ISSN: 2572-5971

Review Article

Advances in Nutrition & Food Science

A Review of Non-gluten Components in Gluten-Free Bread Characteristics keep the dough's baking quality and viscoelastic qualities

Melaku Tafese Awulachew

Department of Food Science and Nutrition Research Directorate, Ethiopian Institute of Agricultural research, Ethiopia.

***Corresponding author**
Melaku Tafese Awulachew, Department of Food Science and Nutrition Research Directorate, Ethiopian Institute of Agricultural research, Ethiopia.

Submitted: 18 Nov 2021; **Accepted:** 26 Nov 2021; **Published:** 02 Dec 2021

Citation: *Melaku Tafese Awulachew. (2021). A Review of Non-gluten Components in Gluten-Free Bread Characteristics keep the dough's baking quality and viscoelastic qualities. Adv Nutr Food Sci, 6(2), 72-76.*

Abstract

Gluten, the protein responsible for dough's cohesive and elastic properties, is found in wheat. Gluten-free bread has recently gained popularity as a result of its acceptability for celiac disease sufferers. During proofing and baking, however, the batters do not retain carbon dioxide gas. In comparison to typical wheat breads, this results in a bread with a smaller loaf and specific volume, low moisture, thick structure, crumply texture, and high crumb hardness. One of the most important variables in maintaining and searching for replacement components to replace gluten qualities for attractive product quality and structure is product idea expertise. In this context, non-gluten ingredients such as starch, sourdough, gums/ hydrocolloids, hydroxypropyl methylcellulose, whey protein, and dietary fiber help to improve gluten-free bread quality. Furthermore, adding Gum to gluten-free flour enhances dough features by boosting water absorption capacity and making the dough viscoelastic, resulting in enhanced loaf and specific volume, soft texture, and a longer shelf life by delaying bread staling. Food gums could be widely used in the baking industry to improve water holding capacity, control food pasting properties and improve moisture content, modify product texture, volume, and cell structure, and maintain overall product quality during storage and shelf life by keeping moisture content constant and delaying staling. The goal of this study was to accesses the rheological characteristics and quality of non-gluten components for dough quality enhancement.

Keywords: Non-gluten ingredients, Gum, Celiac disease, Gluten-free bread, Dough and Bread quality.

Introduction

Bread is a basic item that is enjoyed all over the world and is considered an important source of carbohydrate in the food pyramid [1; 2]. It's often made with a baking dough made of wheat flour, leavening agents, and water [3]. Gluten is a protein found in wheat that gives dough its cohesive and stretchy properties. Because gluten makes bread inappropriate for those with celiac disease [4], different gluten-free grains are being used to substitute wheat.

Gluten-free cereals lack a substance that is analogous to gluten and gives the dough its cohesive and elastic properties, determining the final bread quality. Gluten is one of the most essential structure-building proteins in wheat-based goods, and it is responsible for their attractive quality and structure. Because of its unique viscoelastic qualities, developing gluten-free dough with comparable quality and structural properties is a difficult challenge and a huge industrial hurdle. Gluten-free product development has remained a technologically fascinating subject for researchers and the food industry [4]. A number of hydrocolloids or gums have recently been employed to create a polymer network that functions similarly to wheat gluten protein [5].

Gum Arabic is a dried, gummy exudate (polysaccharide) derived from the stems and branches of Acacia sanegal and seyal when the stem is wounded by tapping wounds, fungal infestation, or beetle infestation. It is a non-toxic, odorless, and tasteless natural substance made up mostly of high molecular mass polysaccharides and their magnesium, calcium, and potassium ions, which hydrolyze to produce arabinose, galactose, rhamnose, and glucuronic acid [6]. In the baking sector, especially where non-wheat flours are employed, its viscosity and sticky qualities are important.

This is due to the fact that such baking items necessitate polymeric ingredients that replicate the viscoelastic properties of gluten in dough [7, 8].

