Baking KETO

BAKERguide Vol. 3-2

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WHAT IS THE KETO DIET?

Ketogenic (keto) diet is a carbohydrate-restrictive, high-fat diet that has gained significant popularity in the last few years. This regimen recommends a caloric diet plan, typically consisting of 70% fat, 20% protein, and 5% carbohydrates.

In the 1920s, before insulin became available, keto diets were developed to treat type-1 diabetes patients through dietary modifications. Subsequent research showed that keto diets can also be effective in reducing seizures, pediatric epilepsy, and cluster headaches. The beneficial effects of keto diets in treating various neurological disorders, including Autism, Alzheimer's, and Parkinson's disease as well in mood stabilization have been highlighted in recent investigations.

Keto diets are based on the principle that depleting the body of carbohydrates (carbs), the primary source of energy, forces it to break down fat for fuel. In the liver, the broken down fats produce metabolic by-products (acetoacetate, β-hydroxybutyrate and acetone) known as ketone bodies or ketones. Once these substances are formed in sufficient amounts, the body is assumed to have entered a state of ketosis.

Mainstream keto diets, however, started with the discovery that the physiological and biochemical basis occurring during abstinence from carbohydrates can help induce effective weight loss and improve several parameters of cardiovascular risk. It should be noted that modern keto diets designed for weight loss are quite different from the ones that were practiced in the early part of the twentieth century for medical treatments.

Keto Diet Market Opportunities

- **64%** of US keto dieters plan to stick with the diet.
- Keto market is valued at **12.45 USD billion** as of 2024, and it's expected to expand with a compound annual growth rate (CAGR) of **5.8%** from 2025 to 2030.
- US sales of keto-differentiated bread and baked goods is expected to expand with a compound annual growth rate (CAGR) of **9.0%** from 2024 to 2034.
- Consumer surveys indicate that foods labeled "keto-friendly" appeal to those actively trying to limit their sugar and/or total carbohydrate intake.

"Ketogenic Diet Market Size And Share: Industry Report, 2030." Ketogenic Diet Market Size And Share | Industry Report, 2030, www.grandviewresearch.com/industry-analysis/ketogenic-diet-market. Accessed 11 Feb. 2025.

KETO-FRIENDLY BAKING INGREDIENTS

Wheat flour contains 70-75% carbohydrates with starch constituting about 90% of total carbohydrates. Elimination of these components to meet the 'keto' claim is a delicate task and can only be achieved by creating network structures mimicking wheat dough using a combination of keto-friendly ingredients, such as:

- Nut and seed flours
- Dietary fiber (resistant starch, fructooligosaccharides/inulin, oat bran, psyllium husks, etc.)
- Proteins (wheat, dairy, eggs, seeds, etc.)
- Fats (butter, oils, lard, cocoa butter, margarine)
- Non-caloric sweeteners (erythritol, monk fruit, stevia, inulin, sucralose, allulose)

Nut Flours

Nut flours are the main candidates for replacing wheat flours in keto baking. Due to their high fiber content and absence of gluten, nut flours are also promoted as 'better-for-you' gluten-free baking ingredients.
Examples of nut flours include:

- Almonds
- Cocunuts
- Walnuts
- Hazelnuts
- Pistacchios
- Macademia

Almond and coconut flours rank at the top of the most used alternative flours in keto baking, while pistachios, walnuts, hazelnuts, and macadamia flours are typically added to introduce a more distinct, indulgent sensory appeal and nutty taste, especially in cakes, cookies, and desserts (Ling et al., 2016).

Component	Wheat Flour	Almond Flour	Coconut Flour	Chia Seed Flour	Flaxseed Meal	Lupin Flour (Yellow)
Carbohydrates (%)	76.3	5.6	68.7	5.6	35	46
Fiber (%)	2.7	3	38.5	38	9.1	37
Net Carb (%)	76.6	7.1	25	0.8	5	3
Protein (%)	10	6.1	18	20	20	40
Fat (%)	1	14.2	8	37	40	6.7

Table 1. Composition of flours from wheat, almond, coconut, chia seed, flaxseed meal, and lupin.

ALMOND FLOUR

Almond flour's favorable nutritional composition and its sensory attributes have been the main drivers in its use as a keto flour substitute. However, almond flour cannot solely replace wheat flour's functionality. It can perform best when combined with oat bran or other dietary fibers to help provide better structure-building properties.

Formulas containing almond flour can be manipulated relatively easily to enhance their textural properties and to provide a consumer-acceptable finished product. One of the drawbacks of baking with almond flour is its tendency to produce lighter colored, spongy-textured products. However, this makes it suitable for pancakes and similar baked goods.

COCONUT FLOUR

Coconut flour offers an excellent nutritional profile with a highly desirable taste, especially in baked sweet goods and desserts. In keto formulations, coconut flour is considered more economical due to its favorable replacement ratio of wheat flour (0.25:1).

Seed or Bean Flours

This category can include flours from various types of seeds or beans. The three main seed/bean flour types that have shown promising results in keto baking include:

1. Chia seed flour 2. Flaxseed flour 3. Lupin flour

Seed flours such as chia flour, flaxseed meal and lupin flour have been used successfully in gluten-free baking and are excellent components of keto baking formulas. These flours have a good nutritional profile (Table 1), high water binding capacity and good gelling properties, necessary attributes for structure formation and stabilization. One drawback is their tendency to produce dry finished baked products.

Chia flour and flaxseed meal are often used in combination in many keto formulas. Lupin flour, although highly functional, may impart a bitter taste, and is often used in baked products that require some seasoning especially when combined with almond or coconut flours.

Native Starch Alternatives

Starch is one of the main building blocks in bread dough. Through its gelatinization, it plays a major role in determining the overall quality of baked goods and their shelf stability. However, starch is not a keto-friendly ingredient so a host of dietary fibers have been used to replace some of its functionality. Bakers should keep in mind that adding dietary fibers to formulas will impact the dough/batter rheological properties, development time, and the final quality.

Net carbs of of resistant starch substitutes (g/100 g)

Psyllium Husks: 0 g/100g

Inulin: 6.3 g/100g

Resistance starch: 1.9 g/100g

Native starch: 90 g/100g

Oat bran: 5.7 g/100g

RESISTANT STARCH

Resistant Starch (RS) is defined as a type of starch that resists digestion in the small intestine and can be fermented in the colon. Five categories of resistant starch are identified (RS1–RS5) based on the mechanism of their resistance to digestion (Higgins and Brown, 2013). Multiple types of resistant starches are available to bakers. RS2 can be found in high amylose wheat and high amylose maize. RS4 can be found in resistant wheat starch or resistant tapioca starch. It's the most used source of resistant starch in keto baking. When compared to other fibers, RS4 has minimal impact on water absorption and dough processing. When used in combination with wheat protein isolates, the desirable viscoelastic properties of wheat flours can be replicated.

