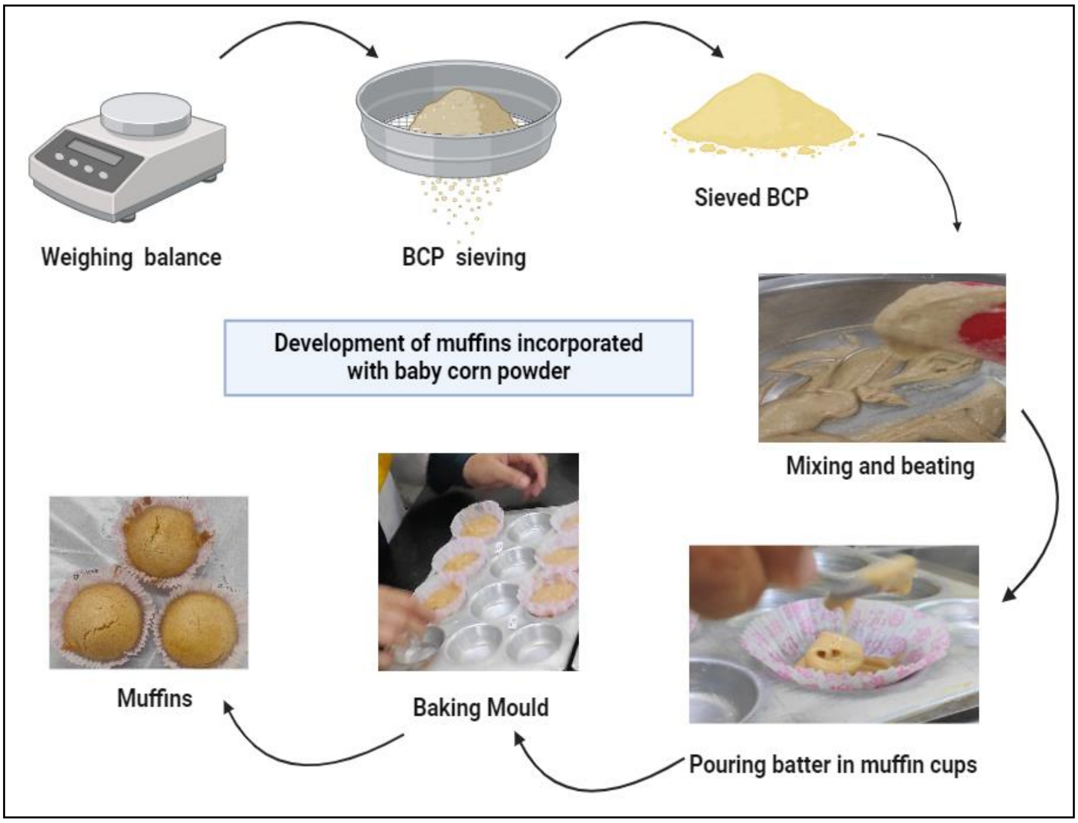


Figure 31. Baby corn powder incorporated muffins

6.12.1 Physical characteristic of muffins

Weight, height and diameter of muffins

The table 43 provided presents the physical characteristics of muffins with varying levels of Baby Corn Powder (BCP), focusing on fiber enrichment. The treatments represent different ratios of wheat flour (WF) to BCP, with the control having no BCP (100:0) and subsequent treatments containing increasing proportions of BCP (10, 20 and 30%). As the proportion of BCP increases from T_1 to T_3, there's a clear trend of decreasing muffin weight, height, and diameter compared to the control. This reduction in weight suggests a decrease in overall muffin density, likely due to the lower caloric density of BCP compared to wheat flour (Howarth et al., 2001).The decrease in height and diameter indicates potential impacts on the rising ability and expansion of the muffins during baking, possibly due to factors such as the absence of gluten in BCP or its influence on batter consistency. These findings align with previous research studies on fiber enrichment in baked goods (Cauvain, 2016).The increasing fiber content led to reductions in muffin height and diameter, supporting the observed trends in the presented table (Adsare and Annapure, 2024). Additionally, research by Ramya and Anhita, 2020 reported similar trends of decreased weight with increased fiber content in muffins. Typically, incorporating fiber into bakery ingredients results in a decrease in both the volume and height of the finished product as reported by Grigelmo-Miguel et al., (2001) observed comparable outcomes when they substituted part of the oil in the formulation with peach dietary fiber.