As previously stated, there are a number of gums available for use in the food industry, and their molecular structure and chemical makeup vary based on aspects such as origin and extraction processes [9]. As a result, the goal of this study is to determine wheth-

er local Arabic gum is suitable for improving the cohesive and elastic properties of dough in order to improve the baking quality of gluten-free bread.

Techniques

This review report was created by searching the literature for non-gluten components, gum, Celiac Diseases, gluten free bread, and dough and bread quality utilizing available scientific information and relevant literatures. The logical term operant was used to find objects that matched terms in a search.

The fundamentals of the paper

This review report will help bakers target gluten-intolerant customers by replacing wheat in bread recipes with gluten-free cereal. Also, because gluten-free cereals can be used instead of wheat in regions where wheat is not available, this evaluation is critical for persons living in places where wheat is not available. This document can also be used as input by anyone interested in Ethiopian gums. Celiac disease is now one of the most prevalent health issues in many nations [10]. Gluten proteins from regularly consumed dietary sources such as wheat, rye, barley, and most likely oats cause it [11]. Celiac disease involves inflammation of the small intestine lining and damage to the intestinal mucosa, resulting in nutrient loss, particularly gluten from wheat. As a result, diarrhea, anemia, exhaustion, flatulence, weight loss, and osteoporosis develop [12]. Celiac illness affected about 1 (0.05 percent) of 2000 pregnant women with a median age of 25 years [13]. Celiac disease affects around 1% to 2% of the world's population, and the only effective therapy is to avoid gluten-containing foods for the rest of their lives and develop gluten-free formulations that have similar product qualities to those acquired with wheat [14].

Gluten, on the other hand, is important in breadmaking because it gives dough its viscoelastic properties. Dough qualities like as elasticity, mixing tolerance, stretching resistance, gas retention, volume, and texture are all determined by the gluten network [15]. So, the substitution of wheat flour with gluten free cereal flour fails to form viscoelastic dough when they are kneaded with water in a conventional bread making process. They form a batter rather than dough. Moreover, the batters tend not to retain carbon dioxide gas during proofing and baking. Thus, resulting in a bread with reduced loaf and specific volume, low moisture, dense structure, crumply texture and high crumb hardness compared to popular wheat breads [16]. As a result, the use of quality improvers has become an unavoidable part of increasing dough and bread quality. Various gluten-free formulations have recently been developed using non-gluten ingredients like alternative starches, dairy products (whey protein), gums, and emulsifiers. These alternatives help to mimic viscoelastic properties of gluten and thus improve the final quality of gluten-free bakery products [11].

Gluten-free bread's influence

Gluten-free goods that completely omit gluten, proteins found in dietary sources such as wheat, barley, rye, oats, and derivatives of these grains, have recently become popular among persons with celiac disease or other gluten-related allergies. Celiac disease is a condition in which the gastrointestinal tract becomes inflamed as a result of eating gluten-containing foods. It is an immune-mediated mechanism in those who are genetically predisposed to this protein. As a result, the only treatment for celiac disease is a gluten-free diet for the rest of one's life [17]. Gluten is a large structural protein complex found in wheat that has functional qualities that give it a special place in wheat flour and goods made from it. The gluten network influences dough qualities like elasticity, mixing tolerance, stretching resistance, and gas retention. As a result, a lack of it may result in liquid dough, which can therefore lead to poor-quality bread [18].

Rice and corn, the two most abundant cereals on the planet, are widely used to make gluten-free breads. Gluten-free bread has also been made with other ingredients such as sorghum, potato, cassava, leguminous seeds, and buckwheat. In terms of quality and acceptance, commercially produced gluten-free breads fall short of their gluten-containing counterparts. As a result, nongluten components such as starches and hydrocolloids are being used to replicate the viscoelastic qualities of gluten and improve the ultimate quality of bread [19].

