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Review Article

Quality and functional attributes of muffins with incorporation of fruit, vegetable, and grain substitutes: A review

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Abstract
Raw ingredients directly affect the quality of processed foods. Along with improvements in processing technology, processed food production has grown significantly. The percentage of bakery products in total food consumption is very high, and soft bakery foods despite having a short shelf life, are well-liked because of their deliciousness. Special attention is paid to muffins with various combinations of nutritive ingredients and organoleptic qualities. Recent research studies have extensively covered the use of various fruits, vegetables, and grain and their by products as raw materials and value-added incorporation in the muffin to produce a nutrient-rich and highly valuable muffin. The present study provides a detailed observation of three major categories of incorporated ingredients, including fruits, vegetables, and their processing by products, as well as some other grain-based ingredients used as raw materials that add value. The study compiles a brief for their use in baked goods while reviewing the literature on ingredients. The findings of the literature analysis show an increase in the nutritional content of bioactive substances like antioxidants in the muffins. It has been revealed that using ingredients derived from fruits and vegetables is safer and more effective in terms of nutrition. Muffins may have a higher quality and better nutritional profile when certain combinations of fruit- and vegetable-based ingredients are added to the main ingredient. It will be helpful to researchers, food manufacturers, and small and medium-scale bakery unit operators about various aspects of the raw materials and properties connected with new muffin formulations and the standardization of stabilized products.

Keywords: Bakery products, Convenient foods, Enriched muffins, Muffins, Value added muffins

INTRODUCTION

Muffins are baked food items made from the grain ingredients flour, sugar, fat, and flavors (Samokhvalova *et al*., 2020). The term "muffin" first appeared in a British magazine called "London Laboure" in 1851, where the muffin started. People from all age groups can be served muffins as breakfast or snacks because they come in a variety of sizes, shapes, and flavors. The global muffin market's expansion is due to consumer inclination towards innovative health products (Shih 2020). Trends for recent food consumption include products with natural ingredients, whole grains, minimum fat or healthy fat, sugar substitutes, flavor diversity, vegan, gluten-free, dairy-free, etc. As of November 2019, bakery franchises launched vegan muffins in

various flavors of plant fiber and minerals; also, in October 2018, Health Warrior, Inc. launched a high-protein, gluten-free, soy-free, non-GMO, dairy-free vegan muffin. “The market for these products is projected to continue expanding between 2021 and 2026 at a CAGR of 8.5%, reaching a value of USD 12.39 billion. The only restraint in the market is due to increasing health adversities like cardiovascular disease, high blood pressure, and obesity; however, many factors influence a customer to purchase such products, including cost, convenience, taste, and nutrition(Silveira *et al*., 2012). Due to globalization, increased exchange of cultures, and changing palates of consumers due to innovations in flavors and added ingredients, the Indian bakery industry is witnessing growth.

TYPES OF MUFFINS AND CHARACTERISTICS

The different types of muffins are categorized based on how they are made, e.g., bread muffins (produced by large commercial bakeries), which have nearly 12% fat and sugar, and (produced by smaller institutions or made at home). Cake-like muffins essentially contain more fat and sugar because they are made with soft wheat flour, which has approximately 18–40% fat and 50–70% sugar. The sensory qualities of the finished product are significantly influenced by the ingredients used in muffins, including flour, sugar, fat, and egg (Arifin *et al*., 2019). Quality parameters of common muffins with desirable and undesirable characteristics are mentioned in Table 1. Muffins based on wheat are readily available in the commercial market. Muffins must be appropriately prepared, but they also have several flaws that make them less desirable and crucial from a health perspective. As per the necessity of the current scenario, muffins need to be reformulated as a healthier, guilt-free option for people (low-fat, low-sugar, and high-fiber products), leading to a healthier life, considering food intolerances and specialized diet necessities (sports nutrition diet, veganism, children, women, seniors, and diabetic consumers). There should be approaches to decrease the use of preservatives, additives, sugar or artificial sweeteners, and other chemicals that result in subpar muffin preparation used in the production of muffins, which is unhealthy and healthy possible ingredients should replace these chemicals. There may be technical modifications in muffin production to get the healthy muffins desired (Kupiec *et al*., 2021). For example, during muffin preparation, batters are used with more fluid or contain more water than doughs; they can be poured and flowed in a matter of seconds. The important properties that include healthy, nutrient-rich and consumer-appealing muffins must meet a golden-brown rounded top, symmetrical shape, moist and tender appeal, and touch, with streaks, a free, slightly yellow or creamy white inside, which is again composed of the uniform cell, a sweet flavor and pleasant aroma, and moderate size are the characteristics of a desirable muffin (Rolim *et al*., 2020).