Table 43. Physical characteristics of muffins with different levels of BCP (Fibre enriched)

Treatments (WF:BCP)	Weight(g)	Height(cm)	Diameter(cm)
Control (100:0)	54.02±0.02[a]	2.5±0.2[a]	5.97±0.06[a]
T1 (90:10)	52.02±0.01[b]	2.3±0.2[ab]	5.6±0.1[a]
T2 (80:20)	52.03±0.02[b]	2.1±0.1[bc]	4.6±0.37[b]
T3 (70:30)	52.03±0.03[b]	1.87±0.12[c]	4.17±0.16[c]

Results are expressed as means of triplicate ± standard deviation. Identical letters within a column denote no significant differences ($p < 0.05$).

6.12.2 Proximate composition of muffins with different levels of BCP

The table 44 illustrates the outcomes of a study investigating the impact of integrating baby corn powder into muffin, with each treatment identified by the ratio of wheat flour (WF) to baby corn powder (BCP) utilized. As the proportion of BCP increases, there is a discernible increase in moisture content from T_0 (27.83± 0.41) to T_3 (29.30 ± 0.21), likely attributed to the moisture-retaining characteristics inherent in baby corn powder and presence of appreciable content of dietary fibre (Jauharah et al., 2014,Rosli and Anas,2012). Nasar and Jayasena (2012) suggested that increased levels of dietary fiber can aid in preserving moisture by impeding evaporation during the baking process. Likewise, comparable rises in moisture content were noted in bread samples crafted with alternative natural components like breadnuts flour (Malomo et al., 2011), pumpkin flour (See et al., 2007), and rice bran (Marerat et al., 2011).In contrast, ash content remains relatively consistent across treatments, with a marginal rise evident in treatments featuring higher BCP ratios, suggesting a stable mineral composition (McClements, 2003). The fat content exhibits a subtle elevation with increasing BCP proportions, possibly influenced by the fat content present in baby corn (Lim and Rosli et al., 2013).The marked increase in fiber content as BCP proportion rises, indicating the substantial fiber content inherent in baby corn powder (Rosli and Anis, 2012). Likewise, protein content experiences a significant boost with greater BCP inclusion, reflecting the protein-rich nature of baby corn. In summary, the results suggest that incorporating baby corn powder into muffin can significantly enhance fiber and protein content while minimally affecting moisture and ash levels, and marginally increasing fat content. This presents an opportunity to improve the nutritional profile of muffins without compromising texture or taste.

Table 44. Proximate composition of muffins with different levels of BCP (Fibre enhanced)

Results are expressed as means of triplicate ± standard deviation. Identical letters within

Treatments (WF:BCP)	Moisture (%)	Ash (%)	Fat (%)	Fibre (%)	Protein (%)
Control (100:0)	27.83±0.41[c]	1.23±0.60[b]	21.75±0.42[c]	0.63±0.01[d]	9.02 ± 0.02 [d]
T_1 (90:10)	28.22±0.32[bc]	1.28±0.10[b]	22.65±0.32[b]	1.19±0.03[c]	9.98 ±0.05 [c]
T_2 (80:20)	28.52±0.16[b]	1.32±0.80[b]	22.98±0.22[ab]	1.38±0.01[b]	10.32± 0.03 [b]
T_3 (70:30)	29.30±0.21[a]	1.44±0.60[a]	23.44±0.21[a]	1.93±0.03[a]	11.05±0.02 [a]

a column denote no significant differences ($p < 0.05$).