Resistant starch provides excellent sensory properties, mainly clean taste, in both yeast and chemically leavened baked foods. However, it can increase the water absorption and decrease the development time of bread doughs. Resistant tapioca starch (90% dietary fiber) can be used at high inclusion levels in keto bread.

OAT FIBER (BRAN)

Oat bran's nutritional profile and its excellent textural properties make it a suitable ingredient for keto-friendly baked goods. In addition to its high content of dietary fiber, mainly beta-glucan, oat bran offers bakery products wide versatility and structural consistency that's similar to wheat bran. Oat bran moisture retention can help produce baked products with an extended shelf life.

The successful incorporation of oat fiber into bread is highly dependent on the dough making method. The sponge method is the most acceptable from the sensory standpoint. Typically, oat bran can be safely added up to 10% in bread, while maintaining acceptable eating qualities.

In keto baking, oat bran fiber is used in combination with almond flour and often results in bread with a firm texture and open crumb structure. At very high concentrations, oat bran may lead to slightly dry breads.

INULIN

Inulins are fructooligosaccharides that are typically incorporated into foods and bakery formulations to help with sugar and fat reduction. Their low net carb (6.3g/100g) have made them an essential component of keto baked goods. The inulin molecule consists of 30-35 fructose units which occur in various polymer chain lengths (degree of polymerization or DP). Depending on the amount of inulin used in baked products, health claims such as 'a source of dietary fiber' or 'a prebiotic' are allowed by the FDA.

The successful replacement of sugars by inulin in baked products is dependent on the degree of polymerization of the inulin and the targeted rheological parameters for the specific bakery matrix. Typically, inulins with lower DPs do not significantly impact the viscoelastic properties of doughs and batters while inulins with higher DP can increase dough and batter viscosity and eventually lead to baked products with dry mouthfeel.

Despite the scarcity of research on the impact of inulins on yeast fermentation and activity, it is conceivable to predict that due to the higher viscosity of doughs made with high DP-inulins, yeast activity may be retarded due to restricted diffusion compared to those made with lower DP. In general, higher yeast levels are required in keto bakery systems compared to standard formulations. Commercially available inulins may contain various levels of mono- and disaccharides (glucose/fructose/sucrose) ranging from <5% to as high as 12%. This very property allows the successful use of inulins in yeasted-baked goods where yeast can feed on the available free sugars for fermentation.

PSYLLIUM HUSK

Psyllium husk is a fiber-rich ingredient commonly used in many ketogenic products. It performs best when combined with almond flour and/or oat bran. One challenge with psyllium husk is its extremely high water-binding capacity and, therefore, the tendency to form dense baked products. A high ratio of almond flour to oat bran fiber can improve this effect and help bread structure, flavor, and texture.

Proteins

Proteins are often incorporated into keto baking formulas to help enhance the product's nutritional profile, improve moisture retention, and provide good foaming and emulsification properties. Dairy and plant-based proteins, mainly isolates, can be used. Caseinates and whey proteins are excellent water binders with acceptable flavor. Soy and pea proteins can improve viscosity and other rheological functions of bread doughs. Although, they may impart flavors not typical of bread and baked goods.

WHEAT PROTEIN ISOLATE

One of the most used proteins in keto baking is wheat protein isolate. It's derived from vital wheat gluten, which is the non-water soluble fraction of wheat flour. Wheat proteins' viscoelastic properties are attributed to a proper balance of the two major components of gluten, namely gliadin and glutenin. Upon hydration, gliadin provides dough cohesiveness and extensibility while glutenin provides dough elasticity and tolerance.

Wheat protein isolates are essential for optimizing the texture and gas retention capabilities of keto products and are also favored in specific baking applications for their ability to provide enhanced rheological and textural properties. In comparison to vital wheat gluten (75% protein), wheat protein isolates also offer higher percentages of total protein (80-90%) that can help to reduce the net carbohydrate count of the finished product. Wheat protein isolate contains gluten allergen.

WHEY PROTEIN ISOLATE

Whey protein isolate is used commercially for partially replacing gluten in bread and baked products. Its addition helps with promoting good gelling and structure building as well as trapping leavening gas cells. Whey protein isolate can extend the shelf life of breads and reduce staleness as well. Whey protein isolate contains dairy allergen.

SOY PROTEIN ISOLATE

Similar to other plant proteins, soy protein isolate is used in various keto baking recipes. Desirable functional properties of these proteins include good viscosity control and enhanced dough elasticity. Soy protein isolate can also provide good foaming and water binding properties and can produce breads and cakes with good crumb texture. Compared to milk or egg proteins, soy protein isolate is more economical. Soy protein isolate contains soy allergen.

Two main drawbacks that can limit the wider usage of soy protein isolate in foods and baked goods are the lingering bitter taste and potential allergenicity.

FORMULATING WITH PROTEIN

Ensuring consistent protein quality is essential for controlling the cost of bread production, both from formula and process standpoints. Consistent protein quality is critical for improving bakery line efficiencies and reducing waste, in addition to eliminating the need for dough conditioners and emulsifiers.

Despite these advantages, many challenges are often encountered when replacing wheat flour with alternative ingredients:

1. Doughs and batters made with nut flours often lack proper dough viscoelastic properties.
2. Some nut flours such as cashew can contain excessive carbohydrates to meet ketogenic requirements.
3. Improving texture of keto baked goods can be achieved by formula (using protein isolates) or process adjustments (modified bake temperatures).
4. Flavors of coconut, chickpea, flaxseed, and soy flours can be overwhelmingly strong if not properly optimized. Flax and sesame meal often produce inferior crumb structures.

Fats

In keto baking, fats improve the plasticity of the baked goods, increasing the feel of 'moistness' in the product. To keep the same mouthfeel and texture of high sugared cakes, an increase in fat content is needed in keto bakery goods. Just be cautious, as high fat with a high water activity food system may increase the rate of rancidity. In such instances, look into using an antioxidant ingredient like Butylated Hydroxytoulene (BHT) or Butylated hydroxyanisole (BHA).

FAT INCORPORATION METHODS FOR CAKE

Creaming method: the fat is beaten with the sugar until it becomes light, fluffy, and pale in color. The incorporated air results in volume build up in the batter which forms nuclei into which other gasses—water vapor from the moisture and carbon dioxide from the baking powder—migrate and expand on heating. All-in-one method: liquid ingredients containing baking soda are mixed separately and further combined with the dry ingredients including baking powder mix right before baking. In this method, the leavening action is due mainly to the reaction between the leavening acid and baking soda.

