



1001 G Street, N.W.
Suite 500 West
Washington, D.C. 20001
tel. 202.434.4100
fax 202.434.4646



#866

Writer's Direct Access
Melvin S. Drozen
(202) 434-4222
drozen@khlaw.com

May 30, 2019

Via FedEx

Paulette Gaynor, Ph.D.
Office of Food Additive Safety (HFS-200)
Center for Food Safety and Applied
Nutrition
Food and Drug Administration
5100 Campus Drive
College Park, MD 20740

Re: GRAS Notification for Amano's Lipase Enzyme Preparation

Dear Dr. Gaynor:

We respectfully submit the enclosed (new) GRAS notification (in electronic format, *i.e.*, CD)¹ on behalf of our client, Amano Enzyme, Inc. (Amano) for a lipase enzyme preparation derived from *Penicillium camemberti* for use as a processing aid for (1) dairy processing (*i.e.*, the production of enzyme-modified cheese) and (2) fats and oil processing (*i.e.*, the production of dietary ingredients derived from fats and oils including, but not limited to, gamma linolenic acid (GLA), docosahexaenoic acid (DHA), and eicosapentaenoic acid (EPA)). The enclosed GRAS notification provides detailed information related to the intended uses, manufacturing, and safety of the enzyme.

As described in the enclosed GRAS notice, Amano's lipase is an acylglycerol lipase that was originally developed for production using a non-genetically modified (GM) strain of *P. camemberti* U-150 (designated internally by Amano as strain AE-LG) and is covered for use in fats and oil processing as described in GRN 68. The lipase may also be produced using a strain derived from *P. camemberti* U-150 by self-cloning as described in this notice. The new, genetically modified (GM) strain is designated internally by Amano as AE-LGS and produces higher yields than the non-GM strain. The intended uses of the lipase, as set forth in this GRAS notice, are expanded as compared to the intended uses of the lipase as described in GRN 68.

¹ All electronic files included in this submission have been checked and found to be virus free.

KELLER AND HECKMAN LLP

Paulette Gaynor, Ph.D.

May 30, 2019

Page 2

We look forward to FDA's review of this submission and would be happy to answer any questions. Thank you for your attention to this matter.

Sincerely,

A solid black rectangular box used to redact the signature of Melvin S. Drozen.

Melvin S. Drozen

Enclosure

GRAS Notice for Lipase Derived From *Penicillium camemberti*

Prepared for: U.S. Food and Drug Administration
Office of Food Additive Safety (HFS-200)
Center for Food Safety and Applied Nutrition
5100 Paint Branch Parkway
College Park, MD 20740-3835

Prepared by: Keller and Heckman LLP
1001 G Street, NW
Suite 500 West
Washington, DC 20001

Date: May 30, 2019

Table of Contents

Part 1 – Signed statements and certification 2

1.1 Applicability of 21 C.F.R. part 170, subpart E..... 2

1.2 Name and address of the notifier..... 2

1.3 Name of the notified substance 2

1.4 Applicable conditions of use of the notified substance 2

1.5 Basis for the GRAS determination 4

1.6 Exclusion from premarket approval 4

1.7 Availability of data and information 4

1.8 Applicability of FOIA exemptions..... 4

1.9 Certification..... 4

Part 2 – Identity, method of manufacture, specifications, and physical or technical effect..... 6

2.1 Scientific data and information that identifies the notified substance 6

2.2 Description of the method of manufacture 11

2.3 Specifications of the food-grade material 12

2.4 Data and information bearing on the physical or other technical effect..... 12

Part 3 – Dietary exposure..... 13

Part 4 – Self-limiting levels of use..... 15

Part 5 – Experience based on common use in food before 1958 16

Part 6 – Narrative 17

6.1 Safety of *Penicillium camemberti* production strains AE-LG and AE-LGS 17

6.2 Safety of enzyme preparation from *Penicillium camemberti*..... 18

6.3 No allergenicity concerns for enzyme preparation from *Penicillium camemberti*..... 20

6.4 Pariza and Johnson decision tree analysis..... 21

6.5 Conclusion 23

Part 7 – List of supporting data and information 24

7.1 References..... 24

7.2 Tables 24

7.3 Figures..... 25

**GRAS NOTICE FOR LIPASE DERIVED FROM *PENICILLIUM CAMEMBERTI*
SUBMITTED BY AMANO ENZYME, INC.**

Part 1 – Signed statements and certification

1.1 Applicability of 21 C.F.R. part 170, subpart E

We submit this GRAS notice in accordance with 21 C.F.R. part 170, subpart E.