Gluten-free bread characteristics

Gluten-free bread tends to be of lower quality than wheat bread. Lack of gluten, the key protein matrix capable of expanding dough and retaining gas, results in weak dough (batter) with high permeability to gas carbon dioxide and significant difficulties maintaining structure, resulting in a loss in baked good volume. The absence of the gluten network in gluten-free bread produces a rapid loss of moisture, which might result in a crumply structure and rapid staling [20]. Water holding and network building properties of dairy proteins delay the staling process and allow baked foods to retain moisture for longer [21]. Bread with no gluten has a pale, bland flavor and taste. Because commercial gluten-free bread is primarily made of carbohydrates, it lacks fiber, vitamin, and nutritional content.

Non-gluten ingredients used to improve gluten-free bread quality

Cereals

In gluten-free systems, starch and its derivatives, such as malto-dextrins, are the predominant texture and structure-forming agents. They are often employed in the formulation of gluten-free bakery products to improve dough consistency and bread quality. For usage in gluten-free products, starches can be physically and chemically changed. In gluten-free dough and bread, resistant starches have also been used to substitute starch [17, 22].

Sourdough bread

Sourdough is a bread made from wheat and water that has been fermented with lactic acid bacteria and yeast starter cultures that are either added or found as contaminants in the flour. A growing number of works on using sourdough in gluten-free breadmaking are being published these days. Sourdough fermentation has long been known to improve dough qualities such as gas holding ability, gluten-free bread structure, flavor, and shelf life. It also improves the bread's texture and nutritional content, slows the aging process, and guards against mold and bacterial spoilage [23, 24]. Several studies published recently suggest that sourdough fermentation can be used to improve the dough-handling characteristics of gluten-free batters. Controlling the fermentation and maintaining consistent quality parameters of the sourdough for gluten-free

dough production requires a good understanding of the microbial interactions that occur during sourdough fermentation [4].

Gums/hydrocolloids

Gums are a broad category of long-chain polymers that are mostly utilized to improve gluten-free bread quality. They are capable of managing both the rheology of dough and the texture of an aqueous food system during emulsion stabilization, suspension, and foaming in the food industry [20]. They are employed as stabilizers, thickening agents, gelling agents, water binders, texturizers, and adhesives in a variety of food applications. Gum increases gluten-free wheat dough characteristics by boosting water absorption capacity and making the dough viscoelastic, resulting in bread with better loaf and specific volume, soft texture, and long shelf life by delaying bread staling [25]. Similarly, Xanthan gum in bread boosted the dough's water absorption capacity as well as the softness and yield of the bread [26]. In addition, using varying concentrations of Guar Gum and Gum Arabic increased the functional qualities of sorghum flour, resulting in bread of acceptable quality [27]. Gear gum has also been shown to delay bread staleness by a softening effect induced by a putative suppression of amylopectin retrogradation [28].

Hydroxypropyl methylcellulose

The best gluten replacer is hydroxypropyl methylcellulose, which has been widely utilized. It's used as a gluten-free bread improver, giving it a higher specific volume, a smoother crumb, and better sensory qualities. When utilized, it causes the bread to increase in volume, moisture content, and crumb firmness [29]. Hydroxypropyl methylcellulose enhances the volume and quality of gluten-free dough by improving gas retention and water-holding capacity during proofing [30].

Whey protein

Whey protein is a functional agent that is added to bread to help it absorb more water and provide more nutrients [21]. When mixed with starch, a mesoscopically structured whey protein particle system has some of the elastic and strain hardening properties of gluten. However, upon kneading, the extensibility is reduced and the particles are more stable than gluten particles, owing to an excessive amount of internal crosslinking. The ability to create disulfide bonds affects the qualities of the particle network, even if too many disulfide bonds might result in stiff dough and poor bread attributes. According to several research, adding 6% whey protein powder to gluten-free bread increased the protein level by two times without changing the dietary fiber content [31]. In comparison to gluten-free bread, gluten-free bread enriched with whey protein has a darker brown hue, owing to a stronger mallard browning reaction and caramelization. Whey protein supplementation also improves gluten-free bread tissue characteristics such as kneading capabilities, loaf size, and volume [32].

