

Influence of Gluten on Starch Gelatinization and Puffing Characteristics in Extruded Foods

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Introduction

Extrusion cooking has emerged as an important processing technology in the modern food industry, owing to its efficiency, versatility, and capacity to produce a wide range of ready-to-eat and semi-cooked products [1, 2]. Extrusion facilitates the conversion of basic raw materials into intricate, appealing food structures, encompassing puffed snacks, breakfast cereals, texturized plant proteins, and modified starches [4, 5]. Puffed extruded foods hold a distinctive position because of their unique porous structure, light texture, appealing crunch, and convenience. The creation of these structures is primarily regulated by the process of flash expansion, which occurs when the cooked starchy melt exits the extruder die and undergoes an abrupt decrease in pressure. The rapid depressurization results in water vaporization, bubble nucleation, and cellular expansion inside the matrix—processes that ultimately determine the puffing characteristics, volume, density, and texture of the final product.

The conversion of native starch granules into a viscoelastic, amorphous melt that can expand and set into an airy structure is known as starch gelatinization, and it is the fundamental process of expansion [8]. Temperature, moisture content, shear pressures, feed composition, and interactions between starch and non-starchy components like proteins or lipids all affect the extent and nature of gelatinization [9, 10]. The use of gluten-rich additions, such as wheat gluten, essential wheat gluten, or gluten-containing flours, has grown in popularity as the food industry shifts toward nutritionally enhanced and high-protein snack products [3, 6]. In addition to increasing the protein content of a food, gluten also affects its texture, expansion, and structural integrity through functional changes. However, because of its special rheological and water-binding characteristics, its incorporation adds a great deal of complexity to the extrusion system.

Gladians and glutenins are the main components of gluten, a composite protein structure that gives it its distinctive viscoelastic behavior. As is the case with bread dough, gluten creates cohesive, elastic networks in wet systems that can sustain enlarged structures and trap gases. However, the role of gluten is much different and frequently less predictable during extrusion, where circumstances vary significantly in terms of temperature, pressure, and mechanical shear. The production and stability of expanding bubbles, melt viscosity, water distribution, and overall structural development during

extrusion can all be affected when gluten-rich additives are added to starchy extrudates [7, 11].

The inclusion of gluten or other protein-rich substances tends to decrease puffing, which is one of the most consistent findings across research [12]. There are several reasons for the reduction in expansion. First, gluten increases the dough's elasticity and melt-proofness, resulting in a more resistant matrix that stops bubbles from forming at the die exit [7]. Smaller, denser air cells and lower overall expansion ratios are the results of an elastic matrix's resistance to deformation during steam expansion. Second, starch granules and gluten compete for water, which is necessary for starch swelling and gelatinization [3]. Lack of moisture prevents starch from properly gelatinizing, which results in the development of a less uniform, less extensible melt. Third, gluten alters the extrusion dough's rheological characteristics, frequently raising die pressure and melt viscosity in ways that could offset the expansion forces provided by flash-off [10].

Protein–starch interactions, which might include physical entanglement, hydrogen bonding, or hydrophobic associations depending on the processing conditions, also affect how gluten and starch interact during extrusion [11]. These interactions could change the extent of granule rupture and molecular dispersion, as well as the thermal transitions of starch, such as the onset and peak temperatures of gelatinization [3]. In the presence of gluten, a greater gelatinization temperature suggests that more energy is needed for starch to go through its distinctive changes. The extrudate's capacity to expand and create homogeneous pore structures may be hindered by incomplete or partial gelatinization if the extrusion conditions do not provide sufficient thermal and mechanical energy.

The importance of starch gelatinization in the extruder cannot be emphasized. A continuous, viscoelastic matrix that retains water and steam, allows bubble formation, and stabilizes cell walls during expansion is created by gelatinization. The dispersed starch molecules in a fully gelatinized melt can create strong films that stretch and retain vapor during expansion. On the other hand, intact granules or semi-swollen particles are left behind by partial gelatinization, which impairs bubble formation and disrupts melt continuity. Therefore, puffing performance is immediately impacted by any element that inhibits gelatinization, like the presence of gluten.