Water

Water is an essential component of baking formulations and is responsible for triggering various biochemical and chemical processes including:

- Hydration
- Transport mechanisms (evaporation-condensation)
- Dispersion medium (several aqueous phases coexist and exchange water from one to another)
- Dough temperature control
- Water activity control (relative humidity controls water displacements)

Several factors affect water usability in baking formulas including taste, mineral content, and microbiological quality. Minerals such as calcium, magnesium, and sodium determine water hardness/softness and provide nutrients for yeast, thus determining dough quality.

Hard

(>100 ppm)
It strengthens the dough and quickens fermentation.

Medium

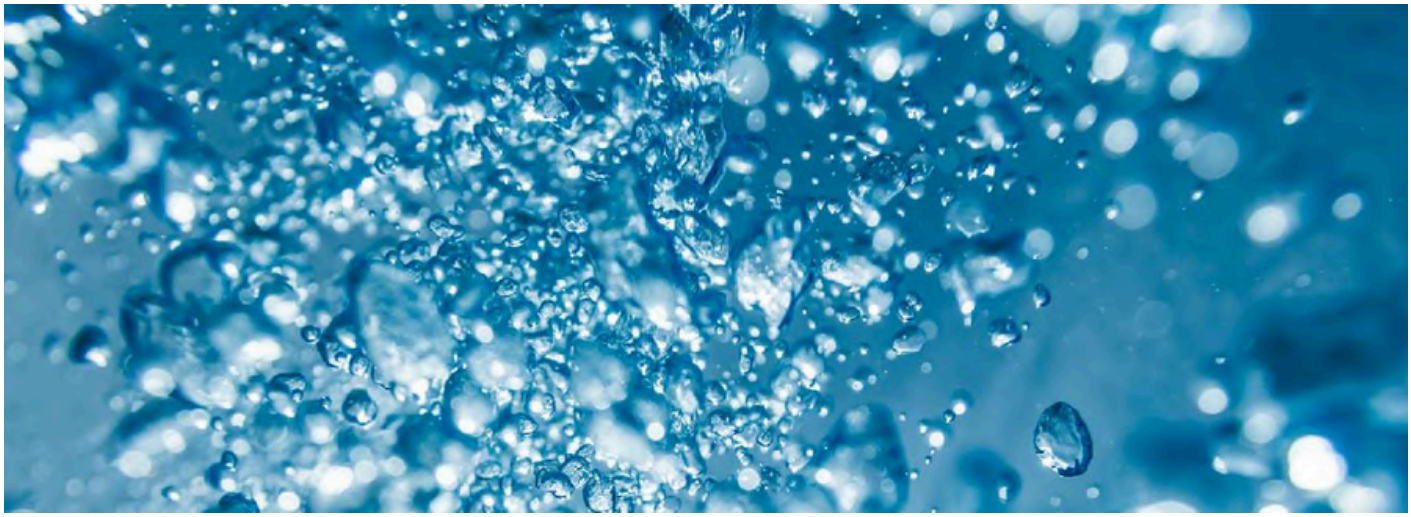
(50-100 ppm)
Best suited for baking.

Soft

(<50 ppm)
It produces sticky, soft and slack dough and decreases fermentation rate. May require yeast nutrients.

Hydration affects the process of bread building and the nature of the final product. Generally, the more water in the dough, the more open the final bread's crumb. Bread can also be classified according to three categories based on hydration:

- Stiff: 50-57% hydration (bagels, pretzels)
- Standard: 58-65% hydration (French, Challah, and other European breads that are characterized by dense structure and ability to hold up structure).
- Rustic: 65- >80% hydration (ciabatta, pizza, and focaccia breads that are characterized by airy crumb and large, irregular holes. This type of bread requires careful shaping and longer baking times.)



Leavening Systems

YEAST

Saccharomyces cerevisiae (baker's yeast) can ferment and metabolize a variety of sugars under anaerobic conditions with preference for glucose, fructose, and maltose. As a result, it produces carbon dioxide, ethanol, and other organic and flavor compounds. Yeast is a unique component of bakery formulations due to its contribution to:

- Leavening: carbon dioxide production that is essential for the dough leavening action gives bread its volume, unique crumb grain and overall texture.
- Dough maturation and flavor development: a result of the production of ethanol and small amounts of organic compounds, such as ketones and aldehydes. This is responsible for mellowing the dough and making it machinable, as well as imparting flavors and aromas to bread.

Yeast Form (moisture:solids*)	Handling and Applications
Compressed (70:30)	• Shelf-life: 2–3 weeks under refrigeration • Can be added directly to mixer • Application: medium-sized and high-speed bakeries • Activity: high although lower than cream yeast
Cream (85:15)	• Shelf-life: 2–3 weeks under refrigeration • Requires storage in agitated tanks. It can be pumped directly to mixer by a bulk ingredient handling system • Application: high-speed bakeries, easiest and most accurate scaling • Activity: highest, less prone to variations in performance
Active dry yeast, ADY (5:95)	• Shelf-life: 1 year under vacuum (oxygen-free) packaging • Must be activated in warm water for 5–10 minutes before adding to • dough • Application: retail bake shops, in-store bakeries • Activity: lowest
Instant dry yeast, IDY (5:95)	• Shelf-life: 1 year at vacuum packaging • Can be added directly to mixer without activation • Application: retail bake shops, medium-sized bakeries • Activity: higher than ADY but lower than compressed

Table 3. Forms of Yeast in Bread Making
**Solids include protein, carbohydrates, cell lipids, minerals, and vitamins*

Yeast activity is controlled by the prevailing pH (optimal 5-7), temperature (optimal growth is between 104–122°F / 40– 50°C and is inactivated at 140°F / 60°C), moisture and dough hydration, osmotic pressure (salt and sugar increase osmotic pressure, which in turn slows down yeast activity), food supply (mainly sugars provided by flour, amylase activity or added to formula) and fermentation time.

Keto Baking with Yeast

- Creating a flour replacement system that not only is low in carbohydrates but also functional. Yeast has traditionally been able to ferment on damaged starch in wheat flours, yet native starch replacements in keto formulations do not have damaged starch.
- Supplying yeast with fermentable sugars while not adding sugars to the mix. Low sugar systems result in light colored crust and loaves with reduced volume, due to a weaker leavening medium. Inulin provides some simple sugars naturally.
- Making sure that there are adequate yeast nutrients to support fermentation activities

Due to these limitations, yeasts are often supplemented with chemical leavening systems in keto formulations.

