

POTATO APPLICATION

# GLUTEN-FREE CRACKERS









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# INTRODUCTION

The purpose of the study was to provide formulation and application information on the use of potato ingredients in gluten-free crackers for food manufacturers. Due to the known multifunctionalities of dehydrated potato ingredients, it was hypothesized that the potato ingredients would be able to provide different functional benefits that could be tailored by food formulators for desired product attributes.

## KEY TAKEAWAYS

The addition of dehydrated potato ingredients in gluten-free crackers resulted in:

### ENHANCED BROWNING

Gluten-free baked goods do not brown as well as wheat-containing products; the addition of each potato ingredient tested improved browning, color and flavor development.

### MORE UNIFORM SHAPE

Potato flour and granules made for crackers with a flatter, more even shape than control, which had a concave, curved appearance after baking.

### APPEALING APPEARANCE

Panelists preferred the more natural, whole-grain-like appearance of samples made with potato ingredients; they were more golden brown and less gray in hue.

### IMPROVED FLAVOR

Potato flour, standard potato flakes and low-peel/low-leach (LP/LL) potato flakes enhanced the savory aroma and flavor profile in crackers, without contributing excessive “potato” flavor. Crackers made with potato granules tasted most similar to control but with an enhanced sweetness and oat flavor profile that was preferred over control.

### STURDY, CRISP STRUCTURE

Potato flour resulted in crackers with good structure, a crisp snap and more pleasant eating experience than control; they are recommended for crackers where a savory flavor is desired. Standard potato flakes also enhanced structure in crackers, providing a firm clean snap and more neutral and sweeter flavor profile.

### TENDER, FRIABLE TEXTURE

Potato granules resulted in crackers with a sturdy yet tender structure that was slightly crumblier in comparison to other tests; tasters found it pleasant to eat, with a sweeter flavor profile compared to control. LP/LL potato flakes produced light, crisp yet friable crackers with both excellent eating qualities and structural integrity and are highly recommended for use in any snack cracker.

# APPLICATION OVERVIEW

## BACKGROUND

Crackers have been a longtime staple. They are easy to prepare, travel well and keep well for long periods of time.<sup>1</sup> Some crackers are neutral in flavor, meant to be served with flavorful toppings, while others are highly seasoned and meant to be eaten by themselves. Crackers can be cut to any size or shape, made thin and delicate or thick and sturdy. The selected ingredients and processing methods are equally important in determining eating qualities in the final baked good. Gluten-free crackers rely on a combination of various flours and starches to replicate the functional properties of wheat flour, which give crackers structure.

## TYPES OF CRACKER FORMULAS

In their most basic form, crackers are made from a dough consisting of flour and water, rolled thin and baked until completely dry and crisp. Depending on the desired texture and flavor, ingredients may be added such as whole grains, fats, sweeteners, nuts, seeds and seasonings. There are generally three major types of crackers: savory, chemically leavened and saltine.<sup>2</sup> Savory crackers may be either unleavened or yeast-risen, while chemically leavened crackers rely solely on ingredients like baking soda and baking powder. Saltine crackers are typically leavened with both yeast and baking soda. Yeast and saltine crackers require a long fermentation period, up to 24 hours, while chemically leavened crackers are much quicker to make as they do not require a fermentation step.<sup>2</sup>

## SELECTED CRACKER APPLICATION

Oat flour is commonly used in gluten-free crackers as it is neutral in flavor and bakes into a crisp texture with a slightly sweet whole-grain profile. A chemically leavened oat-flour-based gluten-free baked cracker formula was selected to determine the benefits of various potato ingredients in application.



# INGREDIENTS AND FUNCTION

## STARCHES AND FLOURS

Starches and flours form the bulk of a cracker formula, playing an integral role in the formation of structure. In gluten-free baked goods, a combination of starches and flours are used to replicate the functional properties of gluten-containing wheat flour, such as white or brown rice flour, cornmeal and cornstarch. A typical defect in gluten-free crackers is a starchy, gritty mouthfeel, as the starches do not fully gelatinize during baking. The control gluten-free cracker formula used in this study contained the following starches and flours:

**OAT FLOUR** is neutral in flavor and cost effective as the bulk flour of gluten-free cracker formulas. However, when used without a combination of supporting starches, the texture can be gritty due to its high amylose starch content. It does not brown as well as wheat flour and can contribute a grayish hue.