Byproducts from food industries (fruit and fruit processed products, and vegetables and vegetable processed products) Cereals, legumes, nuts, and oilseeds added to wheat-based bakery products are responsible for enhancing the physiochemical properties, organoleptic properties, and nutritional parameters of the products (Martins *et al*., 2017). It has been found fre-

Table 1. Quality parameters of muffins with desirable and undesirable characteristics

Parameters	Desirable characteristics	Undesirable characteristics	
Crust color	Golden brown is the ideal color for the crust; whole-grain flour or additional ingredients like nuts, dried fruit, or spices can make it darker.	Crust color	Wenniger & Wenniger (2005)
Texture	Both grain and physical condition have an effect. Being easily broken and slightly crumbly is a desirable quality.	Extreme crumbling and toughness without crumbling	Cross (2007)
Volume	Bell-shaped or mushroom-shaped.	Volume	Reinhart (2011)
Surface	The muffin should have a pebbled surface, be round, and have a golden-brown color.	Deflating, burnt	
Aroma	The sense of smell can identify aroma. It could have a sweet, rich, musty, or flat aroma. Pleasant, natural, sweet, and fragrant aromas are what you want to smell like.	Aromas that are sharp, bitter, or foreign should be avoided	Cross (2007)
Flavor	The sweet flavor is appealing and desirable.	Flavor	
Cell uniformity and size	They can be assessed by cutting the muffin vertically into two equal halves, followed by making an ink print or photocopy.	Cell uniformity and size	Cross (2007)
Aftertaste	Enjoyable and sweet.	Bitter or strange	Mouritsen & Styrbæ (2017)
Mouthfeel	Gritty, hard, tough, tender, light, and moist are some possible adjectives to describe traits.	Mouthfeel	Mouritsen & Styrbæk (2017)

quently successful in increasing the quality of the formulated products by incorporating such functional ingredients into bakery products at a rate of 10%. These useful ingredients enhance bakery goods' nutritional profile but can also degrade certain sensory and practical qualities. Cakes and biscuits enhanced with these useful ingredients cannot compete nutritionally with bread's healthier profile. Industrial byproducts made from fruit that are used as functional ingredients differ significantly in their physicochemical makeup depending on where they came from and may stand out because of the amount of fiber, protein, and/or minerals they contain(Bravo-Núñez and Gómez 2023)In general, adding fruit-based industrial byproducts to functional ingredients can enhance the nutritional qualities of bakery goods. On the other hand, they may also deteriorate some sensory and functional qualities. It is necessary to strike a balance when incorporating fruit-based industrial byproducts to produce healthier bakery goods that can compete in sensory qualities with the advancements in the bakery industry.

BASIC MUFFIN INGREDIENTS AND PREPARATION

The detailed analysis of muffins indicates the presence of moisture, protein, fat, carbohydrate, ash, crude fiber, etc. Muffin ingredients typically include the following: wheat flour (525 g), margarine (345 g), refined sugar (320 g), eggs (300 g), water (165 g), baking powder (7.5 g), and salt (3 g), along with any other necessary additives (Purnomo *et al*., 2012). The steps with methods and technology applied for muffin preparation are mentioned in Table 2 and Fig. 1.

Incorporated muffins

Fruit and fruit product incorporation

Various fruits have been used as a key ingredient in several bakery products over the past few decades, adding fiber, vitamins, and minerals to the finished product(Majerska *et al*., (2019). Table 3 lists the characteristics of the muffins when fruit and fruit products are added as important ingredients, along with the beneficiary population of the prepared muffins.The functionality of baked food can be improved by using fruit and vegetable pomace for its functional properties. Various fruits and processed products are used to prepare bakery products, such as biscuits, cookies, crackers, cakes, muffins, and scones. Fruit pomaces can provide better sensory properties and functional attributes to baked food products like cakes (Prashant Sahni, 2018). As a substitute for wheat flour in muffins, Mango pulp flour has been evaluated for its physical and sensory properties. This results in an increasing level of MPF with decreased chewiness, gumminess, hardness, and crumb color. Ajila *et al.* (2008) also reported functional attributes of mango in bakery goods.

Vegetable and vegetable product incorporation

Researchers use vegetables and products made from processed vegetables to make muffins, which have been efficiently and effectively produced for the last few decades (Majerska *et al*., (2019). Together with the beneficiary population for the prepared muffins, Table 4 summarizes the qualities of the muffins when vegetables and vegetable products are added as significant ingredients.The tomato processing byproduct that was used to make the muffins was discovered to be rich in minerals, vitamins, and antioxidants, and lycopene found in tomatoes also showed a medicinal role in that the tomato pomace muffins had anti-cancer properties, and it was popular among people of all ages as a convenient food item (Mehta *et al.,* 2018). As red capsicum contains phytochemicals like capsanthin, b-carotene, lutein, and zeaxanthin, their incorporation increases levels of phenolics and flavonoids in the red capsicum pomace powder muffin product (Nath *et al.,* 2018).There are several advantages to adding cabbage outer leaf powder, a good source of dietary fibers, to muffins that are intended for people who want to control their weight and obesity (Heo *et al.,* 2019).