CHEMICAL LEAVENING AGENTS

Chemical leavening agents such as baking ammonia, baking soda, and baking powders provide baked goods with several attributes including:

- Leavening: the breakdown of leavening agents produces gases that control the product expansion upon
- heating/baking process.
- Tenderizing: As leavening gases form and expand, dough cell walls stretch and thin out to produce a tender
- texture that is easy to bite through.
- pH adjustment: Most batters and doughs have a neutral pH in the absence of baking powder, baking soda, or
- other chemical leaveners. Cream of tartar, a leavening acid, tends to decrease pH while alkali ammonia and
- baking soda tend to increase pH. Baking soda needs to be properly neutralized with the right amount of
- leavening acids.

The use of more bicarbonates in Keto formulations is needed as this increases the pH, improving the Maillard reaction.

Bicarbonate Type	Application
Sodium bicarbonate, or baking soda	All sweet goods
(NaHCO3) Potassium bicarbonate (KHCO3)	Low sodium cakes
Ammonium bicarbonate (NH4HCO3)	Very low moisture products like crackers and biscuits

Table 4. Common leavening acids and bases

Flavors

Baking formulations often include a single or combination of flavors unique to the baked product and influential to consumers' purchasing decisions (Table 5). Flavors can be added either as dry powders, granules, or liquid emulsions. Good flavors are compatible with the baked product, have positive aroma, balance, flavor release and mouth sensations with no unpleasant notes.

Flavor	Baked goods
Butter, almond, vanilla	Cookies, cakes, cream
Fruit flavors/inclusions	fillings Fillings in cakes
Cinnamon and other spices	Sweet rolls
Cheese, hot peppers	Pretzels, bagels, crackers

Table 5. Flavors commonly used in baked goods

Flavors can be added as essential oils (mint), oleoresins (ginger, cinnamon, and black pepper), extracts (vanilla), concentrated fruit juices, flavor aromatics or even adjuvants that are essentially non-flavor ingredients but enhance the impact of compounded flavors.

Encapsulated flavors including stabilized emulsions or dry microcapsules are often used in baked goods to help provide thermal stability and to extend their release throughout the product life cycle. Encapsulation can also help with reducing the interaction of flavors with proteins, fats and carbohydrates, and other components of the baking formula.

CLASSES OF FDA-DEFINED FLAVORS (21 CFR 101.22):

- Natural flavors encompass any essential oil, oleoresin, essence, extractive, protein hydrolysate, distillate, product of roasting, heating or enzymolysis, which contains the flavoring constituents derived from a spice, fruit or fruit juice, vegetable or vegetable juice, edible yeast, herb, bark, bud, root, leaf or similar plant material, meat seafood, poultry, eggs, dairy products, or fermentation products.
- Artificial flavors are flavorings that do not meet the definition of natural.

Salt

Sodium chloride (NaCl) is an essential component of bread and many other baked goods. It is a taste enhancer, dough strengthener, and loaf volume builder. NaCl also controls fermentation, a result of its negative effect on yeast activity. The undesirable health effects of salt, mainly increased blood pressure, has forced formulators to seek alternative ingredients such as potassium chloride (KCl) which provides similar functionality and rheological properties without the negative impact on blood pressure.

One challenge with KCl is its bitter taste. Autolyzed yeast extract (AYE) is another commonly used salt alternative, composed of yeast peptides and amino acids.

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Sweeteners

Traditional bread flour contains 1.4-2.1g of sugars per 100g which is typically used by the yeast to produce the carbon dioxide essential for dough rise and volume build up. In addition to sweetness, sugar also provides many rheological and sensory benefits that can be very challenging to replicate in keto baking, mainly in keto sweet goods.

Sugar can also act as a humectant, texturizer, browning agent, foaming, and bulking agent. It is also essential for controlling water activity and extending shelf life. Keto-friendly sugar substitutes (Table 6) cannot perform many of the functions of sugar, and with restricted net carbohydrate count in keto baking, sugar substitutes are typically used often at much lower levels than sugar due to their high sweetening power compared to regular sugar (sucrose).

Typically, allulose is used in combination with monk fruit in soft and moist baked goods such as cookies. It is 70% as sweet as sugar and is available in liquid and granulated forms. It cannot be used by yeast. In addition to its good bulking properties, allulose usage is favored in baking due to its ability to undergo Maillard browning reactions. Combining allulose with other high potency sweeteners help enhance its functionality.

KETO SWEETENERS

Sweetener	Net carb	Comments
Erythritol	5	70% sucrose sweetening power, economical and versatile. Erythritol can also help lower water activity of keto formulas, enhancing the shelf life of the baked product.
Monk fruit	0	100-150% sucrose sweetening power. Bakers should avoid using special monk fruit-molasses blend for their high net carb.
Stevia	0	30-150% sucrose sweetening power
Inulina	1	10% sucrose sweetening power. It is a bulking agent and texturizer with high water absorption capacity. Inulin is a prebiotic with demonstrated health benefits.
Sucralose (Splenda)	0	600% sucrose sweetening power. Substitution with sucralose should be done based on volume, not weight, because granular sucralose is much lighter than sugar. When baking with sucralose, monitor the products carefully for doneness because the baked product will not brown.
Allulose	0-5	70% of sucrose sweetening power
Aspartame	85	200 times sweeter than sucrose
Neotame	0	8,000 times sweeter than sucrose

Table 6. Common keto-friendly sweeteners

DRAWBACKS OF ARTIFICIAL SWEETENERS

- Their lack of good creaming abilities
- Their inability to contribute to browning (except allulose)
- They do not contribute to texture
- They do not help with keeping the quality of baked products
- Some sweeteners can have a negative impact on the final product's taste
- Many artificial sweeteners have low heat stability are unstable under baking temperatures (e.g., aspartame)

In the absence of sugar, the yeast can be starved and may switch from aerobic to anaerobic respiration leading to alcoholic fermentation and ethanol production. The ethanol mostly evaporates during the baking process, and some aroma remains in the bread.

Keto sweet baked goods such as cakes and cookies can be made with zero grams net carbs per serving using almond flour, butter, and egg whites as well as inulin, erythritol and stevia to deliver bulk (solids) and sweetness. However, cookies formulated with erythritol lack browning and they don't spread as wheat flour cookies.

Dough Conditioners

Dough conditioners are essential ingredients that compensate for fluctuations in flour quality. Any baking ingredient that can improve the production and/or consistency of the dough is considered a dough conditioner.

Bread dough conditioners include:

- Reducing agents that can shorten mixing and proofing times
- Enzymes that help expedite proofing
- Oxidants that strengthen dough structure
- Emulsifiers that build dough tolerance to handling
- Fibers that provide good water binding capacity

Keto dough conditioning can be formulated to be a clean label as well. Examples include organic acids, natural reducing and oxidizing agents, hydrolases, and long dough fermentations. On occasions, combinations of enzymes and hydrocolloids or enzymes with lecithin are used as dough conditioning systems to help improve dough softness and extensibility, two properties of considerable importance in keto baking.