6.12.3 Textural characteristics of developed muffins incorporated with different levels of BCP

The inclusion of BCP led to an augmentation in the hardness attribute of muffins, as outlined in Tables 45 . This observed increase in hardness may be linked to a potential reduction in fat content, as suggested by Kaur et al., (2021). Notably, a significant disparity in resilience values between the control and BCP-enriched muffins was observed. Resilience, portraying the product's capability to rebound after deformation, exhibited a decline upon BCP supplementation, possibly attributable to the denser matrix of the product, as indicated by Baixauli et al., (2008).Furthermore, the cohesiveness of BCP muffins was notably inferior to that of the control, suggesting a greater propensity for crumbliness and requiring more energy for chewing, as defined by Sanz et al., (2009). Our empirical observations indicated that muffins with a higher concentration of BCP tended to crumble more readily during handling, underscoring the significance of cohesion in preserving product integrity during consumption.Springiness, a critical quality characteristic of muffins, denotes the sample's capacity to restore its original height between compressions (Nath et al., 2018). Despite the textual alterations induced by BCP, the sensory evaluation scores indicated a high degree of acceptability.

Table 45: Textural characteristics of developed muffins incorporated with different levels of BCP (fibre enriched)

Treatments (WF :BCP)	Hardness (N)	Resilience (%)	Cohesion (%)	Springiness (%)
Control (100:0)	31.46	24.44	58.29	81.19
T1 (90:10)	30.96	21.15	58.06	77.48
T2 (80:20)	39.1	21.1	52.26	76.98
T3 (70:30)	40.73	19.97	55.03	74.0

6.12.4 Color characteristics of muffins

The color values of the developed muffins (crust and crumb) for both formulations were analysed. The color characteristics of muffins, particularly the crust and crumb, were analysed in relation to varying levels of baby corn powder (BCP) incorporation, as depicted in the provided table 46. A consistent trend was observed across treatments, where L* values for crust decreased from 64.83± 4.30 to 44.86 ± 4.30 while a* and b* values for crust increased from 4.20±0.91, 43.66±2.02 to 15.36±1.72 , 48.33±1.45 respectively (reflecting heightened redness-greenness and yellowness-blueness, respectively) as the proportion of BCP increased (T_1 to T_3) compared to the control (100:0), as detailed in Table 45.These findings align with prior studies by Walker et al., (2014), Nath et al., (2018) which demonstrated how vegetable powders can significantly influence the color attributes of baked goods due to their inherent pigments.

Table 46: Color characteristics of developed muffins incorporated with different levels of BCP (Fibre enhanced)

	Crust			Crumb		
Treatments (WF:BCP)	L*	a*	b*	L*	a*	b*
Control (100:0)	64.83±4.00[a]	4.20±0.91[b]	43.66±2.02[c]	72.90±1.49[a]	4.53±1.26[b]	34.53±2.00[a]
T1 (90:10)	62.13±5.27[a]	4.76±1.25[b]	39.20±1.85[b]	69.30±6.85[a]	5.43±1.95[b]	40.00±0.95[b]
T2 (80:20)	50.50±4.25[b]	13.23±0.15[a]	47.26±2.50[ab]	53.10±3.51[b]	9.36±1.53[a]	46.63±1.96[a]
T3 (70:30)	44.86±4.30[b]	15.36±1.72[a]	48.33±1.45[a]	53.93±3.73[b]	9.50±1.47[a]	42.30±4.68[ab]

Results are expressed as means of triplicate ± standard deviation. Identical letters within a column denote no significant differences ($p < 0.05$).