Moisture distribution in the dough is another important variable regulated by gluten. Because gluten has a

high water absorption capacity, its incorporation changes the hydration patterns within the combination [3]. Whereas starch granules require free water to swell and gelatinize, gluten can bind water inside its protein matrix, making it unavailable for starch transformation. This limited availability may lead to a harder melt and lower expansion. Furthermore, gluten's elastic nature enables the matrix to contract more quickly after expansion, resulting in denser and firmer extrudates.

In spite of these difficulties, adding gluten is not always harmful. In fact, when certain textures or product functions are desired, gluten may be useful. For example, extrudates with enhanced hardness, chewiness, and structural integrity can be produced by gluten enrichment, which may be advantageous in products where breakage resistance or crispness control is necessary [7]. Nutrition bars, meal replacement crisps, and high-protein extrudates frequently depend on these qualities. Additionally, gluten might enhance extruded products' cohesiveness and form retention, especially during subsequent steps like drying, coating, or packaging.

The relationship between gluten and starch also gives chances for product innovation. Understanding how gluten impacts gelatinization and expansion can help technologists modify extrusion conditions to obtain more controlled or targeted textures [12]. For instance, altering barrel temperature, screw speed, or feed moisture can compensate for gluten's restrictive effects on expansion. Higher mechanical shear may promote starch disruption despite the presence of gluten, whereas optimizing the moisture content can facilitate better starch swelling. Similarly, pre-gelatinized starches or other starch sources can be combined with gluten-containing formulations to balance elasticity and expandability.

The impact of gluten on microstructure during extrusion is another fascinating aspect. Compared to their starch-only counterparts, gluten-rich extrudates frequently have thicker cell walls and smaller, more uniform pores. Studies using scanning electron microscopy often show compact structures in protein-enriched extrudates, which is consistent with their decreased expansion. Textural characteristics like crispness, hardness, and breakability are directly impacted by these microstructural changes. Compared to highly puffed items, products with more compact structures are typically firmer and less brittle, offering a distinctive eating experience.

The growing consumer demand for gluten-modified products, plant-based proteins, and fortified snacks highlights the importance of fully comprehending the behavior of gluten during extrusion [3]. Extrusion is still the method of choice for creating innovative, nutrient-dense foods; the difficulty is in obtaining a balance between desirable sensory qualities and nutritional increase. This requires an advanced understanding

of the ways in which starch conversions, expansion behavior, physicochemical characteristics, and ultimate product quality are impacted by gluten-rich additions.

The goal of this article is to give a thorough explanation of the dual role of gluten in extrusion systems, taking into consideration the complexity of these interactions. It specifically focuses on two interrelated themes : (i) how puffing characteristics, such as expansion ratio, density, texture, and structural development, are affected by gluten-rich additives; and (ii) how gluten affects starch gelatinization and associated physicochemical changes that take place inside the extruder. By exploring these aspects, the essay seeks to highlight the ways in which gluten influences extrusion behavior and to identify methods for enhancing product quality in extrudates that contain gluten.

Future research on ingredient functionality, extrusion refinement, and innovative product formulations will be guided by a better knowledge of these interactions, which will also help build high-protein, gluten-modified extruded foods. Understanding the gluten-starch interaction is essential for improving both scientific knowledge and industrial practice as customer preferences shift toward healthier, protein-enriched substitutes and the food industry continues to develop with extrusion technology.