**TAPIOCA STARCH** is high in amylopectin, which gelatinizes at a lower temperature than other starches, requiring less water and yields a clean, snappy break. It also stales more slowly than high amylose starches such as rice.

## SWEETENERS

In crackers, sweeteners such as granulated sugar act as tenderizers and contribute to sweetness, browning and flavor development. A small amount of granulated sugar was used in the control formulation.

## FATS

Fats are often used at low levels in unleavened crackers, contributing to richness and a more tender, friable texture. Common fats used include butter, margarine, shortening or oil. Butter was used in the formulation tested, providing a tender texture and moist mouthfeel and contributing to flavor development.

## SALT

While salt is a minor ingredient in cracker formulas, it does serve an important function as a flavor enhancer. Without it, the crackers may taste dull or flat and less balanced.

## LEAVENING

Chemical leaveners, such as baking powder and baking soda, provide a lightened texture to crackers, reacting with each other, water, acid or heat to form gases that expand during baking. Chemical leaveners affect the spread, height, shape, color and flavor of crackers. Baking powder was used in the formulation tested.

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## POTATO COMPOSITION

Potato ingredients have a wide range of functionality, and different dehydrated potato ingredients may be considered for use in application. Water absorption is a key attribute to consider; potato ingredients with native starch intact absorb less water, while potato flakes, flour and granules absorb more water. The amount of gelatinization, starch availability (damage) and presence of intact or damaged potato cells influence the functionality of the

potato ingredient. Ultimately, knowledge about these ingredients allows product developers to choose attributes for different applications. The high water-holding capacity of the starch in potato ingredients contributes to the functionality in many foods, especially baked goods.

## **STARCHES**

In general, potato starch granules are very large in size compared to the starch in other grains such as wheat or corn and include a mixture of 25% straight chain (amylose) and 75% branched chain (amylopectin) molecules.<sup>2</sup> Potato ingredients manufactured using heat have a high water-holding capacity; this is due to the gelatinization of starches during the process. In addition, high amylopectin starches are helpful in producing moist eating qualities and extending shelf life of gluten-free baked goods.

## **SUGARS**

The sugar content of potatoes can vary depending on the variety, maturity and physiological state of the potatoes. The main sugars present are sucrose, glucose and fructose.<sup>3</sup> The latter two are reducing sugars, which react with amino acids in the Maillard reaction to produce brown color and flavor compounds, which may or may not be desirable in the finished product.

## **FIBERS**

Non-starch polysaccharides, such as cellulose, hemicellulose, pentosans and pectic substances, make up the crude fiber of the potato.<sup>4</sup> Fibers absorb many more times their weight in water and help to produce moist baked goods with good eating qualities over time. One medium potato with the skin provides two grams of dietary fiber, while dehydrated potato ingredients typically contain between two to three grams of dietary fiber per hundred grams.<sup>5</sup>

## **PROTEIN**

Protein is found throughout the potato as part of the cellular membranes, cytoplasmic structures and enzymes. The protein fractions include albumin, globulin, glutelin, prolamine, as well as other proteins.<sup>6</sup>

Protein quality is often expressed in terms of its biological value (BV), which takes into account the amino acid profile of the protein along with its bioavailability. Egg protein has a biological value of 100 and is considered the reference protein. Potatoes have a relatively high BV of 90 compared with other key plant sources of protein (e.g., soybean with a BV of 84 and beans with a BV of 73).<sup>7</sup> It is a common misconception that plant proteins are missing or lacking in essential amino acids. Potatoes contain all nine essential amino acids and their amino acid profile is comparable to other key vegetable proteins. In addition, potatoes have lower levels of the sulfur-containing amino acids, which have been shown to increase calcium excretion and may negatively impact bone mineral density.<sup>8</sup>

Dehydrated potato ingredients typically contain between seven to nine grams of protein per hundred grams.<sup>9</sup>

## **LIPIDS**

Lipids are found at very low levels in potatoes (<0.2%).<sup>5</sup> Lipids in potatoes include free fatty acids, triglycerides and phospholipids, and are found in the cytoplasmic membrane of the potato cell. Most of the fatty acids are unsaturated and, therefore, can undergo oxidation, which can be important in manufacture and storage of dehydrated potato products.<sup>4</sup>

## DEHYDRATED POTATO INGREDIENTS

There are many starch and flour ingredients to consider when formulating gluten-free bakery products and dehydrated potato ingredients offer many functional benefits. However, dehydrated potato ingredients vary considerably from one another in their functional attributes and should be selected based on desired product attributes, such as color, browning, texture and flavor (see Table 1).