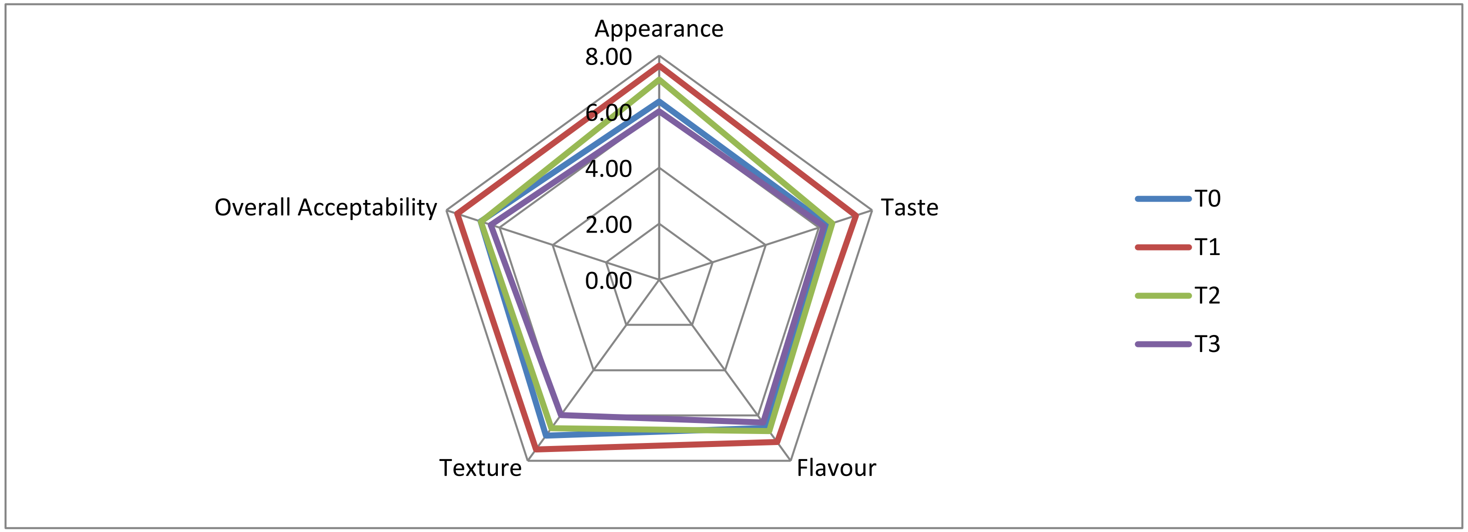
6.12.5 Sensory evaluation of developed muffins

The presented Table 47 provide a comprehensive insight into the sensory evaluation based on 9 point hedonic scale of muffins, with different levels of BCP (Fiber Enriched).Sensory attributes such as appearance, taste, flavor, texture, and overall acceptability were evaluated to assess the sensory characteristics of the muffins across different treatments. From the data, it can be observed that treatment T_1 (90:10) received the highest scores across all sensory attributes compared to the other treatments. Specifically, it scored significantly higher in appearance, taste, flavor, and overall acceptability compared to Control, T2 (80:20), and T3 (70:30). This indicates that muffins with 10% BCP had a more appealing appearance, better taste, and more enjoyable flavor and texture compared to other variations. While darker color is often undesirable in many food products, consumers often perceive darker muffins as being healthier compared to lighter ones (Walker et al., 2014).Hence overall T_2 was found to be best. On the other hand, T_3 (70:30) consistently received the lowest scores across all attributes. This suggests that muffins with 30% BCP had less favorable sensory characteristics compared to the other treatments, indicating potential issues with taste, flavor, and texture at higher BCP levels.

Table 46. Sensory evaluation of muffins with different levels of BCP (Fibre enriched)

Treatments	Appearance	Taste	Flavour	Texture	Overall Acceptability
T_0	6.36 ± 1.58^{b}	6.33 ± 1.37^{b}	6.55 ± 1.20^{b}	6.89 ± 1.56^{b}	6.71 ± 0.98^{b}
T_1	7.64 ± 0.72^{a}	7.39 ± 0.92^{a}	7.17 ± 1.19^{a}	7.5 ± 0.73^{a}	7.59 ± 0.93^{a}
T_2	7.14 ± 1.31^{a}	6.5 ± 0.83^{b}	6.69 ± 0.84^{ab}	6.56 ± 0.71^{b}	6.70 ± 0.80^{b}
T_3	6.01 ± 1.38^{b}	6.18 ± 1.51^{b}	6.31 ± 1.32^{b}	5.98 ± 1.52^{c}	6.33 ± 1.27^{b}

Results are means ± standard deviation (n=40). Different alphabets in a column indicate significant differences ($p < 0.05$).