Conclusion

The structural, textural, and functional quality of extruded foods are ultimately determined by the addition of gluten-rich additions to extrusion formulations, which have a substantial impact on both puffing features and starch gelatinization behavior. Because gluten is inherently viscoelastic, it enhances the biopolymeric network inside the extruder and improves melt flexibility, forming a matrix that frequently prevents vapor-driven expansion. This leads to improved microstructures, smaller cell diameters, decreased expansion ratios, and less puffing. In addition to competing with starch for available water, gluten creates protein–starch interactions that impact the starch's overall gelatinization profile, granule swelling degree, and thermal transitions. Important quality criteria like crispness, hardness, density, and porosity of extrudates are impacted by incomplete or limited gelatinization, which further reduces expansion.

Despite these difficulties, adding gluten might also be advantageous from an economic perspective. Gluten serves as a functional component that fortifies the extrudate matrix in instances where improved structural integrity, increased protein content, or controlled textural qualities are required. Even in gluten-rich formulations, processors may vary the degree of starch transformation and expansion behavior by optimizing extrusion variables, such as feed moisture, barrel temperature, screw speed, and die configuration. Additionally, combining gluten with pre-gelatinized starches or other types

of carbohydrates presents chances to improve nutrition while also achieving desired sensory qualities.

Overall, the significance of comprehending protein–starch interactions in extrusion systems is highlighted by this dual perspective on puffing features and starch gelatinization. The knowledge gathered from researching the impacts of gluten serves as a basis to develop innovative, nutritionally improved extruded foods with specific functionality and texture. Future research on ingredient modification, process optimization, and microstructural design of extruded products, as well as industrial applications, will be greatly influenced by these findings as consumer demand continues to change toward high-protein and healthy snacks.

References

1. Altan, A., McCarthy, K. L., & Maskan, M. (2008). Extrusion cooking of barley flour and process parameter optimization using response surface methodology. *Journal of Food Engineering*, 88(2), 164–173.
2. Ascheri, D. P. R., Carvalho, C. W. P., & Andrade, C. T. (2006). Effect of extrusion conditions on the structure of cassava starch and the physical appearance of extrudates. *Carbohydrate Polymers*, 65(3), 425–432.
3. Brennan, C. S., Monro, J. A., & Brennan, M. A. (2016). Effect of protein enrichment on starch gelatinization during extrusion: A review. *International Journal of Food Science & Technology*, 51(1), 1–9.
4. Chiu, C. W., & Solarek, D. (2009). Modification of starch. In J. BeMiller & R. Whistler (Eds.), *Starch: Chemistry and Technology* (3rd ed., pp. 629–655). Academic Press.
5. Hagenimana, A., Ding, X., & Fang, T. (2006). Evaluation of rice flour modified by extrusion cooking. *Journal of Cereal Science*, 43(1), 38–46.
6. Ilo, S., Okechukwu, P. E., & Berghofer, E. (1999). Protein enrichment of extruded rice flour with soy flour: Effects on extrudate properties. *Journal of the Science of Food and Agriculture*, 79(6), 805–812.
7. Koksel, H., Scanlon, M. G., & Page, J. H. (2015). The role of gluten in textural properties of extruded foods. *Food Research International*, 69, 123–131.
8. Singh, N., Singh, J., Kaur, L., Sodhi, N. S., & Gill, B. S. (2003). Morphological, thermal and rheological properties of starches from different botanical sources. *Food Chemistry*, 81(2), 219–231.
9. Wang, S., Li, C., Copeland, L., Niu, Q., & Wang, S. (2016). Starch retrogradation: A comprehensive review. *Comprehensive Reviews in Food Science and Food Safety*, 14(5), 568–585.
10. Xie, F., Yu, L., Su, B., & Liu, H. (2009). Rheological properties of starch during extrusion, a review. *Starch/Stärke*, 61(11), 702–715.
11. Zhang, B., Dhital, S., & Gidley, M. J. (2013). Synergistic and antagonistic effects of gluten and starch during heating and extrusion. *Food & Function*, 4(9), 1216–1225.
12. Zhu, S., & Rinzema, A. (2014). Effect of protein–starch interactions on extrudate expansion and microstructure. *Food Hydrocolloids*, 44, 1–10.