### POTATO GRANULES

Potato granules are a spray-dried slurry of cooked potato. The granules are made of precooked individual potato cells with cellular material still around most of the cells. The cells are relatively strong and don't readily break apart during reconstitution, resulting in less starch damage. They are high absorbing with low water-holding ability with relatively low viscosity. Compared to other potato ingredients, they hold water without much cohesion, with texture similar to wet sand rather than mashed potatoes. They do not have the gelling properties of other potato ingredients, and leave moisture for other ingredients to absorb, which can be preferable depending on the application.



### POTATO FLAKES

Standard potato flakes are precooked flaked layers of individual potato cells with some broken cellular material, allowing some starch to escape the cell. Because they are cooked, cooled and cooked again, the starch retrogrades and is less sticky. The cells are more intact unless or until the resulting product is overmixed. Retail potato flakes have moderate water-holding ability with moderate viscosity. The water-holding capacity increases if the flakes are ground. They are bright white in color and, when reconstituted, have the dry, mealy texture and flavor of freshly cooked mashed potatoes. Standard potato flakes can be ground to various sizes—often called “ground standard flake.” In fact, they can be ground so finely that they resemble flour, but they differ considerably in functionality from potato flour.



### LP/LL POTATO FLAKES

Low-peel/low-leach potato flakes (LP/LL) are fully cooked, flaked layers of individual cells with a relatively high level of broken cells and high levels of released starch. As their name suggests, LP/LL flakes are also very lightly peeled to retain more potato flavor. Light peeling affects the color of the final product, making these flakes more off-white than white. These flakes have high water-holding ability with high viscosity and are stickier and more cohesive than retail potato flakes. LP/LL flakes are typically used to manufacture fabricated potato snacks, including sheeted and extruded snacks, but have some functional attributes that could be desirable in other products, such as baked goods.



### POTATO FLOUR

Potato flour consists of precooked flaked layers of individual cells with very high level of broken cells and released starch. Potato flour has very high water-holding capacity and high viscosity. While potato flour may look like finely ground potato flakes, the two products are very different. True potato flour produces a sticky product when liquid is added and is best used in small amounts to extend other flours. The particle size of potato flour is larger than that of other flours; granular potato flour will pass through a 40-mesh, or 420-micron screen, while fine flour passes through an 80-mesh, or 177-micron screen.



## DEHYDRATED POTATO INGREDIENT CHARACTERISTICS

Potato Ingredient	Cell Damage	Free Starch	Water Absorption	Viscosity	Rehydrated Texture
Granules	Low	Low	Low	Low	Similar to mashed potatoes
Standard Flakes	Low-moderate	Moderate	Moderate	Moderate	Similar to mashed potatoes
Standard Flakes – Ground	Moderate-high	Moderate-high	Moderate-high	Moderate-high	Sticky
LP/LL Flakes	High	High	High	High	Sticky
Flour	Very high	Very high	High	High	Very sticky

Table 1 (modified from Potatoes USA)

## FORMULATIONS

A control gluten-free cracker formula (Table 2) was created to compare with test formulas containing potatoes. Test formulas were created with potato ingredients, replacing 25% of the oat flour (Table 3) with one of four dehydrated potato ingredients: flour, granules, flakes or LP/LL flakes.

### CONTROL CRACKERS

Ingredient	Percent	Batch (g)
Flour, oat, whole	58.40	233.60
Water	26.00	104.00
–	–	–
Butter, unsalted, melted	7.00	28.00
Sugar, cane	5.00	20.00
Tapioca starch	2.00	8.00
Salt, fine	1.25	5.00
Baking powder	0.35	1.40
<b>Total</b>	<b>100%</b>	<b>400.00</b>

Table 2

### TEST CRACKERS 25% OAT FLOUR REPLACEMENT

Ingredient	Percent	Batch (g)
Flour, oat, whole	43.80	175.20
Water	26.00	104.00
<b>Potato Ingredient</b>	<b>14.60</b>	<b>58.40</b>
Butter, unsalted, melted	7.00	28.00
Sugar, cane	5.00	20.00
Tapioca starch	2.00	8.00
Salt, fine	1.25	5.00
Baking powder	0.35	1.40
<b>Total</b>	<b>100%</b>	<b>400.00</b>

Table 3

# PROCESSING

## PRODUCTION

Consistent batching, portioning and baking procedures were used to limit variables where possible; however, a different cutting method was used for the potato tests after it was determined to be more efficient and consistent than that used on control; this resulted in slightly irregularly shaped control samples. The baking sheets and other equipment used was identical and each was prepared for portioning in the same manner. Bake times were not adjusted or optimized for each test formula. Instead, a standardized time and temperature was used to ensure each test experienced the same conditions.