6.12.6 Cost analysis of the baby corn incorporated muffins

The muffins enriched with fibre, computed cost is Rs. 32.15/pc, 34.812/pc, 37.472/pc , 40.132/pc , for control, 10%, 20% and 30% incorporation of baby corn powder respectively.

Table 48. Cost analysis For Muffin Formulation (100:0)

Ingredients	**Amount Used (g)**	**Cost as per amount used (Rs)**	**Total Cost/Kg (Rs)**
Wheat flour	100	6.9	69
BCP	0	0	335
Baking powder	5	2.325	465
Sugar	81	3.24	40
Milk	90	5.22	58
Oil	55	8.525	155
Muffin cups	3.5	1.442	412
Electricity Supply	600 watts	4.5	7.5
Total		32.152/pc.	

Table 49. Cost analysis For Muffin Formulation (90:10)

Ingredients	**Amount Used (g)**	**Cost as per amount used (Rs)**	**Total Cost/Kg (Rs)**
Wheat flour	90	6.21	69
BCP	10	3.35	335
Baking powder	5	2.325	465
Sugar	81	3.24	40
Milk	90	5.22	58
Oil	55	8.525	155
Muffin cups	3.5	1.442	412
Electricity Supply	600 watt	4.5	7.5
		34.812/pc	

Table 50. Cost analysis For Muffin Formulation (80:20)

Ingredients	Amount Used (g)	Cost as per amount used (Rs)	Total Cost/Kg (Rs)
Wheat flour	80	5.52	69
BCP	20	6.7	335
Baking powder	5	2.325	465
Sugar	81	3.24	40
Milk	90	5.22	58
Oil	55	8.525	155
Muffin cups	3.5	1.442	412
Electricity Supply	600 watt	4.5	7.5
		37.472/pc	

Table 51. Cost analysis For Muffin Formulation (70:30)

Ingredients	Amount Used (g)	Cost as per amount used (Rs)	Total Cost/Kg (Rs)
Wheat flour	70	4.83	69
BCP	30	10.05	335
Baking powder	5	2.325	465
Sugar	81	3.24	40
Milk	90	5.22	58
Oil	55	8.525	155
Muffin cups	3.5	1.442	412
Electricity Supply	600 watt	4.5	7.5
		40.132/pc	

CHAPTER 7

SUMMARY AND CONCLUSION

CHAPTER 7- SUMMARY AND CONCLUSION

The present study on "Characterization of Baby Corn and its Valorization for Powder Development" aimed to tackle the issues related to the high perishability of baby corn owing to its increased water activity and respiration rate. By focusing on two varieties, Syngenta 5417 and Pusa HM 4 male sterile procured from Punjab and Haryana, the research conducted an in-depth analysis encompassing physical dimensions, yield, composition, antioxidant activity, textural properties, mineral composition, and the kinetics of blanching and drying. Variations in physical traits, particularly the classification based on size into short, medium, and long, reflected diverse stages of maturity. The influence of genotype potential and environmental factors on yield was evident, with long-graded cobs exhibiting superior antioxidant activity.

Noteworthy, within various blanching methods (hot water blanching, steam blanching and microwave blanching at different time- temperature/power combinations), microwave blanching emerged as effective means to prolong shelf-life while minimizing nutrient loss. Drying trials were carried out at varying temperatures (50, 60, and 70°C) using tray, vacuum, and sun drying methods. Validation of fitted parameters relied on those yielding the highest R^2 and the lowest values of chi-square (χ 2) and root mean square error (RMSE). Insights into effective moisture diffusivity and activation energy were provided by drying kinetics, aiding in determining optimal processing conditions.