Grain and miscellaneous ingredient incorporation

Several additional ingredients are added to muffins for their functional qualities and the main ingredients, are

Table 2. Muffin preparation steps with methods and technology applied

Process stage of muffin preparation	Methods/technology applied
1) Mixing	(a) Cake method: mixing shortening and sugar until smooth, followed by adding liquid ingredients, and then mixing in dry ingredients. (b) Muffin method: contains two to three steps. The dry ingredients must first be combined. Next, combine the shortening or oil and other liquids. The liquid mixture should then be added to the dry ingredients, and the dry ingredients should continue to be mixed until moistened
(2) Pouring	Hand pouring is used for small businesses and home bakeries; depositors are used for industrial manufacturing.
(3) Baking	For a typical two-ounce muffin, complete baking in a convection oven at 160°C to 180°C for 25–35 minutes at 204°C or just a little higher.
(4) Cooling	Muffins should be allowed to cool for 60 minutes on a cooling rack to give the structure time to "set" and reduce the likelihood of condensation forming inside the package.
(5) Packaging	For merchandising, the items can be individually wrapped or put into plastic form trays.

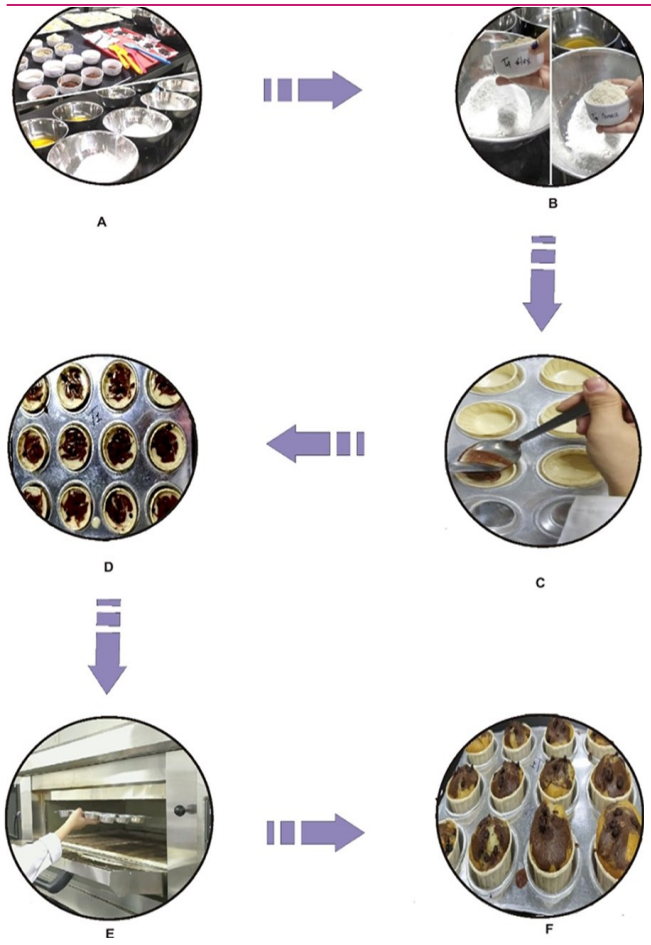

Fig. 1. *Showing muffin preparation process (A) Scaling of ingredients (B) Mixing wet and dry ingredients (C) Scooping batter into muffin liners (D) Muffin liner filled with batter (E) Baking of muffin in the oven (F) Cooling prepared on a rack*

fruits, vegetables, and processed byproducts (Larrosa and Otero, 2021). Muffins' volume and softness increase after the addition of whey protein concentrate and egg white protein as an egg substitute(Bala *et al.,* 2019). This also encourages fat distribution throughout the batter, providing more space for gas to expand while preparing eggless muffins. According to Padhi *et al.* (2015), soy flour muffins have a synergistic effect on protein, dietary fiber, and bioactive that have emulsifying, binding, and texture properties. They also increase water-holding capacity, encourage feelings of fullness, and prevent cardiovascular disease. Cocoa Fiber Muffins prepared using Dietary Fiber provide antioxidants, flavor, colour, sponginess, and springiness with health benefits in preventing hypercholesterolemia (Martínez-Cervera *et al*., 2011). The attributes of the muffins after some miscellaneous ingredients and products are added as significant ingredients, along with the beneficiary population for the formulated muffins, are detailed in Table 5.