## METHOD

In sheeted crackers, the dough is mixed, fed through a hopper onto a line, where it is then extruded into sheets and cut into the desired shapes. The formed crackers are then baked in a continuous oven, cooled and packaged.

**For these tests, a modified benchtop process with an Imperia electric pasta machine was used:**

1. In a stainless-steel bowl, whisk together the flour, starches, sugar, baking powder and salt until thoroughly combined.
2. Pour the water and melted butter into the dry ingredients and fold together with a rubber spatula until the dough comes together.
3. Gently knead into a ball and cover with plastic wrap; allow to rest for 30 minutes to hydrate.
4. Sheet the dough once through the pasta machine to setting #5.
5. Cut the sheet into 1 inch by 1 inch squares to form crackers.
6. Place the cut crackers on parchment-lined baking sheets set half-inch apart from one another.
7. Bake at 350°F for 12 minutes, or until light golden brown.
8. Allow to cool completely on the sheet pan, then package for storage.

Note: Potato ingredients were added with the dry ingredients in step 1.

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# SENSORY EVALUATION

Cracker samples were evaluated by panelists and commentary was recorded. The following attributes were assessed:

## COOKED APPEARANCE

The visual appearance of the crackers was assessed, with the following areas considered: color and browning, shape, rise, texture, cracking and crumb formation.

## COOKED AROMA

Crackers should have a mild aroma with toasty, floury notes. Aroma intensity and likability were assessed.

## ANALYTICAL MEASURES AND NOTES

Crackers were all baked in the same conditions, in the same oven, on the same day and analyzed using industry-standard evaluation methods.

### PROCESSING NOTES

An ideal cracker dough should be pliable enough to roll and sheet but firm enough to maintain its shape when cut. Test formulas were adjusted with any necessary water added until the texture of the dough matched that of the control.

### WATER ACTIVITY

Crackers should have a crisp, dry texture that allows for long-term storage without softening or spoilage. Water activity ( $A_w$ ) is defined as the ratio of vapor pressure of the moisture in the product to the vapor pressure of pure water. Water activity ( $A_w$ ) is a common analytical measure to determine the water available for participation in microbial activity.<sup>10</sup> Even a small change in water activity can greatly increase or decrease microbial growth because most microorganisms require relatively high humidity to proliferate. The target  $A_w$  for shelf-stable crackers is 0.50. Room temperature samples were tested on day one only, measured with an Aqualab Paw Kit Water Activity Meter.

### RISE AND SPREAD MEASUREMENTS

Crackers were measured with scientific calipers, in stacks of ten and the average height calculated.

### BRITTLENESS

To assess the sturdiness of the crackers and determine differences in comparison to control, panelists broke a sample cracker in half by hand, noting the force required, hardness of the snap and how intact or crumbly the fractured pieces of cracker were.

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### TEXTURE

The texture of a cracker should be dry and firm but not excessively hard. Crackers should be neither too hard, nor too soft or tender. Gluten-free crackers should neither dry out the mouth nor leave a gritty or starchy residue.

### FLAVOR

The flavor of gluten-free oat-based crackers should be whole-grain forward and taste of oats, slightly sweet with some toasted notes. Crackers should not be floury or starchy, or taste of any off notes, such as bitter, grassy, vegetal or cardboard-like flavors.

### OVERALL LIKABILITY

Considering all sensory aspects, crackers were rated on overall acceptability and ranked by panelists.



## RESULTS

The results of this study, including processing notes, analytical measures, sensory commentary and photographs are summarized below in Tables 4–8.