Moreover, particle characterization underscored the stability and functional capacity of baby corn powder. The significance of packaging materials in maintaining quality attributes was highlighted in storage studies, with aluminium laminate exhibiting superior performance followed by polypropylene and low-density polyethylene. Additionally, the enhancement of nutritional value and sensory appeal through the incorporation of baby corn powder (10,20 and 30%) into muffins, with a focus on fiber enhancement, suggested the potential for market acceptance.

The primary objective of the study was to develop a value-added product from baby corn at a maturity stage with limited economic significance. By transforming this underutilized resource into a functional powder and demonstrating its application in muffins, the research contributes to both food product development and sustainable resource utilization. The study provides a pathway for farmers to convert surplus or less-marketable produce into a high-value ingredient, potentially increasing their income and diversifying revenue streams. The developed baby corn powder has wide applicability, such as in bakery products, soups, sauces, and as a nutritional supplement. Its incorporation into muffins demonstrated its suitability for health-focused formulations, aligning with consumer trends. By promoting the utilization of underexploited agricultural resources, the research aligns with global goals for sustainable food systems. This research adds to the growing body of knowledge in food science by demonstrating practical applications of baby corn powder in product development, with potential for scaling to other food systems.

In conclusion, this study presents a comprehensive understanding of strategies to enhance the commercial viability and nutritional quality of baby corn, thereby facilitating sustainable agricultural practices and innovative food product development. It emphasizes the importance of customized post-harvest practices and exploration of innovative processing techniques to maximize the economic potential and nutritional value of baby corn. The characterization of baby corn powder opens avenues for its integration into various food applications, while future research should concentrate on optimizing processing parameters and exploring innovative product formulations to further leverage the potential of baby corn as a valuable commodity.

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Research article

Effect of different blanching methods on kinetics of physico-chemical, functional properties, and enzyme inactivation in baby corn

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ABSTRACT

Baby corn, characterized by its high water activity and elevated respiration rate, poses a formidable obstacle to prolonged storage under standard ambient conditions and necessitates specialized treatments for transportation to distant locations. One of the primary postharvest challenges associated with baby corn is the occurrence of brown pigment formation because of enzymatic browning at the apex of its immature ovules, cut surfaces, and silk attached to the young ears. The present study was undertaken to investigate the effect of different blanching treatments on peroxidase inactivation, physicochemical properties, and functional properties of baby corn. The treatments applied were hot water blanching (HWB) at temperatures ranging from 70°C to 90 °C for 30–240 s, steam blanching (SB) for 30–240 s, and microwave blanching (MWB) at power levels of 360 W–900 W for 30–300 s. Results indicated that 90 % peroxidase enzyme inactivation occurred under different methods as 90 °C for 60 s for HWB, 100 °C for 60 s for SB, and 540 W for 30 s for MWB. These blanching methods have shown significant effects on the properties under investigation. MWB demonstrated the highest retention of ascorbic acid (94.15 %) and minimal color changes ($\Delta E = 5.72$) in comparison to hot water and steam blanching. Similarly, the result for total flavonoid content for 540 W, 90 °C and 100 °C for 30, 60, and 60 s were found to be 3.01,1.99 and 2.10 mg QE/100g, phenols 48.98, 47.99 and 48.03 mg GAE/100g and DPPH (%) 42.55, 34.20 and 37.08 % respectively. The findings suggest that microwave blanching of baby corn at 540 W for 30 s holds promise to inactivate the peroxidase enzyme with better retention of physicochemical and functional properties.

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Review Article

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Investigating the Influence of Drying Temperature and Tray Loads on Kinetics, Moisture Diffusivity, Retention of Bioactive Compounds, and Color Characteristics of Baby Corn