“Stack prebiotic fibers to reduce net carbs! Mixing soluble tapioca fiber with inulin or FOS will give your baked goods a chewy, indulgent mouthfeel while stabilizing any potential gastrointestinal effects that may occur from too much dietary fiber. The combination of fibers also drives down your net carbs, creating added appeal on the NFP! Learn more!”

KETO PRODUCT DEVELOPMENT

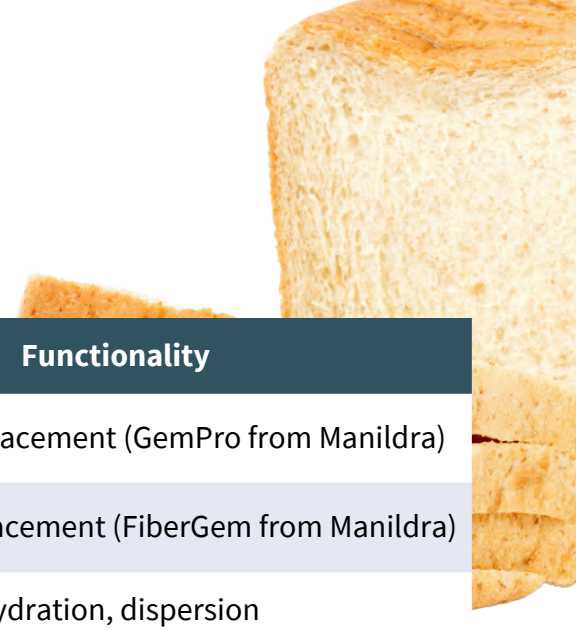
Consumer surveys show that one of the main reasons people fail to adhere to a keto diet is the temptation of bread. With a slice of bread containing on average 15g of sugar, it's not a feasible product to consume on the diet. Bread and bakery products, due to their high carbohydrate content, developing keto-friendly bakery products may be challenging. Bakers know that eliminating essential components such as wheat flour, sugar, and starch can dramatically impact functionality as well as its sensory properties. However, the recent launches of various bread and sweet baked goods have proven that keto baking can be formulated and commercialized with great consumer acceptability. The key to these successful introductions is that formula modifications need to be made using the ingredients' combination approach (matrices) rather than single ingredient replacements. ***Here are our favorite picks:***

Company	Product	Composition
Sola	White Bread	Each slide contains 40 calories and 4 g of protein
Orowheat	White Bread	Each slide contains 40 calories and 5 g of protein
Highkey cookies	Chocolate Chip Cookies	Each piece contains 37 calories and 1 g of protein
HighKey Sea Salt Crackers	Keto Crackers	7 grams of protein and just 4 net carbs per serving
ChocZero	Keto Butter Cookies	Each serving contains 140 calories, and 3 g of proteins
Quest	Chocolate Chip Muffins	Each serving contains 200 calories, and 10 g of protein
Clif Bar	Luna Keto Brownie Bites	The first five ingredients are cassava fiber, almond flour, dates, soy protein concentrate and sugar-free (chocolate) chips.
Ratio	Chocolate Brownie Soft Baked Bar	Each bar is made with almond flour, unsweetened chocolate, and crunchy pecans.
Legendary Pastry	Strawberry Protein Pastry	Each serving contains 20 g of protein, and 4 g of net carbs
Inked keto	Timber Wolf Keto Seeds Bread	Each slide contains 45 calories, and 1 g of net carb
IQ Bar	Chocolate Sea Salt Bar	Each bar contains 170 calories, and 12 g of protein
Base Culture	Original Keto Bread	10 clean ingredients like almonds, flax, and eggs, combine to create a nutrient-packed bread
Mission	Zero Net Carbs Tortillas	Each serving 110 calories, and 7 g of protein

Table 7. Commercially available keto baked goods in the US market

NET CARB = TOTAL CARBS — FIBER — SUGAR ALCOHOLS

KETO BREAD



FORMULATION

Ingredients	Formulation %	Functionality
Wheat protein isolates	24.79	Wheat flour replacement (GemPro from Manildra)
Resistant (wheat) starch	44.08	Wheat flour replacement (FiberGem from Manildra)
Water	48.21	Hydration, dispersion
Oil	2.07	Tenderizing
Psyllium husk powder	2.07	Improve texture and increase fiber content
Salt	0.69	Flavor enhancer
Instant dry yeast	1.52	Leavener and flavor
Stevia	0.69	Sweetener
Dough enzymes	0.69	Butter machinability

Table 8. Typical keto bread formulation

PROCESS OVERVIEW OF KETO BREAD

This general overview is typical of any bread-making process. However, due to the nature of keto flour, more emphasis is on the dough mixing stability of the keto dough. Longer mixing times are to be expected, so be careful with maintaining a lower final dough temperature. An alternative is to hydrate the functional proteins and fibers first before adding in the other ingredients. This will reduce mixing times and temperatures.

DOUGH MAKING PROCESS

Baking is a multi-step process which involves several major steps (Figoni, 2011). Not much research has been performed on keto doughs. Due to the lack of damaged starch found traditionally in wheat flour, we are not sure at this point in time if anything outside a straight dough has any benefits for keto dough processing. Therefore, with a straight dough process, keto doughs can be quickly processed within a 3-4 hour window. Mixing keto doughs can be a little complicated, as we get the gluten to hydrate and interact with each other while enveloping the non-protein molecules.

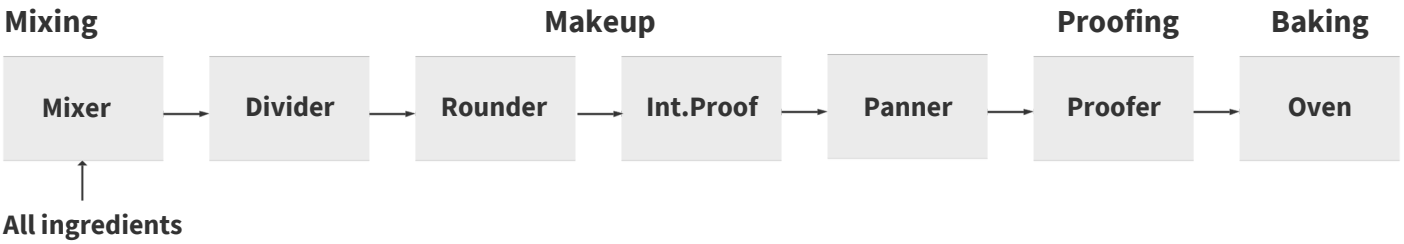


Figure 1. Dough making process for keto bread.