Dietary fiber

Polysaccharides that cannot be digested by human digestive enzymes in the colon are referred to as dietary fiber. When dietary fiber is integrated into food systems, it provides a wide range of functional qualities. Its presence aids in the alteration and enhancement of food texture, sensory properties, and shelf life. Soluble and insoluble fibers, for example, can be utilized to replace gluten in bakery items like cakes and bread [33]. Researchers discovered that using them in bakery items improved the specific volume, crumb color, and crust color. Gluten-free breads with larger loaf volume and crumb softness are made using dietary fiber from cereal grains like maize and oat [34].

Studies on the Rheological characteristics of dough

For many researchers, getting the data needed to characterize the dough's rheology has proven to be a difficult task. Dough rheology provides information on the material's mechanical properties and processing performance, with the goal of predicting ultimate product quality such as mixing behavior, sheeting, and baking performance. Gluten is a protein found in wheat that gives dough its viscoelastic and extensible qualities, allowing it to develop good pastry items [20]. The absence of gluten in a product has a substantial impact on both the rheology of the dough and the quality of the finished product. In comparison to wheat dough, gluten-free doughs have inferior elasticity and cohesion, poor gas holding capacity, weak strength, inconsistencies while mixing, and poor texture. Gums/hydrocolloids are commonly used to improve dough rheology by allowing the dough to bind more water, increase dough viscosity, consistency, and strength, increase cohesiveness and extensibility, increase gas retention capacity and rheo-ferment graphic index, and increase elasticity in corn, rice, and buckwheat dough [35].

Discussion

Gum Arabic (Acacia-Senegal) manufacture in Ethiopia

Ethiopia is one of the countries having a high concentration of Acacia species. Acacia Senegal and Acacia seyal are the two Acacia species most commonly used in the production of gum arabic in the country [36]. Ethiopia currently produces three forms of gum arabic: Humera, Gumero, and Harar-Sidamo. The Ethiopian production system can be classified into two categories: intentional tapping and spontaneously oozing collection. The majority of the gums produced were sent to foreign markets without being added value. Ethiopia is divided into Somalia, Gambella, Oromia, and Tigray [37].

Gum Arabic's Importance in Gluten-Free Bread

In the backing sector, especially where non-wheat flours are employed, its viscosity and sticky qualities are important. Gum Arabic improves gluten-free dough features by causing the dough to bind more water in the gluten-free dough matrix, improving cohesion and gas retention. It also improves dough stability and consistency, can be used as thickening agents by raising batter viscosity at room temperature and forming gels that lend viscos-elastic behavior to dough, resulting in enhanced loaf and specific volume, and can help baked goods retain moisture. Making the bread have a soft texture and a lengthy shelf life by preventing it from rotting. Furthermore, gum Arabic is utilized in the backing sector to maintain overall product quality during storage while also extending shelf life by maintaining a steady moisture content and preventing staling [25].

Gum's potential health advantages

The joint FAO/WHO expert committee on food additives determined that gum Arabic is safe to consume on a daily basis for humans. Since the 1970s, the US Food and Drug Administration (FDA) has regarded it as a safe dietary fiber. Gum Arabic possesses dose-dependent prebiotic effects in healthy human volunteers.

Normal human volunteers who consumed varied daily doses of gum Arabic (5, 10, 20, and 40 g) for up to 4 weeks saw significant increases in Bifidobacterial, Lactose bacteria, and Bacteroides, implying a prebiotic impact. In animals and people, there is also a drop-in plasma cholesterol level [38]. Gum Arabic has been shown to have anti-obesity benefits in both people and animals when used as a dietary supplement. It is high in dietary fiber, which aids in weight loss and fat deposition. For example, healthy women took either gum Arabic or a placebo every day to see if it may prevent obesity by several mechanisms, such as decreasing caloric density of food and reducing fat absorption in the small intestine. Those who took the gum Arabic experienced a significant drop in body mass index and body fat percentage at the end of the six-week research period [39].