1.2 Name and address of the notifier

Company: Amano Enzyme, Inc.
Name: Mr. Hiromichi Yoshida (Quality Assurance Department)
Address: 27 Hanno, Kunotsubo
Kita-Nagoya, Aichi Prefecture 460-8630
JAPAN
Phone: 81 (0) 568.21.4044
Fax: 81 (0) 568.26.6160

1.3 Name of the notified substance

The notified substance is lipase derived from *Penicillium camemberti*. The lipase may be produced from *P. camemberti* U-150 as previously described in Amano's GRN 68. Alternatively, the lipase may be produced by a strain derived from *P. camemberti* U-150 by self-cloning as described in this notice. The original, non-genetically modified (GM) strain of *P. camemberti* U-150 is designated internally by Amano as strain AE-LG. The new, GM strain is designated as AE-LGS. The intended uses of the lipase are expanded as compared to the intended uses of the lipase described in GRN 68. Amano's GM and non-GM *P. camemberti* enzyme preparation contains dextrin, which is used as a diluent and is GRAS affirmed at 21 C.F.R. 184.1277.

1.4 Applicable conditions of use of the notified substance

1.4(a) Foods in which the substance is to be used

The lipase is intended for use as a processing aid for dairy processing (*i.e.*, the production of enzyme-modified cheese) and fats and oil processing (*i.e.*, the production of ingredients derived from fats and oils including, but not limited to, gamma linolenic acid (GLA), docosahexaenoic acid (DHA), and eicosapentaenoic acid (EPA)). By comparison, GRN 68 describes a narrower intended use of the lipase derived from *P. camemberti* AE-LG for use only in the production of ingredients derived from fats and oils, rather than also covering use of the enzyme for dairy processing as described in this GRAS notice.

1.4(b) Levels of use in such foods

Lipase is a processing aid. It has no activity in the finished food due to the denaturation of the enzyme by heat treatment during processing of the food or food ingredient made using the lipase. Some manufacturing uses of the lipase additionally entail depletion of the substrate and later food processing steps, including reduction of water activity and altering the pH, which prohibit enzyme activity in the finished food or food ingredient.

Further, the inactivated enzyme – which is water soluble – is removed from foods or food ingredients such as GLA, DHA, and EPA that are produced with a washing step that follows the enzyme treatment in the manufacturing process. Nevertheless, in calculating the estimated daily intake (EDI) of the lipase, it is assumed that the maximum amount of lipase used in the applications of interest (*i.e.*, dairy processing and fats/oils processing) remains in the food ingredient when it is consumed.

The use level of the lipase is expressed in terms of the amount of Total Organic Solids (TOS) of *P. camemberti* enzyme preparation, in milligrams (mg), that are added to the fat substrate and may potentially be present in each kilogram (kg) of raw material (*i.e.*, component of the finished food). The TOS is calculated by subtracting the weight of ash from the weight of the dry matter comprising the enzyme preparation. Ash in the enzyme preparation (*e.g.*, mineral salts used in the fermentation) generally does not exceed a few percent. Any food material that contains monoglycerides and diglycerides could be suitable for use as a substrate for the lipase.

The intended use of Amano's lipase derived from *P. camemberti* in dairy processing and fats/oils processing, with representative examples of substrates, is described in greater detail as follows.

Dairy processing

Lipase is added to emulsified cheese homogenates (the raw material), along with animal or microbial enzymes, at levels ranging from **25 to 2,522 mg TOS/kg raw material** during the incubation stage in making enzyme modified cheese (EMC). A subsequent heat treatment of the EMC at 90°C for 15 minutes inactivates the lipase. The EMC may be used as an ingredient in foods such as soup, snack foods, and processed cheese.