This review concludes the physical, biochemical, organoleptic, and nutritional profiles, quality attributes, and functional properties of prepared products made from various fruits, vegetables, and other ingredients. These conclusions are based on research and the findings of related literature. Utilizing the byproducts of the fruit and vegetable industries in preparing useful goods is a significant aspect of the development of the food industry(Gowe 2015). Byproducts from these industries have valuable components for health benefits, and when they are used to produce food products, they add value to the product, help to reduce environmental pollution and help the national economy by improving waste management (Bharat Helkar and Sahoo 2016). In addition to posing a risk to the public's health due to disposal issues and environmental pollution caused by fruit byproducts, Lyu *et al.* (2020) claim that apple pomace can be used to enhance the quality of confectionary bakery products. The following discussion focuses on how the authors attempt to relate the variation of the key physiochemical parameters of muffins made from the ingredients.

PROPERTIES OF MUFFINS

Carbohydrate

Carbohydrate content is reported to be higher in fruit-based incorporations as most of the fruits are rich in natural sugar. However, since vegetable and vegetable byproduct-based ingredients do not contain significant sugar, the products may contain more carbohydrates than sugar depending on the quantity and type of carbohydrates in the raw materials. Cross-linked cassava starch (CCS) muffins were created by substituting modified cassava starch for fat to mimic fat's physiochemical and sensory characteristics(Rodriguez *et al.,* 2017). The monosaccharides fructose and glucose make up the natural sweetener honey, which is comparable in sweetness to granulated sugar (sucrose). Due to its sweet flavor and alluring chemical characteristics, honey is a common ingredient in baking. Additionally, it gives food a distinctive flavor when used as a sweetener.

Fat

Various researchers talked about fat content when describing formulations. The fat content analyzed in various formulations of muffins indicates that ingredients rich in an organic component like starch or fiber sugar do not increase the fat content in the final product, whereas the dry fruits and cocoa-based incorporation are responsible for the increase in fat content of the prepared product. Most fruits and vegetable-based ingredients are rich in sugar and fiber but have minimal fat, so there is no significant change in the fat values of the products. They generally decrease the total fat content in a smaller share. As fat is a crucial ingredient in bakery products, including muffins, researchers have taken several approaches to reduce or replace fat content with a suitable substitute without compromising the

Table 3. Characteristics and major ingredients of the muffins after fruit and fruit product incorporation

Development Using	Characteristics	Product Name	Beneficiaries	Ingredients	Reference
Mango dietary fiber (MDF)	High phenolic and antioxidant activity.	MDF muffin	All age groups	MDF, milk, eggs, vegetable oil, sugar, salt, baking soda, and yeast are all ingredients in maida.	Ajila *et al*., (2008)
Pomegranate	Bioactive compounds, phytochemicals like phenolics, flavonoids, carotenoids	Pomegranate derived phytochemicals	All age groups	Dry ingredients (flour, salt, and baking powder), water, pomegranate pomace, flour, peel phytochemicals extracted using SFE, egg, and essence are combined with fat and sugar	Topkaya and Isik (2019)
Feijoa and persimmon processing products	A higher concentration of vitamins and minerals, such as iodine and iron, and a lower concentration of sugar and fat.	Iodine And Iron Fortified Muffin	Iodine deficiency diseases, iron deficiency anemia, pregnant women, and people at risk	Feijoa and persimmon processing products	Ivanova *et al.* (2021)
Apple skin powder (ASP)	Flavonoids and phenolic acids, among other phytonutrients, prevented the growth of HEPG2 (human hepatocellular liver carcinoma).	ASP muffin	All age groups	Salt, vegetable oil, baking powder, egg powder, skim milk powder, and wheat flour are all ingredients.	Rupasinghe *et al.*, (2007)
Raspberry pomace (RP),cranberry pomace powder (CP)	Rich source of antioxidants.	Raspberry and cranberry pomace powder muffin	All age groups	Wheat flour, fat, sugar, water, fat free dry milk powder, baking powder, and dry egg whites; salt, RP, and CP powders	Mildner-Szkudlarz *et al.*, (2016)
Date fruit fiber concentrates (DFC)	vitamins (A, B1, B3, C), Carbohydrates, dietary fiber, and macro-elements like hosphorus, iron, calcium, and potassium, as well as antioxidant dietary fiber that delays aging due to its water holding capacity (WHC), all inhibit the oxidation of lipids.	Fiber concentrates muffin	All age groups	Wheat flour, sugar, eggs, baking powder, sunflower oil, and date fruit fiber concentrates from Tunisia varieties, DFC 165 and DFC 180, were obtained through steam treatment at different temperatures of 165 and 180 degrees Celsius, respectively.	Mrabet *et al.,* (2016)
Dacryodes macrophylla L. Fruit	Mineral contents (especially Na and K), increased specific gravity, increased adhesiveness, antioxidant activity	Moreton Bay or Australian banyan	All age groups	Wheat flour, Sugar, Vegetal oil, Milk Baking powder, Eggs, Baking soda Dacryo-des macrophylla L. Extract	Sandrine *et al.,* (2022).

quality of the products. Since 1975, the number of cases of obesity has tripled, according to WHO (2020), and muffins with fat substitutes may help address this problem. The decrease in fat content brought on by the fiber addition also caused a reduction in calories that ranged from 1.02% to 12.14% in a reformulated muffin (Harastani *et al.,* 2021) . In the formulation of the muffin, using 30% pureed pumpkin as a replacement for butter was found to be the most acceptable (Arifin *et al.,* 2019). A similar % reduction in total fat of 45% was observed when 50% inulin was used as a fat replacer (Zahn *et al.,* 2010). Baixauli *et al.* (2008) noted minor variations in moisture, sweetness perceptions, and grittiness when resistant starch was used in the formulation, but otherwise, the overall acceptability was the same.