MIXOLAB STUDIES OF KETO DOUGH:

Keto flour (green line) and regular flour (blue line) were rheologically studied. While the keto flour experienced 75% water absorption, the wheat flour experienced 60% water absorption. This difference resulted in a longer mixing time for the keto dough, less mixing tolerance, and reduced starch gelatinization, with a structure set mainly by proteins. This fundamentally shows the difference in the textures of the two types of dough. The keto dough experiences more softness over shelf life, due to the lack of staling in starch molecules. This can be seen with almost no data from starch gelatinization.

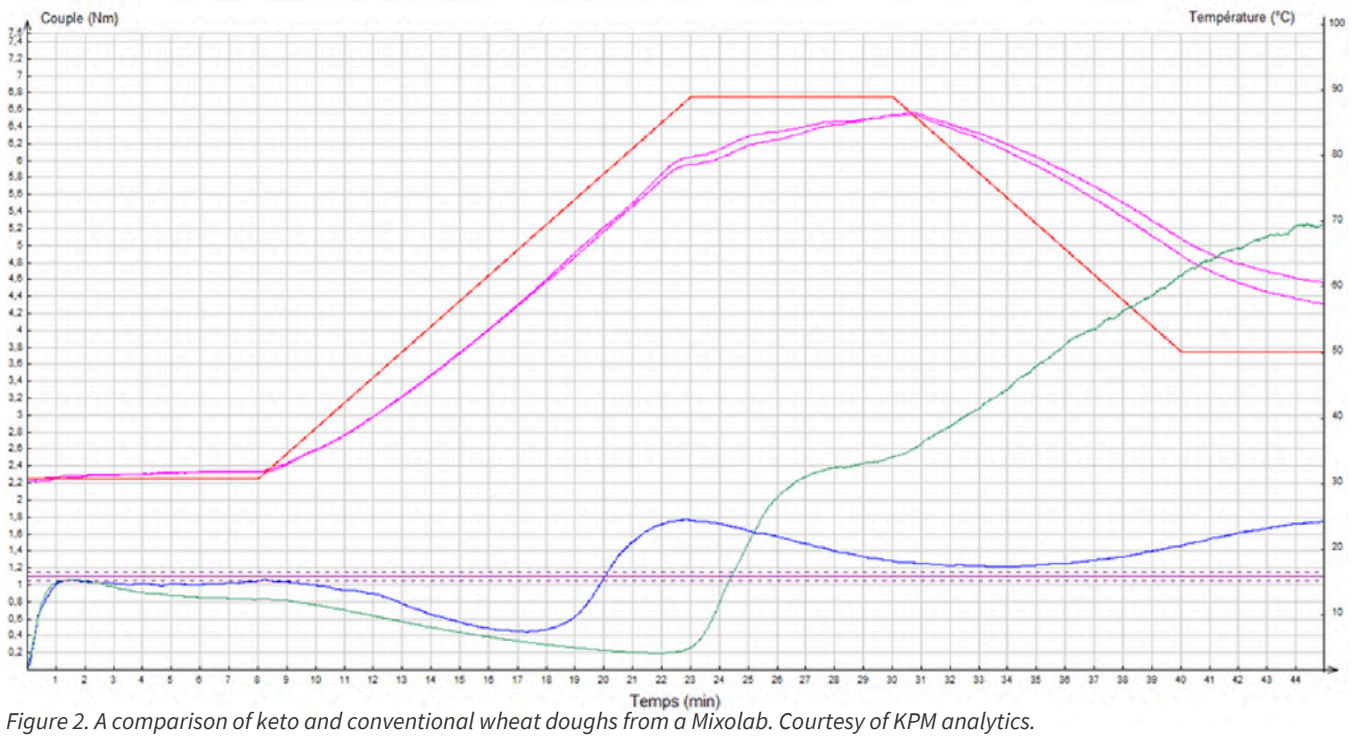


Figure 2. A comparison of keto and conventional wheat doughs from a Mixolab. Courtesy of KPM analytics.

BAKING PROCESS

Baking involves simultaneous heat and mass transfer phenomena which helps set the final structure of the baked product. While both yeast and chemical leaveners can generate gas for volume build-up, yeast is essential for the development of unique flavors in breads and some baked goods. Typically, baking times range from 20–60 minutes for pan bread and 10-15 minutes for buns and dinner rolls, depending on the type of oven and heating pattern. Keto pan breads would need to be baked at a lower temperature and longer baking times. This is to allow more water to bake off, so that water activity within the bread can be reduced. Due to the lack of sugars, keto bread are prone to molding if not enough water is baked out of the bread.

The baking process is responsible for major weight loss in the dough/batter, mainly moisture (8–12%) and volatile organic compounds, especially in pan breads and buns. Chemically leavened products may have higher bake losses.

Thermal profiling should be used to determine baking time and temperatures. This would lead to specific S-curves that could be catered to your keto bread.

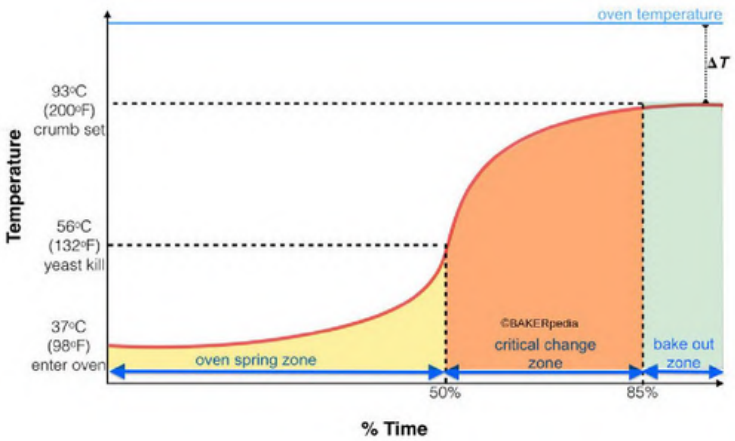


Figure 3. Thermal Profiling Curve

COOLING

Baked products experience ‘carryover’ cooking until their temperature drops to ambient level. The main goal of cooling is to decrease the internal temperature of the baked bread from 93– 97°C (200–208°F) to 32–43°C (90–110°F). At these temperatures, slicing would be easier. Once cooled, the structure becomes firmer, fats resolidify, sugars recrystallize, and starch retrogradation continues for several days leading to a hard, dry, and crumbly structure.