Fats and oil processing

Lipase is added at levels ranging from **50 to 252 mg TOS/kg raw material** (*i.e.*, edible fats and oils, such as shea oil, fish oil, or borage oil) prior to refining (deacidification and dehydration), bleaching, and deodorizing. The lipase hydrolyzes diglycerides into monoglyceride and/or fatty acids but does not react with triglycerides. The bleaching and deodorizing steps involve heat treatments that are expected to denature the lipase. Fat and oil ingredients made using the lipase may be used as an ingredient in bread, pastry, and confections.

1.4(c) Purpose for which the substance is to be used

Amano's *Penicillium camemberti* enzyme preparation (acylglycerol lipase or lipase) catalyzes the hydrolysis of ester bonds between fatty acids and glycerols in monoglycerides and diglycerides that are present in edible fats and oils of plant and animal origin.

In dairy processing, the lipase hydrolyzes milk fat to generate free fatty acids that enhance the flavor of EMC.

In fat and oil processing, the lipase-modified fats and oils have a low diglyceride content, exhibit rapid crystallization rates, are less susceptible to hydrolysis, and have unchanged triglyceride compositions.

1.4(d) Description of the population expected to use the substance

Amano's *P. camembertii* enzyme preparation is expected to be consumed by any population that consumes enzyme modified cheese and/or foods and beverages that may contain ingredients such as DHA, EPA, and GLA.

1.5 Basis for the GRAS determination

The statutory basis for our conclusion of GRAS status is through scientific procedures in accordance with 21 C.F.R. §§ 170.30(a) and (b).

1.6 Exclusion from premarket approval

The notified substance is not subject to the premarket approval requirements of the Federal Food, Drug, and Cosmetic Act (FD&C Act) based on our conclusion that the notified substance is GRAS under the conditions of its intended use.

1.7 Availability of data and information

If the Food and Drug Administration (FDA) asks to see the data and information that are the bases for our conclusion of GRAS status, either during or after FDA's evaluation of our notice, we agree to make the data and information available to FDA. Further, upon FDA's request, we will allow the Agency to review and copy the data and information during customary business hours at the above address and will provide FDA with a complete copy of the data and information, either in an electronic format that is accessible for the Agency's evaluation, or on paper.

1.8 Applicability of FOIA exemptions

This GRAS notice does not contain confidential business information (CBI) exempt from disclosure under the Freedom of Information Act per 5 U.S.C. § 552(b)(4).

1.9 Certification

We certify that, to the best of our knowledge, our GRAS notice is a complete, representative, and balanced submission that includes unfavorable information, as well as favorable information, known to us and pertinent to the evaluation of the safety and GRAS status of the use of the substance.



Name: Tomonari Ogawa
Title: Director, Quality Assurance Division

May 29, 2019

Date

Please address correspondence to Amano's counsel:

Melvin S. Drozen
Keller and Heckman LLP
1001 G Street, N.W., Suite 500 West
Washington, DC 20001
Phone: (202) 434-4222
Email: drozen@khlaw.com

Part 2 – Identity, method of manufacture, specifications, and physical or technical effect

2.1 Scientific data and information that identifies the notified substance

The trade name for Amano's *Penicillium camemberti* enzyme preparation, described below, is Lipase GS "Amano" 250G. The product is a low odor, water soluble granule with a color that is light yellowish brown to light brown. Food grade dextrin is used as a carrier for the enzyme in accordance with good manufacturing practice (GMP). Dextrin is affirmed as GRAS at 21 C.F.R. § 184.1277. The lipase enzyme component is extracted and purified from the submerged fermentation and processing of a stable non-pathogenic strain of *P. camemberti* AE-LGS (a strain number used internally by Amano) that has been shown to be non-toxic under the growth conditions for enzyme production. *P. camemberti* AE-LGS is a self-cloned derivative of *P. camemberti* AE-LG (a strain number used internally by Amano). The enzyme preparation derived from *P. camemberti* AE-LG (trade name Lipase G "Amano" 50) is described in GRN 68.¹ Lipase GS "Amano" 250G and Lipase G "Amano" 50 are equivalent.