Dietary fiber helps to keep blood sugar levels in check. While there isn't much clinical study on acacia fiber and diabetes, there is some. Gum Arabic's fiber may aid to prevent against diabetes-related problems. Several varieties of gums have been proven to help with ailments like diarrhea, sore throats, kidney infections, wound infections, and gum infections. Only sporadic studies assessing their antibacterial properties have been published, leading to underestimation and, at times, over-desires for gums and gum products in treatments [39].

Characteristics of Ethiopian-grown gum Arabic

Ethiopia's dry areas have a lot of potential for commercial production of natural gums like gum Arabic. Gum Arabic quality criteria must meet specified chemical specifications, according to international specifications. The majority of gum Arabic produced in Ethiopia meets the international standard's suggested standards [40]. Gum Arabic's chemical composition varies depending on its source, climatic conditions, soil environment, and the age of the trees used to make it.

Conclusion

The properties of gluten-free doughs and an alternative way for overcoming the difficult chores involved in dough preparation. Hydrocolloids (gums) have been extensively studied as gluten-free dough and baked goods additions and improvers. A variety of investigation reports illustrate the history of gluten-free bread and its characteristics in traditional bread production when compared to popular wheat bread. The literature, on the other hand, focuses on alternate methodologies or non-gluten components that can be employed to improve the quality of gluten-free bread baking. The majority of gum arabic farmed in Ethiopia has qualities that are in line with international standards and have significant potential health advantages. In this case, local gums may be preferable for manufacturing cakes, confectioneries, and gluten-free bread due to their pasting and farinographic qualities.

Reference

1. López, E. P., & Jiménez, P. L. (2016). Effect of different proportions of brea gum in the functional characteristics of wheat flour starch: impact on the physical quality of bread. 36(1), 83–89. https://doi.org/10.1590/1678-457X.0030.
2. Kurek M. A., Wyrwisz J., Brzeska M., Moczkowska M., Karp, S., & Wierzbicka A. (2018). Effect of different beta-glucan preparation pretreatments on fortified bread quality. Food science and technology, 38(4), 606–611. https://doi.org/10.1590/fst.06917.
3. Ibrahim M., Salleh A., and Maqsood T. (2015). Bread towards functional food: An overview. International Journal of food engineering,(January2015). https://doi.org/10.18178/ijfe.1.1.39-43.
4. Deora Singh N., Deswal Aastha, Mishra Niwas A. & Hari. (2014). Alternative approaches towards gluten-free dough development: Recent trends. Food engineering reviews, 6(3), 89–104. https://doi.org/10.1007/s12393-014-9079-6
5. Brites Carla, Cristina Rosell M, Concha Collar and Trigo M.J. (2010). Maize-Based Gluten-Free Bread : Influence of processing parameters on maize-based gluten-free bread : Influence of processing parameters on sensory and instrumental quality. (May 2016). https://doi.org/10.1007/s11947-008-0108-4.
6. Mothe C. G. Rao M. A. (2000). Thermal behavior of gum arabic in comparison with cashew gum. Thermochimica Acta, 357–358, 9–13. https://doi.org/10.1016/S0040-6031(00)00358- 0.
7. Hemeda, H. M., & Mohamed, E. F. (2010). Ban bread quality as affected by low and high viscous hydrocolloids gum. World journal of dairy & food sciences, Vol. 5, pp. 100–106. Retrieved from http://www.idosi.org/wjdfs/wjdfs5(2)/1.pdf.
8. Soibe Gesare, Shitandi Anakalo, Mahungu Symon and Chikamai M. (2015). Effect of the gum Arabic on the physico-chemical and baking properties of the wheat plantain composite flour. Journal of food research and technology, 3(3), 98–105.
9. Suhail Ahmad, Mudasir Manzoor and Kaiser Saiqa. (2019). A review on latest innovations in natural gums based hydrogels: Preparations & applications. International journal of biological macromolecules, 136, 870–890. https://doi.org/10.1016/j.ijbiomac.2019.06.113.
10. Elkhalifa Elmoneim, Mohammed Ashwag, Mustafa Mayada and Abdulla.A. (2007). Use of guar gum and gum Arabic as bread improvers for the production of bakery products from sorghum flour. Food science and technology research, 13(4), 327–331. https://doi.org/10.3136/fstr.13.327.
11. Meybodi L.,Mohammad A., and Feizollahi Z. (2015). Gluten-free bread quality : A Review of the improving factors. 2, 81–85.
12. Milan Jafar, Malekin Gisoo. (2016). Hydrocolloids in food industry. (February 2012). https://doi.org/10.5772/32358.
13. Gudeta, A. N., Brundin, C., Feyissa, D. M., Balcha, T. T., & Agardh, D. (2019). Prevalence of celiac disease autoimmunity in Ethiopian pregnant women : A cross sectional study from the Oromia region. 7(3), 74–77. https://doi.org/10.12691/ijcd-7-3-1.
14. Bhattacharya Suvendu and Dipjyoti Saha (2015). Rheology of rice flour dough with gum Arabic: small and large-deformation studies, sensory assessment and modeling. Journal of food science, 80(8), E1735–E1745. https://doi.org/10.1111/1750-3841.12941.
15. Tzia C. and Sabanis D. (2011). Food science and technology international. https://doi.org/10.1177/1082013210382350.
16. Bourekoua Hayat, Benatallah L., Zidoune Mohammed, and, & Rosell Cristina M. (2018). Developing gluten free bakery improvers by hydrothermal treatment of rice and corn flours. Food science and technology 73(February),342–350. https://doi.org/10.1016/j.lwt.2016.06.032.
17. Naqash Farah, Gani Asir, Gani Adil ang Masoodi G. (2017).