Protein

The protein content of the muffins varies in different formulations in such a way that the protein content of dry fruits and some millet, cereal, and pulse-based formulations of muffins contained ingredients rich in protein components that increased the protein content in the final product(Rustagi *et al.,* 2024)In contrast, fruits and vegetable-based ingredients, rich in sugar and fiber but lacking protein did not increase the protein con-

Table 4. Characteristics and major ingredients of the muffins after vegetable and vegetable products incorporation

Development Using	Characteristics	Product Name	Beneficiaries	Ingredients	Reference
Tomato processing byproduct	Lycopene, among other minerals, vitamins, and antioxidants, has anti-cancer properties	Tomato pomace muffin	All age groups.	Tomato pomace, white flour, sugar, salt, yeast, butter, baking soda, and milk powder	Mehta *et al.* (2018)
Red capsicum pomace powder	Ascorbic acid, phenolics, and flavonoids as well as capsanthin, b-carotene, capsorubin, lutein, and zeaxanthin	Red capsicum pomace powder muffin	All age groups.	Red-capsicum mature fruits, freeze-dried capsicum pomace powder, wheat flour, white sugar, vanilla extract, baking powder, fresh white eggs, and butter	Nath *et al.*, (2018)
Pumpkin puree	Vitamins and phytochemicals	Pumpkin puree	All age groups	Sugar, salt, baking powder, egg, pumpkin, milk, and butter are all-purpose ingredients.	Arifin *et al.* (2019)
Modified cassava starch	Alternatives to fat, mimic the physiochemical and sensory characteristics of fat.	Cross-linked cassava starch (CCS) muffin	Overweight and obese.	Wheat flour, baking powder, whole milk, powdered sugar, butter, margarine, eggs, salt, orange flavor, and sodium propionate are all ingredients in CCS gel.	Rodriguez-Sandoval *et al.* (2017)
Chinese Cabbage outer leaf powder	Good source of dietary fibers, and antioxidants.	Kimchi byproduct powder muffin	Obese and overweight.	Commercial soft flour, sugar, butter (obtained from Seoul milk ICA in Seoul, South Korea), skim milk powder, vanilla extract, baking soda, eggs, and milk and kimchi byproducts	Heo *et al.* (2019)
Green pea flour	Phenylalanine, lysine, and threonine are essential amino acids, protein, and dietary fibre sources.	Green pea flour muffin	All age groups.	Eggs, milk, butter, sugar, flour, green pea flour, and sodium bicarbonate	Gomes *et al.* (2022)

tents. Therefore, there was no significant change in the protein values of the products, and generally, a decrease in the total fat content in a smaller share was observed in such formulations. Muffins fortified with gluten-free flour were made using white rice flour to avoid gluten-related issues (Bhaduri 2013).

Moisture

The muffins' moisture content depends on the moisture-holding capacity of the ingredients and compounds present in the muffins. Fiber-rich ingredients play a significant role in moisture holding and increase the overall moisture of the products. Fruits and vegetable-based ingredients are rich in fiber, so there is a general increase in the amount of water in such formulations. Mrabet *et al.* (2016) deliberated that the date fruit fiber concentrates used in the preparation of fiber concentrates muffins have good water holding capacity (WHC) which is why the final product is rich in moisture content.

Crude fiber

Ingredients rich in crude fiber, such as fruit and some vegetables, directly impact the crude fiber content of the final products. However, dry fruits and pulse-based formulation of muffin ingredients rich in protein components do not increase the final product's fibre content. However, refined wheat flour is a poor source of fiber in comparison to replacement powder. Mehta *et al.* (2018) reported that tomato pomace has good organoleptic and physicochemical properties as well as good nutritional potential (dietary fiber, antioxidant activity, vitamin C, and minerals.

Ash

The ash content analyzed by different scientists in various formulations of muffins shows that ingredients rich in organic components decrease the total residue in the final product. In contrast, inorganic compound-containing ingredients are responsible for the increase in the ash content of the prepared product. Most of the fruits and vegetable-based ingredients are rich in organic components, and they tend to decrease the total Ash in the product(Gasparre and Rosell 2022). Ingredients derived from feijoa and persimmon processing products provide minerals and vitamins, including iodine and iron deficiency anaemia, when making iodine and iron-fortified muffins for pregnant women and people at risk of developing iodine deficiency diseases (Ivanova *et al.,* 2021).