PACKAGING

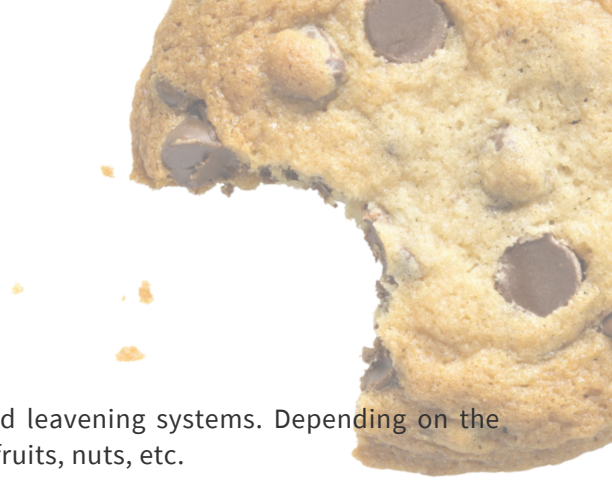
In freshly baked goods, especially high-moisture products like bread, moisture moves from moist crumb to dry crust in a very short time (less than a day). This leads to a loss of crispness and the tendency to become tough and rubbery. This is typically accompanied by a significant loss in fresh bread flavors. Such undesirable changes could be delayed if proper packaging and storage are provided.

Proper packaging provides:

- Food Safety: product protection, containment, and shelf-life preservation
- Customer convenience
- Communication tool (marketing and nutrition labeling)
- Logistics tool for transport and handling
- Traceability mechanism

Bread is usually packaged in low density polyethylene plastic (LDPE) bags which can be closed using wire twist-ties or plastic-clip closures. Choosing appropriate packaging systems should take into consideration the baked product physicochemical properties as well as its expected shelf life. Modified atmosphere packaging is used in limited cases.

KETO COOKIES



Traditionally, cookies are made up of high protein flour, water, fat, and leavening systems. Depending on the type, cookies can often include inclusions such as chocolate chips, dried fruits, nuts, etc.

The development of keto cookies is quite simple due to the inherent nature and stability of the viscous mass of cookie doughs. Also, cookie systems do not rely on gluten development, and so will be less affected by the elimination of wheat flour (Table 7). Bakers should be careful with the inclusions used as some of them may have a high sugar content. Few adjustments are needed for the generation of a consumer-acceptable keto cookie. Fluffiness and chewiness enhancement can be done by proper control of the amount and type of leavening system. Cookie spread is controlled by proper balance of the amount of liquids/fats used. Ideally, non-fat liquids should not exceed 10% of the formula to maintain good dough viscosity.

Proper browning can be manipulated by using allulose (alone or in combination with other artificial sweeteners), incorporation of higher protein levels or by increasing dough pH. On the other hand, cookie crispness can be enhanced by the addition of ingredients (food polymers) with high glass transition temperatures (Tg), and/or by eliminating baking powder and replacing it by baking soda only.

FORMULATION

Ingredient	Total (%)
Nut/bean/seed flour	53.5
Butter	15
Allulose/erythritol	15
Milk	9
Whey protein isolate	4
Fiber	1
Baking powder	1
Salt	0.5
Baking soda	0.5
Flavors	0.5

Table 9. Typical keto cookie formulation

PROCESS FOR KETO COOKIES

A keto cookie process is straightforward, following the basics of creaming, addition of liquid ingredients, then the addition of the dry ingredients. Check out our pages on what a typical cookie process may look like.

KETO CAKE

Standard cakes are rich in sugar, fat, and eggs, and use low protein, soft wheat flour. In cake formulations, batter viscosity, stability, and capacity to form and stabilize air bubbles generated by the leavening system and sugar creaming are key.

In keto cake batters, viscosity can be provided by the type and amount of fiber added. In such systems, proteins (from whey protein isolates, wheat protein isolates, or eggs) are not essential for batter rheology but can contribute to fat emulsification.

In keto cake systems, tenderizing can be achieved by the fat (butter, oil, plastic fat) phase to compensate for the absence of sugar. Sweeteners such as allulose can provide sweetness and browning, important qualities of a consumer acceptable cakes. In addition, allulose along with fiber can provide sufficient levels of bulk in wheat flour-free cakes. Emulsifiers with low HLB such as Propylene Glycol Methyl Ether (PGME)or Mono and Di-glycerides (MDG) are more effective in keto cake systems.

To reduce the chances of creating dense cakes, levels of chia seed flour and some fibers should be controlled along with increased amounts of leavening ingredients. Also, cakes may need to be baked at low temperatures for longer times to ensure proper water evaporation and to decrease water activity. Due to the lack of sugar, preservatives such as encapsulated sorbic acid or potassium sorbates are essential in keto cakes.

FORMULATION

Ingredient	Total (%)
Allulose/stevia	20.28
Water	19.85
Resistant starch	17
Butter	14.06
Milk	9.93
Wheat protein isolate (Gem Pro from Manildra)	6.2
PGME (propylene glycol monoesters)	4
Fiber	1.6
Baking powder	1
Cultured corn	0.9
Salt	0.71

Table 10. Typical keto cake formulation

KETO CAKE PROCESSING

As with many cake formulas, cream the fat and allulose first, add in all the liquids, then fold in the dry ingredients. Bake and cool like regular cakes.

SHELF LIFE EXTENSION SOLUTIONS

Sugar reduces water activity and is therefore a natural preservative. Extending the shelf life of keto products can be challenging due to the lack of sugar. Therefore, a combination of HACCP, GMP, reducing water activity in the product and using preservatives is the trifecta for a longer shelf life.

CALCIUM PROPIONATE

Calcium propionate is the calcium salt of propionic acid. Due to its minimal impact on fermentation, calcium propionate is used in yeasted baked goods as a preservative and a growth inhibitor for mold, and ropy bacteria. Its optimum pH is below 5.5. Calcium propionate is typically added at 0.1-0.3%. However with increased consumers' interest in clean labels, many bakers have limited or eliminated its usage. In tortillas, calcium propionate and potassium sorbate are commonly used together, to achieve a broad spectrum of mold inhibition while maintaining product quality (Davidson and Cekmer, 2016).

CULTURED WHEAT,WHEY AND CORN SYRUP SOLIDS

Cultured wheat is a natural ingredient offering broad-spectrum mold inhibition and antimicrobial activity. It's suitable for both yeasted and chemically leavened baked goods like breads, buns, and cakes. Within bakery products, cultured wheat functions by lowering the dough's pH, which encourages the bacteria present in the culture, such as Propionibacterium freudenreichii, to produce propionic acid. This propionic acid is a potent antifungal agent, effectively inhibiting mold growth.

ROWANBERRY EXTRACT

Rowanberry extract extends the shelf life of baked goods by leveraging its natural antimicrobial properties. Rich in sorbic acid, it inhibits the growth of yeasts and molds, the primary culprits of spoilage in baked products. By disrupting microbial cell membranes, it effectively prevents their proliferation, preserving freshness. This natural preservative is particularly beneficial in items like breads, cakes, and pastries.