Gluten-free baking: Combating the challenges - A review. trends in food science and Technology, 66, 98–107. https://doi.org/10.1016/j.tifs.2017.06.004.
18. Rostamin M. Milan T. and Maleki M. (2016). Physical properties of gluten-free bread made of corn and chickpea flour. (April). https://doi.org/10.1515/ijfe-2013-0004.
19. Bourekoua Hayat, Renata Rozylo, Leila Benatallah, Agnieszka Wojtowicz, Grzegorz Lysiak, Mohammed Nasreddine Zidoune, and Agnieszka Sujak. (2018). Characteristics of gluten free bread : quality improvement by the addition of starches / hydrocolloids and their combinations using a definitive screening design. European food research and technology, 244(2), 345–354. https://doi.org/10.1007/s00217-017-2960-9.
20. Minarro Vivas B. (2013). Development of gluten-free bread formulations. Bellaterra: Universitat Autònoma de Barcelona, 164. Retrieved from https://ddd.uab.cat/record/111681.
21. Kenny Sheila, Wehrle Karina, Stanton Catherine and Elke W. (2000). Incorporation of dairy ingredients into wheat bread: Effects on dough rheology and bread quality. European food research and technology, 210(6), 391–396. https://doi.org/10.1007/s002170050569.
22. Cristina Ballesteros Lopez, Julia Guimaraes Pereira and Gonçalves Junqueira Roberto. (2004). Flour mixture of rice flour, corn and cassava starch in the production of gluten-free white bread. 47(March), 63–70.
23. Moroni Alice, Bello D.and Fabio Elke. (2009). Sourdough in gluten-free bread-making: An ancient technology to solve a novel issue? Food microbiology, 26(7), 676–684. https://doi.org/10.1016/j.fm.2009.07.001.
24. Adediwura T, Falade.M, Naushade Emmambux & John Tylor (2014). Improvement of maize bread quality through modification of dough rheological properties by lactic acid bacteria fermentation.
25. Kohajdova, Z. & Karovicova, J. (2009). Application of hydrocolloids as baking improvers. 63(1), 26–38. https://doi.org/10.2478/s11696-008-0085-0.
26. Sidhu T. & bawa M. (2007). dough characteristics and baking studies of wheat flour fortified with xanthan gum. 2912. https://doi.org/10.1081/jfp-120015588.
27. Lazaridou A., Duta D., Papageorgiou M., Belc N., & Biliaderis, C. G. (2007). Effects of hydrocolloids on dough rheology and bread quality parameters in gluten-free formulations. Journalof-food-engineering,79(3),1033–1047. https://doi.org/10.1016/j.jfoodeng.2006.03.032.
28. Maleki, G., & Milani, J. M. (2014). Effect of different hydrocolloids on Barbari bread texture andmicrostructure. ActaAlimentaria,43(4),584–591. https://doi.org/10.1556/AAlim.2013.0008.