Storage stability

The stability of muffins varies depending on the ingredients and the surrounding environment because they are sensitive to moisture, temperature, and microbes

Table 5. Characteristics and major ingredients of the muffins after miscellaneous ingredient and product incorporation

Development Using	Characteristics	Product Name	Beneficiaries	Ingredients	Reference
Lupin flour	Significant amounts of both soluble and insoluble dietary fiber fractions.	Lupin flour muffin	All age groups.	Lupin flour, sugar, fresh egg, milk, vegetable oil, baking powder, wheat gluten, table salt, water, and vanilla essence are all ingredients in baking	Nasar-Abbas and Jayasena (2012)
Soy flour	Increase water-holding capacity,satiety, prevent cardiovascular disease, and have a synergistic effect on protein, dietary fiber, and bioactives that have emulsifying, binding, and texture properties	Soy flour Muffin	All age groups.	Extra-fine granulated white sugar, salt, defatted soy flour, soft wheat, whey isolate INPRO 90 protein powder, canola oil, citric acid, and 5-dextrose equivalent (5DE) maltodextrin, cold water swelling Novation®4600 native corn starch, WC150 wheat, artificial banana bread, lemon and vanilla flavoring	Padhi et al. (2015)
Garden cress seeds	High in protein and fiber, beneficial for treating rheumatism's clinical complications, including swelling, muscle pain, bronchitis, asthma, piles, and cough	Garden cress seeds muffin	All age groups.	yogurt, milk, lemon juice, coconut oil, baking soda, sugar, cinnamon powder, and vanilla essence	Rabail et al., (2022)
Carob powder	minerals such as calcium, potassium and iron, both soluble and non-soluble dietary fiber. Promising pharmacological effects of polyphenolic compounds included antioxidant, antibacterial, anti-inflammatory, and anti-diabetic properties.	Carob powder muffin	All age groups.	Dry carob pods, wheat flour, sugar, baking powder, salt, fat milk, canola oil, egg, and carob powder made from wheat flour	Červenka et al., (2019)
Almond protein	Amandine is one of 434 different proteins, and it is the most prevalent and water-soluble one. hydrophilic-hydrophobic molecular structure may offer emulsifying properties.	Fortified Corn Muffins	All age groups.	Quark, sugar, baking powder, vanilla sugar, water (20°C), whole wheat flour, whole egg powder, potato starch, aromas (NaCl and beta-carotene), rapeseed oil, and other ingredients.	Ahmed and Araujo (1978)
White rice flour	Rich in carbohydrates and low in fat	Two Gluten-Free Flour Fortified Muffins	All age groups.	Flour, white sugar,salt, baking powder (double-acting), vegetable oil, and 2% reduced-fat milk fresh large eggs	Bhaduri (2013)
Chia seed	proteins, fiber 35.5% with ample soluble & insoluble fibres ,ω3 PUFA, vitamins, minerals. healthy fat 31 to 35% like alpha-linolenic acid (ala), cardioprotective ratio of ω6/ω3 of 1:3. Best source of vegetal proteins (18.9–23%), bioactive peptides having potential as antioxidants, anti-diabetic, anti-inflammatory & hypotensive.	Chia seed-fortified muffins	All age groups.	Baking ingredients include baking soda, sugar, cinnamon powder, vanilla essence, yogurt, milk, lemon juice, coconut oil, and egg whites.	Rabail *et al*., (2022)
Vegetable oil in water cellulose ether emulsions (prepared with two different hydroxypropyl methylcelluloses as fat replacers)	The reduced temperature required for starch to gelatinize and effective at reducing fat	Cellulose ether emulsions muffins	Overweight and obese.	Whole milk, wheat flour, refined sunflower oil or butter, pasteurized liquid egg, sodium bicarbonate, citric acid, and salt (sodium chloride), cellulose emulsion K4M or K250M.	Martínez-Cervera *et al.* (2015)

Contd……...

Table 5. Contd…...

Cocoa fiber	Dietary fiber, antioxidants, the flavor and color of cocoa, the prevention of hypercholesterolemia, and the provision of sponginess and springiness	Cocoa Fiber Muffin	All age groups.	It contains whole milk, refined sunflower oil, pasteurized liquid egg yolks and whites, salt, sodium bicarbonate, citric acid, and soluble cocoa fiber.	Martínez-Cervera *et al.* (2011)
Resistant starch (RS)	preventing colon cancer, managing blood sugar levels, and having a low water-holding capacity	Resistant starch-enriched muffin	All age groups.	RS contains the following ingredients: wheat flour, liquid pasteurized egg white, liquid pasteurized yolk, full-fat milk, refined sunflower oil, sodium bicarbonate, citric acid, and freshly grated lemon peel.	Baixauli *et al.* (2008)
Upcycled sunflower flour	Apparently, having a high antioxidant potential are protein, fiber, essential amino acids, and minerals	Upcycled sunflower flour muffin	Overweight and obese.	Sunflower flour, water, skimmed milk powder, baking powder, salt, sugar, wheat flour, whole egg, and control dough	Grasso *et al.* (2021)
Inulin	Prebiotic properties, fructose, as a sugar and fat substitute, short-chain inulin can be used because of its sweet flavor, high solubility, and low viscosity.	Inulin and Green Banana Flour muffin	Diabetic and obese.	Rapeseed oil, humectant, wheat flour or corn starch, whey powder, skim milk powder, emulsifiers, water, sugar, eggs, raising agents (diphosphates, sodium carbonate, potassium carbonate), acidity-regulating flavoring, sugar.	Harastani *et al.,* (2021)