ENCAPSULATED SORBIC ACID

Sorbic acid is a carboxylic acid and is the most common food preservative against molds, bacteria, fungi, and yeasts. It is favored for its organoleptic neutrality, safety, and efficacy in low moisture foods such as cheeses, and bakery. Sorbic acid is slightly soluble in water, and is available as a fine powder, granules, or microcapsules. It can be incorporated into the baking formula or applied topically to baked goods as a spray or to the packaging material.

Optimal antimicrobial activity is at pH below 6.5 (maximum activity at pH 4.76), an advantage compared to benzoic and propionic acids which lose their activities at pH 4.5 – 5.5. Sorbic acid and its encapsulated form are typically used at 20-6,000 mg/Kg (EFSA, 2015).

DOUGH ENZYMES

Enzymes are protein catalysts which affect chemical changes in biological systems. In the baking industry, enzymes are clean label ingredients. Bakery enzymes are usually added at levels of 0.005–0.01% (50–100 ppm based on flour weight) depending on formulation and process requirements. Optimum activity of enzymes is controlled by prevailing pH, temperature, ratio of substrate: enzyme and their contact time.

In baked goods, enzymes can improve dough structure and increase loaf volume. They can also enhance cell structure, crust color, and provide some sweet flavor without significantly changing the total net carbohydrate content.

KETO BAKING QUALITY

Certificate of Analysis (COA)

A COA for bakery ingredients is a formal and official document that ingredient suppliers send, along with product shipments, to bakeries to provide analytical results which ideally conform to established technical specifications (quantitative and qualitative). A COA specifies expected and actual values and the method of lab analysis used. Analytical tests in a COA include proximate analysis (nutrition labeling, enrichment), microbiological, physicochemical analysis and heavy metal analysis.

These are the important ingredients that COAs need to be verified for keto bread production facility:

- Protein isolates (wheat, whey, soy, etc.)
- Nut or seed flour
- Resistant starch or fiber
- Yeast
- Oil/fat
- Artificial sweeteners

COAs should be collected together with their prospective samples to be sent out to a third party food lab for proximate analysis at least once a year. This can be done more frequently if you are experiencing product quality issues.

Proximate Analysis

Most good manufacturing practices (GMP) have instrumentation that can test the following parameters. Not all parameters are applicable, so please consult a third-party food lab to determine what proximate analysis test needs to be performed. It would be advisable for you to purchase an instrument if you use a third-party food lab frequently for that parameter.

- Moisture content (moisture analyzer, oven)
- Protein content (Kjeldhal, UV, etc.)
- Sugar content (phenol sulfuric acid test, HPLC)
- Fat content (Soxhlet analyzer)
- Ash content (furnace)
- Water activity meter (measures free water, an indication of shelf stability) texture)
- Falling number test: an indicator of grain sprouting and alpha-amylase activity. The instrument measures the resistance of a flour-water paste to a falling stirrer. Results are reported on a 14% moisture basis. Falling numbers of 300 seconds or higher indicate minimal amylase activity and low sprout damage (good quality flour). Results below 250 seconds mean high amylase activity and significant sprouting (sticky dough/ poor bread texture).
- Quick testing using Near Infrared is used to measure quantitative values such as moisture, proteins, fibers, fat, or starch.

Dough Rheology Testing

One of the goals of the mixing process is to achieve an optimum and proper balance of dough handling properties. This is done by testing dough rheology, the study of how deform or flow when a force or stress is applied to them. These following methods measure rheological properties of dough and batter under test conditions, trying to simulate as much as possible the actual processing conditions.

MIXOLAB

The Mixolab not only is a great tool for its potential to analyze keto formulas, but also to analyze a wide range of raw materials individually. The Mixolab determines traditional measurements such as optimal water absorption and protein quality of the flour (dough consistency, tolerance to mixing).

In addition, it has the unique capacity to measure dough properties during heating and cooling, predicting cooking stability of the flour mixture. This could be related to its final product qualities.

ALVEOGRAPH

The Alveograph measures dough characteristics of flours so that the baker can decide on suitability for breads, cakes, or other bakery products. Strong gluten flour has high P values and is preferred for breads.

Because the Alveograph analysis greatly depends on gluten properties, and on the capacity of keto formulas to replace such unique features, it could be challenging to analyze these new flours. However, the new Alveolab offers enhanced setting possibilities that might lead to interesting applications of this technique for keto doughs.

FARINOGRAPH

This instrumental test is used to assess the amount of water needed to make a dough. It can also help assess the effects of ingredients on mixing properties, flour blending requirements, and its uniformity.

Quantitative Analysis

TEXTURE ANALYZER

This instrument uses a load cell to determine texture. It provides the ability to quantify how firm or resilient the crumb may be. The resulting data can help optimize and determine ingredient and processing conditions. A Texture Profile Analysis can tell you a lot about the quality of a keto baked product over shelf life.

VISION ANALYSIS

Vision instrumentation is an excellent way to objectively assess final products attributes. It can quantify the amount, area and depth of the cells structure on the crumb. The crumb analysis capability takes it a step further to produce high-quality images and data of internal crumb structure of bread products. The all-encompassing tool provides a broad range of data for testing, research, quality assurance, and final product inspection, while saving quality engineers a significant amount of time.

SUMMARY

Baking keto products is not as easy as it sounds due to the variety of substitutions you must make in order to reach zero net carbs. As indicated in our initial dough tests using the Mixolab, keto doughs can be made to perform like 100% wheat flour doughs in the mixing process.

We are still looking for more data to understand the physiological changes in keto doughs during the cooking stage. Remember, when a keto baked product is not brown enough on the crust, there aren't enough starches and proteins to support the Maillard reaction and browning. Proper ingredient substitutions must be made to encourage this Maillard reaction.

Lastly, there isn't enough research performed on keto baked goods to understand its staling properties. At this point in time, we cannot confirm if amylase would be a suitable solution, since it does not work on resistant starch.

Good luck in your keto product development and commercialization. Its' an exciting time to be a baker and to experience the cusp of this technological revolution!

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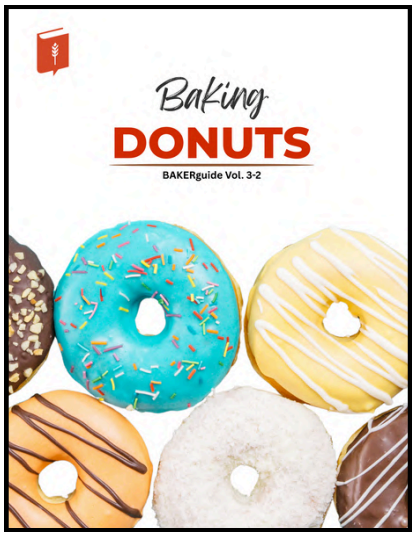

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