### CONTROL CRACKER

Attribute	Results/Comments
Water Added to Dough	None
Dough Quality	Workable, not sticky, produced an even sheet, no residue, strong oat aroma
Average Height	0.14 inches (3.5mm)
Water Activity	0.36 ± 0.02 (21.8°C)
Brittleness	Firm/strong snap requiring moderate force; doesn't crumble, but breaks cleanly
Sensory Attribute	Comments
Appearance	Lightly mottled whole-grain texture, slightly curved shape
Color	Even in color, grayish tan in hue, slightly browned on edges
Aroma	Generic starch, slightly toasty, as expected
Flavor	Toasted oat, bland, tastes like whole grains
Texture	A hard, firm crunch. Some grittiness, tooth packing, quickly formed a bolus in the mouth, sucks the moisture out of the mouth
Overall Likability	As expected

Table 4



## POTATO FLOUR TEST CRACKER: 25% OAT FLOUR REPLACEMENT

Attribute	Results/Comments
Water Added to Dough	8g additional water per 400g batch (2%)
Dough Quality	Firm but still moldable, not sticky, easily torn apart. Able to handle and sheet well
Average Height	0.19 inches (4.93mm)
Water Activity	0.44 ± 0.02 (22.0 °C)
Brittleness	Very hard and sturdy, required more force to break than control. Produced some crumbles
Sensory Attribute	Comments
Appearance	More irregular texture than control, looks like it's whole grain and appealing, flatter than control
Color	Similar in color to control, but browner overall, particularly around the edges
Aroma	Similar to control
Flavor	More flavorful and appealing than control, with a nutty, almost cheesy, savory profile that does not taste as much like whole grains. Some panelists noted a slight bitter aftertaste, most likely due to overbrowning
Texture	Hard but crumbles more easily than control. More appealing, not as tooth packing
Overall Likability	More appealing than control in texture and appearance, but the flavor may only be appropriate for specific applications. Not as well liked compared to granules and LP/LL potato flakes
Recommendation	Adjust oven to prevent overbrowning and development of any bitter flavor notes. Use in a cheesy or flavored cracker

Table 5



## POTATO GRANULES CRACKER: 25% OAT FLOUR REPLACEMENT

Attribute	Results/Comments
Water Added to Dough	20g additional water per 400g batch (5%)
Dough Quality	Produced more crumbs than potato flour test. Easily torn, moldable, did not sheet easily
Average Height	0.15 inches (3.68mm)
Water Activity	0.49 ± 0.02 (22.5°C)
Brittleness	Much easier to snap and more tender than control, with a clean break
Sensory Attribute	Comments
Appearance	Smoother texture than control, some cracking around the edges and a slight curve
Color	Slightly more browned than control
Aroma	Less intense oat than control
Flavor	Slightly sweet, toasty note. Most mild flavor, less whole grain flavor than control in an appealing way. Slightly sweeter, most like control in oat flavor
Texture	Crumbly, not as friable. Turns to paste in the mouth, more tooth packing than potato flour. Unlike control, this does not dry out the mouth
Overall Likability	Prefer the eating qualities of potato flour over the eating qualities of granules. This was the favorite cracker of panelists
Recommendation	Good for cracker applications with necessary processing adjustments. Helps to balance the flavor of other gluten-free starches and adds welcome sweetness

Table 6





## POTATO FLAKES CRACKER: 25% OAT FLOUR REPLACEMENT

Attribute	Results/Comments
Water Added to Dough	25g additional water per 400g batch (6.25%)
Dough Quality	Flaky dough with visible potato flakes. Slightly firm but moldable, easily torn and crumbly
Average Height	0.14 inches (3.63mm)
Water Activity	0.44 ± 0.02 (22.4 °C)
Brittleness	Snaps easily but doesn't shatter, produces more crumbs than control, not as even
Sensory Attribute	Comments
Appearance	Some visual particulates, lots of texture, control looks more processed in comparison. Panelists found this test to be more appealing
Color	Very brown overall, edges browned much more than control. The hue is more golden yellow than gray-brown, looks more appealing than control
Aroma	Toasty, mild
Flavor	Slight bitterness due to overbrowning. Noticeable potato flavor, with slight nutty, toasty and even a hint of savory cheesy notes, which panelists found very appealing but also a large departure from the profile of control
Texture	Nice snappy crunch, like a Wheat Thin. Dissolves in the mouth and slightly drying, leaves some residue but not unappealing
Overall Likability	The cracker was overly browned, but panelists found the texture and flavor to be appealing. Add to crackers for texture. Adjust oven for browning

