Supplementary material

Table S1. Summary of selected tested ingredients. Descriptions, application levels, uses, and potential improvements.

Product name	Description	Usage level	Applications	Potential improvement
Traviata® (T)	Rye sourdough in powder form	1–3% on flour (wheat breads), ≥10% on rye flour (rye bread acidifier)	French/Italian bread, multigrain bread, whole grain bread, parbaked/frozen goods; enhances rye sourdough flavor	Mildly acidic, ideal for flavor enhancement in wheat bread or as a rye bread acidifier
Rigoletto® (R)	Wheat sponge in powder form	1–2% on flour	Wheat/rye breads, improve flavor with minimal fermentation (1 h)	Quick fermentation (1 h) for wheat/rye breads
Panarome® (P)	Liquid concentrated sponge extract	2–3% on flour (bread/pizza); 6–12 mL per 600 g bread (spray with ethanol)	Pan bread, French/Italian bread, buns, frozen doughs (replaces sponge process); pizza (freshness/softness); mold inhibition when sprayed	Dual use (dough incorporation or spray for mold inhibition)
Aroldo® (A)	Deactivated liquid rye sourdough	1–2% on flour (wheat bread), 7–8% on rye flour, or 3–4% on total flour (rye bread)	Replaces traditional sourdough for consistent flavor in wheat/rye breads	Stabilized liquid sourdough for consistent rye flavor
Fidelio® (F)	Liquid-deactivated wheat San Francisco sourdough	2% (wheat breads); 10–12% (San Francisco breads); 1.5% (brioche)	French/Italian bread (mild sourness); San Francisco bread (blistered crust, elastic crumb); brioche (enhances buttery flavor); parbaked/frozen goods	Imparts San Francisco sourdough characteristics

Table S2. Summary of selected commercial fermentate-based ingredients. Descriptions, application levels, and uses.

Product (MicroGard)	Product description	Usage level	Applications
100	A free-flowing powder designed to protect product flavor and enhance food shelf life. This bioprotectant consists of fermentation metabolites derived from dairy cultures (natural metabolites that can inhibit microbial growth in various food products) when used alongside heat processing, pH adjustments, and other formulation modifications. It is effective against certain Gram-negative bacteria, yeast, and molds.	0.1 – 1.5 % depending on the application	Fresh pasta, pasta fillings, sauces, salad dressings, fresh soups, spreads, cheese blends, cottage cheese, yogurt, sour cream, meal replacements
200	A bioprotectant consisting of fermentation metabolites of starter cultures from maltodextrin. It protects product flavor and enhances food shelf life. It contains natural metabolites that may retard microbial growth in numerous food products when used in combination with heat processing, pH adjustments, and other formulation modifications. It is effective against selected Gram-negative bacteria, yeast, and molds.	0.1 – 2.0 % depending on the application	Fresh pasta, pasta fillings, stuffed/gratin potatoes, cheese blends, cottage cheese, yogurt, sour cream, fresh soups, sauces, salad dressings, spreads, meal replacements, marinated meats, cooked sausages, refrigerated meat, meat broth soups.
300	The free-flowing powder protects product flavor and provides a more reliable food shelf life. It is an effective bioprotectant consisting of fermentation metabolites of dairy cultures. It is effective against selected Gram-positive bacteria, yeast, and molds. Their use can be in combination with	0.2 - 1.5%, depending on the application	Flavored kinds of milk, natural/processed cheeses, fresh soups, sauces, salad dressings, cream-style soups, spreads, fresh pasta, pasta fillings, meal replacements, sausages and salami, cooked sausages, refrigerated meat, processed meat, meat in sauces entrees

	heat processing, pH adjustments, and other formulation modifications.		
520	A cultured dextrose-based food produced through the natural fermentation of traditional starter cultures. It enhances the flavor, mouthfeel, and other sensory attributes of various food products. It helps maintain food quality by controlling the growth of unwanted bacteria, including gas producers, spore-formers, and human pathogens.	0.15 - 0.5 % (w/w) in the final food product	Fresh pasta, pasta fillings, fresh soups, sauces, salad dressings, spreads, flavored kinds of milk, meal replacements, natural/processed cheeses, sausages and salami, cooked sausages, refrigerated meat, processed meat, meat in sauces-entrees, cream-style soups
730 CO	A certified organic cultured dextrose-based food produced through the natural fermentation of traditional starter cultures. It enhances the flavor, mouthfeel, and sensory attributes of various food products. It helps maintain food quality by controlling the growth of unwanted yeasts, molds, and bacterial strains. Their use can be in combination with heat processing, pH adjustments, and other formulation modifications.	0.2 - 1.5% depending on the application	Fresh pasta, pasta fillings, deli salads (chicken, tuna, seafood, ham, coleslaw, potatoes, egg, fruits, pasta, rice), mashed potatoes, meat broth soups, fresh soups, sauces, salad dressings, spreads, flavored kinds of milk, meal replacements, natural/processed cheeses, sausages and salami, cooked sausages, refrigerated meat, processed meat, meat in sauces entrees, cream-style soups, ready-to-eat meals
910F	A cultured (fermented) wheat starch-based food produced through the natural fermentation of traditional starter cultures. It enhances the flavor, mouthfeel, and other sensory attributes of baked goods.	0.5% and 1.0%, depending on the application	Whole wheat and white pan bread, tortillas and other flatbreads, English muffins
CS1-50 CO	A certified organic cultured dextrose-based food produced through the natural fermentation of traditional starter cultures. It is effective in various food	0.2 - 1.0%, depending on the application	Low pH dressings and sauces, processed meat products, chilled, pasteurized “ready-to-eat” meals (pasta dishes, cooked potato products,

	products across a wide range of pH levels (3.5-8.0). It helps maintain food quality by controlling the growth of unwanted bacterial strains, including gas-producing, spore-forming, and pathogenic bacteria.	etc.), pasteurized soups, dairy products (direct acidified fresh cheese, pasteurized dairy desserts, yogurt, recombined and flavored kinds of milk), Pasteurized liquid egg products

Table S3. Time to growth model coefficient for mold on bread formulated with two commercial fermentates (A and F).

		Regression
Predictor		Coefficient
β_0	Intercept	2.5655
β_1	T	-0.08967
β_2	C	0.8056
β_3	T*C	-0.1913

T (type of fermentate) and C (fermentate concentration) are normalized values.