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Abstract

The drying kinetics of long-graded baby corn was investigated using a tray dryer at 50-70 °C with a tray load of 0.30-0.45 g/cm². The sample was given pretreatment of microwave blanching to inactivate the peroxidase enzyme. Drying data was fitted in three thin layer drying models viz. Page, Lewis, and Henerson-Pabis. The goodness of models was evaluated based on coefficient of determination (R^2), root mean square error (RMSE), and chi-square (χ^2). Page model was found to be the best-fit model. The effective moisture diffusivity for baby corn pieces at different temperatures (50, 60, and 70 °C) with varying tray loads (0.45, 0.40, 0.35, and 0.30 g/cm²) ranged from 2.40×10^{-11} to 7.11×10^{-12} (m^2/s); 4.06×10^{-12} to 9.94×10^{-12} (m^2/s); 2.94×10^{-12} to 6.80×10^{-12} (m^2/s); 3.65×10^{-12} to 8.01×10^{-12} (m^2/s), respectively. The activation energy was found in the range of 57416.48 to 36499.29 (J/mol) for tray load 0.45 g/cm²-0.30 g/cm² respectively. The effect of different temperatures (50 °C - 70 °C) at tray load 0.3 g/cm² was studied on various heat-labile components of baby corn and color characteristics. A significant reduction in ascorbic acid at $p \leq 0.05$ was found during microwave blanching (21.05 ± 0.15 mg/100 g to 15 ± 0.06 mg/100 g). The effect of drying at different temperatures showed that higher temperatures short time resulted in better retention of ascorbic acid (15.02 ± 0.02 mg/100 g) and total phenolic content (49.02 ± 0.03 mg GAE/100 g). The antioxidant activity in terms of DPPH (% radical scavenging activity) and FRAP was found to be 38.00 ± 0.01% and 124.63 ± 0.01 µg/ml. A significant change in the color values was observed which might be due to the thermal degradation of pigments or nonenzymatic browning reactions.

Keywords

Microwave blanching, Drying kinetics, Moisture diffusivity, Bioactive compounds, Color value

Introduction

Baby corn (*Zea mays* L.) is a type of maize with characteristic traits and harvested as young immature unfertilized, tender cobs having 2-3 cm silks on the ear. The cobs 6-11 cm in length and 1-1.5 cm in diameter with regular row arrangement are ideal for consumption in different forms [1]. Baby corn is harvested 1-3 days after silk emergence and when the length of silk is about 0.5-1.0 cm prior to fertilization. A single-day delay in harvesting degrades the quality and taste of the baby corn making harvesting a crucial step [2]. It is the only vegetable considered to be free from pesticide residues and its nutritional value is also comparable to many high-value vegetables. Due to its sweet and succulent taste, it can be consumed raw or cooked in the form of salad, soup, pickles, and other savory and sweet dishes [3]. Baby corn is a perishable crop with a high respiration

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NATIONAL SYMPOSIUM
on
FOOD PROCESSING 4.0: INNOVATION AND SUSTAINABILITY
APRIL 30, 2024
ORAGNIZED BY
DEPARTMENT OF FOOD SCIENCE & TECHNOLOGY
PUNJAB AGRICULTURAL UNIVERSITY, LUDHIANA-141004, PUNJAB, INDIA

Certificate

BEST POSTER

*This is to certify that the following has been awarded as **Best Poster** at National Symposium on **"Food Processing 4.0: Innovation and Sustainability"** held on **April 30, 2024** at **Punjab Agricultural University, Ludhiana, Punjab, India.***

Title Development and evaluation of baby corn powder incorporated muffins

Authors Ubaida Akbar and Savinder Kaur

Affiliation Lovely Professional University, Phagwara, Punjab.

Dr Savita Sharma, Head, Food Science and Technology
Dr CS Aulakh, Dean, College of Agriculture
Dr AS Dhatt, Director of Research


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NAAC A++
Certificate No. 298062

Certificate of Participation

This is to certify that **Prof./Dr./Mr./Ms. Ubaida Akbar** of **Lovely Professional University, Phagwara** has participated as Delegate/Oral/Poster presenter in the International conference **"Recent Advances in Smart and Sustainable Agriculture for Food and Nutritional Security-2023"** held from **22nd to 23rd November, 2023** organized by School of Agriculture, Lovely Professional University, Punjab.