Table 7



## LP/LL FLAKES CRACKER: 25% OAT FLOUR REPLACEMENT

Attribute	Results/Comments
Water Added to Dough	10g additional water per 400g batch (2.5%)
Dough Quality	Softer, doughy, not sticky. Very easy to handle and sheet
Average Height	0.15 inches (3.88mm)
Water Activity	0.42 ± 0.02 (22.5°C)
Brittleness	Hard snap and clean break, comparable to potato flour, perhaps slightly sturdier
Sensory Attribute	Comments
Appearance	Lots of little fissures, more cracks than any other test. Doesn't look as granular as potato flakes, but slightly uneven. Looks appealing
Color	Browner than control, but similar to other potato tests. Looks more appealing than control, but slightly overbrowned
Aroma	Mild aroma
Flavor	Most appealing flavor, flavorful but not tasting excessively of potato
Texture	More friable texture, not as much tooth-pack as control. Light and crispy crunch, takes less force to bite. Less drying in the mouth
Overall Likability	Different and more savory in flavor in comparison to control, but panelists found this cracker to be the most appealing, along with the potato granules test
Recommendation	Recommended for cracker applications. Adjust oven for browning. Appealing, robust potato flavor in snacks

Table 8



# CONCLUSIONS

## POTATO FLOUR

### CONCLUSIONS

Potato flour used at 14.6% of the cracker formula (25% oat flour replacement) required the least amount of additional water of all the tests, but baked up into the thickest cracker of all the tests. It showed multiple functional benefits, including:

- Easy-to-handle dough that sheets well
- Natural, whole-grain-like appearance
- Flatter and more uniform in shape
- Richer browning and color, particularly around the edges
- More appealing and stronger savory aroma or flavor
- Stronger brown flavor notes
- A sturdy texture with good structure, more pleasant eating experience

### RECOMMENDATIONS

Potato flour would be beneficial in a cracker where a crisp, sturdy texture and stronger, savory flavor profile is desired. To prevent overbrowning and the formation of bitter flavors, oven temperatures and cook times may need to be adjusted, depending on equipment.

## POTATO GRANULES

### CONCLUSIONS

Potato granules used at 14.6% of the cracker formula (25% oat flour replacement) required more additional water than other tests; the dough did not sheet well and was easily torn. However, it was one of the favorite crackers of the panelists. Positive attributes included:

- Natural, whole-grain-like appearance
- Flatter and more uniform in shape
- Richer browning and color, particularly around the edges
- Most like control in flavor, but enhanced the sweetness and oat profile
- A sturdy yet tender structure, with an appealingly friable, crumbly texture and an overall pleasant eating experience

### RECOMMENDATIONS

Potato granules would be beneficial in a cracker where a tender, friable texture and more neutral, sweeter flavor profile is desired. Due to enhanced browning, oven temperatures and cook times may need to be adjusted, depending on equipment.



## STANDARD POTATO FLAKES

### CONCLUSIONS

Standard potato flakes used at 14.6% of the cracker formula (25% oat flour replacement) required the most additional water of all the potato tests; the dough did not sheet well and was crumbly. However, it did show some positive attributes in the gluten-free cracker application:

- Natural, whole-grain-like appearance with visible particulates
- Richer browning and color, particularly around the edges
- Noticeable potato flavor, with slight nutty, toasty and even a hint of savory cheesy notes (but can become bitter if overbrowned)
- A sturdy yet tender structure, with a snappy, crunchy texture

### RECOMMENDATIONS

Potato granules would be beneficial in a cracker where a firm, snappy texture and more neutral, sweeter flavor profile is desired. Due to enhanced browning, oven temperatures and cook times may need to be adjusted, depending on equipment.

## LP/LL POTATO FLAKES

### CONCLUSIONS

LP/LL potato flakes used at 14.6% of the cracker formula (25% oat flour replacement) was one of the favorite crackers of the panelists. Positive functional benefits included:

- Did not require an excessive amount of additional water; dough was easy to handle, sheeted and cut well without tearing
- Natural, artisanal looking, visible texture
- Richer browning and color, particularly around the edges
- Enhanced savory flavor, but not tasting excessively of potato
- Stronger brown flavor notes (can become bitter if overbrowned though)
- Crackers were neither overly hard or fragile, with a light, crisp, friable structure

### RECOMMENDATIONS

LP/LL potato flakes are highly recommended in cracker applications, gluten-free or wheat based. They provide a light, crisp structure and enhance savory flavors. Due to enhanced browning, oven temperatures and cook times may need to be adjusted, depending on equipment.

## OVERALL CONCLUSIONS

Formulators must determine the best ingredients for gluten-free crackers through hands-on testing on the bench and in the plant to achieve the desired results, balancing flavor with functionality. Ultimately, that may mean using a combination of dehydrated potato ingredients with other starches and flours in gluten-free cracker formulations that offer an eating quality as good as or even superior to gluten-containing crackers.

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