29. Bárcenas, M. E., & Rosell, C. M. (2005). Effect of HPMC addition on the microstructure, quality and aging of wheat bread. Food hydrocolloids, 19(6), 1037–1043. https://doi.org/10.1016/j.foodhyd.2005.01.005.
30. Encina Christian, Cadavez M. and Teixeira L. (2019). Bread by a mixture design of xanthan, guar, and hydroxypropyl methyl cellulose gums christian. Foods, 8(156), 1–23.
31. Storck Regina, Zavareze Elessandra, Gularte Arocha and Guerra Dias A. R. (2013). Protein enrichment and its effects on gluten-free bread characteristics. LWT - Food science and technology, 53(1), 346–354. https://doi.org/10.1016/j.lwt.2013.02.005.
32. Lopez Estela, Patricia Perez, Gabriela Teresa and Cuevas, C. M. (2013). Effect of brea gum on the characteristics of wheat bread at different storage times. Food science and technology, 33(4), 745–752. https://doi.org/10.1590/S0101-20612013000400021.
33. Gularte Marcia Arocha & Esthe dela Hera. (2012). Effect of different fibers on the enrichment of gluten-free layer cake. 1–26.
34. Sabanis Y. Lebesi L.and Tzia N. (2009). Effect of dietary fibre enrichment on selected properties of gluten-free bread. LWT - Food science and technology, 42(8), 1380–1389. https://doi.org/10.1016/j.lwt.2009.03.010.
35. Cappelli, A., Oliva, N., & Cini, E. (2020). A systematic review of gluten-free dough and bread: Dough rheology, bread characteristics, and improvement strategies. Applied sciences (Switzerland), 10(18). https://doi.org/10.3390/APP10186559.
36. Lemenih Mulugeta and Habtemariam Kassa. (2011). Opportunities and challenges for sustainable production and marketing of gums and resins in Ethiopia (M. L. H. Kassa, Ed.). Retrieved from www.cifor.cgiar.org.
37. Berta A. (2018). Production and challenges of gum arabic in Ethiopia : Review. 8(24), 33–45.
38. Babiker R., Merghani T. H., Elmusharaf, K., Badi, R. M., Lang, F., & Saeed, A. M. (2012). Effects of gum Arabic ingestion on body mass index and body fat percentage in healthy adult females: Two-arm randomized, placebo controlled, double-blind trial. Nutrition Journal, 11(1), 1. https://doi.org/10.1186/1475-2891-11-111.
39. Ahmed A. A. (2018). Health benefits of gum Arabic and medical use. In gum Arabic: Structure, properties, application and economics. https://doi.org/10.1016/B978-0-12-812002-6.00016- 6.
40. Yebeyen Dagnew , Mulugeta Lemenih &Sisay Feleke.(2009). Characteristics and quality of gum Arabic from naturally grown Acacia Senegal (Linne) wild. Trees in the central rift valley of Ethiopia. Food hydrocolloids, 23(1), 175–180. https://doi.org/10.1016/j.foodhyd.2007.12.008.
41. Dauqan E. & Abdullah A. (2013). Utilization of gum Arabic for. 10(10), 1270–1279. https://doi.org/10.3844/ajassp.2013.1270.1279.