from the outside(Ouma, 2023). Customers are drawn to this practice because adding fruit and vegetables to baked goods enhance their look, texture, nutritional value, sensory qualities, and shelf life. Muffins' nutritional value and storage stability are increased by adding flaxseed meal or oil without affecting the product's freshness and sensory qualities (Kaur and Kaur 2018).

Color

When determining consumer acceptance, color is one of the most important factors. The color of products directly varies as per the incorporation of ingredients. It is related to the components of the additives(Martins *et al.,* 2017) The baking parameters are also responsible for the color of the products. The presence of the pigment in muffins caused a darkening effect, decreasing the lightness (all-purpose flour) and making them more yellowish (carotenoid pigment in pineapple), making them slightly browner and more yellowish in color than the control treatment. Due to the addition of sugar-containing fruits, the muffin's dark color may be the result of the Maillard reaction between reducing sugar and protein. Sangnark and Noomhorm (2004) noted that adding high-fiber ingredients to bread darkens the color of the bread. Adding more protein can hasten the Maillard reaction and result in a browner color because the Maillard reaction is known to be connected to the crust characteristic.

Physical parameters of muffin

The volume of baked muffins noticeably decreases, typically attributed to moisture loss (evaporation) and CO_2 production by leavening agents, which cause expansion during the early baking stages. Due to its lack of sulfur amino acids like cysteine and methionine, which are crucial for heat gelation and have limited disulfide bonds, such protein may have poor gelling properties. Concentrations of branch-chain amino acids (BCAA) in the protein, which are comparable to those in soy protein, suggest that it may be able to alter insulin sensitivity, and gut hormones in flaxseed protein, which are comparable to those in soy, suggest that it may be able to have significant immune-system-boosting effects. Mrabet *et al.* (2016) demonstrated that when date fiber concentrate (DFC-165) was added to wheat flour as a fortifier, better organoleptic parameters and softness were obtained and higher antioxidant capacity but lower cohesion and elasticity.

Baking quality

Muffin quality varies depending on the ingredients and baking techniques used (Belorio and Gómez 2020). Due to the muffin's loss of tocotrienols and tocopherols, the raspberry and cranberry pomace powder raise the baking temperature. Mildner-Szkudlarz *et al.* (2016) discussed how texture, microscopic structure, and viscoelastic properties were improved, and reported that optimal phytochemical retention was reported at an intermediate baking temperature of 180 °C for 20 min.

Antioxidant potential of muffin

A class of substances known as antioxidants significantly inhibit or delay oxidative processes while frequently undergoing oxidation when present in low concentrations compared to oxidizable substances. Phenolic antioxidants have been shown to prevent food from spoiling and fight free radicals in the body. They discussed how phenolic acids, flavonoids, and tocopherols can lower lipid peroxidation in food and enhance food quality by acting as natural antioxidants. Phenolic antioxidants have been demonstrated to prevent food deterioration in addition to scavenging the body's free

radicals. Natural antioxidants like flavonoids, tocopherols, and phenolic acids can lower lipid peroxidation in food and enhance food quality (Ndhlala *et al.,* 2010).

Fruits and their byproducts are great sources of antioxidants, and the food industry has recently begun to pay attention to them as functional food ingredients, especially in baked goods like cookies. Cookies can be made with antioxidant-rich pineapple pomace powder to increase antioxidant activity. This might be because pomace powder has a high content and small particle size, which increases the antioxidant compounds' ability to be extracted. Tańska *et al*. (2016) stated that an increase in antioxidant activity for cookies after baking may be due to both the high concentration of antioxidant-rich pineapple pomace powder used in the cookies and the Maillard reaction, which causes brown color compounds to form during baking. Rupasinghe *et al.* (2007) stated that apple skin-enriched muffins exhibit significant phytochemical content and nutraceutical potential. Bioactive phytochemicals like phenolics, flavonoids, and carotenoids are present in significant amounts as an ingredient in the peel of pomegranate fruits (Topkaya and Isik 2019). The tomato pomace muffins were prepared using tomato processing byproducts to enrich minerals, vitamins, antioxidants, and lycopene (Mehta *et al.,* 2018).