Date of Issue : 23-11-2023
Place : Phagwara (Punjab), India

Prepared by (Administrative Officer-Records)
Organizing Secretary
Head of School

ThinkBIG


Global Indian
Young Scientists Research and Innovation Conference 2023
May 31 – June 2, NASC, New Delhi
Scientific Solutions for Glocal Challenges

Certificate of Participation

Prof./Dr./Mr./Mrs./Ms. ***Ubaida Akbar*** *from* ***Lovely Professional University***
presented a ***ORAL/POSTER*** *entitled* ***Thin layer drying of baby corn and its effect on nutritional, bioactive components, color values and rehydration*** *during the conference.*

Dr. Yelloji- Rao Mirajkar, International Coordinator, GIST Forum, USA
Dr. Rajnish Chaturvedi, Convenor, GI-YSRI 2023
Dr. Shekhar Mande, President, Vijnana Bharati

isarc
INTERNATIONAL SCIENCE AND ART RESEARCH CENTER

CERTIFICATE
of participant

This is to certify that
Ubaida Akbar,
In oral and technical presentation, recognition and appreciation of research contributions to

5. INTERNATIONAL SOCIAL SCIENCES AND INNOVATION CONGRESS
12-13 NOVEMBER 2022 ANKARA/ TURKEY
with the paper entitle

'' Influence of different blanching methods on the physiochemical and antioxidant activity of different blanched baby corn kernels ''

Uzm. Yasemin AĞAOĞLU
Head Of Congress Group

Sefa Salih BİLDİRİCİ
HEAD OF İSARC

ETERNAL UNIVERSITY
BARU SAHIB, SIRMAUR - 173101, HIMACHAL PRADESH, INDIA
International Conference
on
Water, Agriculture, Dairy and Food Processing for Sustainable Economy
(WADFPSE-2022)

Certificate of Participation

This is to certify that ***Ms. Ubaida Akbar*** *from* ***Food Technology and Nutrition, Lovely Professional University, Phagwara Jalandhar, Punjab*** *has Presented a paper virtually entitled* ***"Effect of Different Blanching Methods on the Peroxidase Activity and Ascorbic Acid Content of Baby Corn"*** *in International Conference on "Water, Agriculture, Dairy and Food Processing for Sustainable Economy (WADFPSE-2022)" organized by University Corporated Resoruce Centre conducted (March 25-26, 2022) at Eternal University Baru Sahib, Himachal Pradesh.*

Mr. S. K. Ghosh (Convener) | Dr. Amrik Singh Ahluwalia (Co-Patron) | Dr. Davinder Singh (Patron)

WORKSHOPS

TWO DAYS VIRTUAL TRAINING PROGRAMME

ON

STATISTICAL METHODS IN FOOD PROCESSING

10th – 11th, October 2022

ORGANISED BY

ASSOCIATION OF FOOD SCIENTISTS AND TECHNOLOGISTS(INDIA)

CERTIFICATE

This Is To Certify that Mr/Ms/Dr./Prof.

UBAIDA AKBAR , PhD scholar

of Lovely Professional university, Jalandhar has

attended the" **Two Days Training Programme**" in Virtual Mode on 10th & 11th October 2022

Dr Laxmikanth S Badwaik, Convener, Students Committe, AFST(I)

Dr Ravendra Pratap Singh, Chairman, Students Committee, AFST(I)

Dr.Nandini P Shetty, Hon. Secretary AFST(I)

Dr. Alok Kumar Srivastava, President, AFST(I)

HUMAN RESOURCE DEVELOPMENT CENTER

[Under the Aegis of Lovely Professional University, Jalandhar-Delhi G.T. Road, Phagwara (Punjab)]

Certificate No. 190901

Certificate of Participation

This is to certify that **Ms. Ubaida Akbar** D/o Sheikh Mohd Akbar participated in **Workshop on Data Analysis using SPSS** organized at Lovely Professional University w.e.f. **November 22, 2019** to **November 23, 2019** and obtained **'C'** Grade.

Head
School of Education

Head
Human Resource Development Center