Nutraceutical potential of muffin

The nutraceutical potential of muffins is influenced by dietary fiber and phytochemicals in fruits and vegetables, demonstrating their antioxidant and anti-inflammatory properties, which would be useful in lowering the risk of several non-communicable diseases (Zhu and Xu 2018). Apple skin powder (ASP) prepared ASP muffins rich in phytonutrients, including flavonoids and phenolic acids, inhibited HEPG2 (human hepatocellular liver carcinoma), and showed potential medicinal properties. In addition to masking the flavor of flaxseed and pomace in muffins, honey has many health advantages. It has been demonstrated that adding honey to bread dough has functional advantages for the finished good. It can make the dough more adept at retaining water, yielding more finished goods from a given quantity. Additionally, it helps the bread brown, form a crust, and have a longer shelf life and improve the flavor and texture of the bread. Apple skin has been used as a food ingredient with added nutritional value due to its capacity to retain water and high fiber content, which improves general health (Rupasinghe *et al.,* 2007).

Textural properties

One of the most important characteristics and a key element in determining whether consumers will like muffins is their texture. The high fiber content of the incorporated fiber-rich powder increased the product's crude fiber content (Zhang *et al.,* 2018). However, when compared to the substitute powder, refined wheat flour is a less significant source of fiber. Incorporating pineapple pomace powder into the batter system may prevent the gluten network from forming because insoluble dietary fiber (DF) is this powder's main type of DF. The muffin's cohesiveness, springiness, and precise volume are reduced. The proteins in flaxseed absorb more water, making food products more malleable and pliable when handled and cooked (Alpaslan and Hayta 2006). The addition of PPP and FSM increased the muffin's hardness and gumminess because of the insoluble dietary fiber in PPP, but they may interfere with the formation of the gluten network, causing a decrease in cohesiveness, springiness, and specific volume. Honey was included in the muffin recipe for two purposes: to bind water and to stop the development of gluten, increasing the muffin's tenderness in the lower fat portion. The substitution of high-fiber ingredients into bread darkens the color of the bread, according to observations made by earlier researchers (Sangnark and Noomhorm 2004). The substitution of sugar by high fructose corn syrup also alters the bakery's physicochemical properties, such as a change in fructose content, which also helped prepare the fat-reduced muffins' water bind together (Zargaraan *et al.,* 2016). The proteins from flaxseed could hold onto water better. Increased moisture absorption was found to positively impact the textural qualities of food products during handling and cooking, particularly elasticity and softness (Alpaslan and Hayta, 2006).

Shelf life

Muffins that contained functional ingredients were found to be more stable regarding shelf life (Prastuty *et al.,* 2021) In general, a decrease in off-flavors is reported on flaxseed incorporation. Additionally, muffins made with the incorporation of the flaxseed-based ingredient were found to be more stable over time. Flaxseed meals or oil increase the nutritional value of muffins without affecting their freshness, sensory, or storage qualities. It is known that muffin formulations made with various amounts of pomegranate peel with wheat flour exhibit better functional properties and shelf lives with high levels of oxidative stability and crude fiber (Topkaya and Isik 2019).

Conclusion

The fruits, vegetables, and nutritionally dense grains that Agri byproducts are now widely recognized for adding value to baked goods. The bioactive substances of these incorporations are important for improving the nutritional profile and quality of processed foods. The

review's conclusion, which incorporates adding fruits, vegetables, and nutritious grains as components, improves the muffins' physiochemical, nutritional, textural, and overall quality aspects. The review output provides the nutritional value of muffins through various modifications, such as fiber-rich muffins, sugar-free muffins, antioxidant-rich muffins, and muffins without fat. Simultaneously, various fruits, vegetables, and other raw materials are used in different formulations to properly utilize such ingredients in bakery products and develop value-added products. The present review focuses on delivering a summary of the benefits regarding health and elaborating on the functionalities of different food ingredients and food industry byproducts. Moreover, insights into current muffin offerings, the muffin production process, and an overview of factors affecting muffin sensory and overall quality upon different reformulations have been discussed. The conclusion of review provides detail about the physiochemical characteristics of various muffin formulations here because, in general, the quality, nutritive value, and organoleptic properties of any food product are the primary determinants of the product's success. The review offers a modest database that will aid researchers in their future work and assist small and medium-sized enterprises (SMEs) in introducing new products while keeping an eye on trends and health benefits and growing their businesses. Bakery products need to reduce fat, sugar, and calories and utilize abundant food and food byproducts to get a vast range of healthy products. Nutritional diseases will be reduced with healthier consumption of such reformulations without conscious decision-making to modify food choices among the population. This review will be helpful in the formulation and preparation of muffins using readily available food and food-based processed products to reduce the risk of unhealthy lifestyles being passed down to future generations.

Conflicts of Interest

The authors declare that they have no conflict of interest.

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