More detailed information regarding the identity of the notified substance is provided as follows:

2.1(a) Common or usual name

Lipase derived from *Penicillium camemberti*.

2.1(b) International Union of Biochemistry and Molecular Biology (IUBMB) Enzyme Nomenclature Chemical name

Acylglycerol lipase

2.1(c) IUMB Number

EC 3.1.1.23

2.1(d) Chemical Abstracts Service Registry Number (CASRN)

9040-75-9

2.1(e) European INventory of Existing Commercial chemical Substances (EINECS) Number

679-517-4

2.1(f) Synonyms

¹ The currently accepted spelling of the name of the production organism is *Penicillium camemberti*, with a single-i, rather than *Penicillium camembertii*, with a double-ii.

Monoacylglycerol lipase; monoacylglycerolipase; monoglyceride lipase; monoglyceride hydrolase; fatty acyl monoester lipase; monoacylglycerol hydrolase; monoglyceridylipase; monoglyceridase

2.1(g) Enzyme specificity

Amano's *Penicillium camemberti* enzyme preparation (acylglycerol lipase or lipase) catalyzes the hydrolysis of ester bonds between fatty acid and glycerol in monoglycerides and diglycerides that are present in edible fats and oils of plant and animal origin, releases fatty acids and glycerols. The enzyme does not affect triglycerides.

2.1 (h) Molecular mass and amino acid sequence

The full amino acid sequence of lipase derived from *Penicillium camemberti* is provided in **Figure 1** below.

Figure 1. Amino acid sequence of lipase from *Penicillium camemberti*

```
1  MRLSFFTALS AVASLGYALP GKLQSRDVST SELDQFEFWV QYAAASYIEA DYTAQVGDKL 60
61  SCSKGNCP EV EATGATVSYD FSDSTITDTA GYIAVDHTNS AVVLAFRGSY SVRNWVADAT 120
121 FVHTNPGLCD GCLAELGFWS SWKLVRRDII KELKEVVAQN PNYELVVVGH SLGAAVATLA 180
181 ATDLRGKGY P SAKLYAYASP RVGNAALAKY ITAQGNFRF THTNDPVPKL PLLSMGYVHV 240
241 SPEYWITSPN NATVSTSDIK VIDGDVSFDG NTGTGLPLL DFEAHIWYFV QVDAGKGPGL 300
301 PFKRV
```

From the above sequence, the molecular mass of the enzyme protein is calculated to be 32.9kDa.

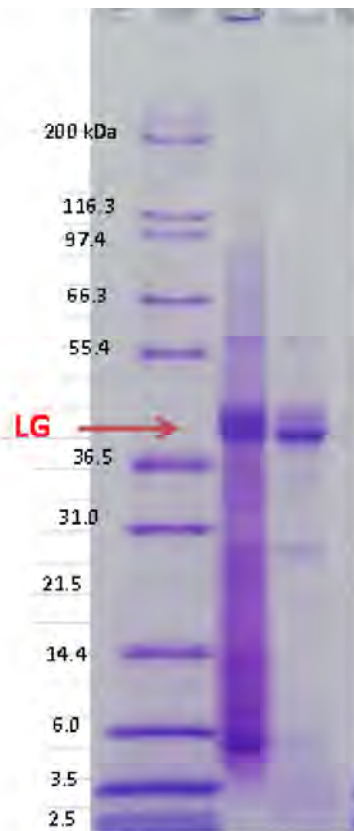
Additional information about acylglycerol lipase derived from *Penicillium camemberti* is available in protein databases such as BRENDA (<https://www.brenda-enzymes.org/>) and UniProt (<https://www.uniprot.org/>).

2.1(i) Equivalence of lipase from *P. camemberti* AE-LGS to lipase from *P. camemberti* AE-LG

P. camemberti AE-LGS is a self-cloned derivative of *P. camemberti* AE-LG (as described in detail in item 2.1(k) below). Based on the analyses that follow, the lipase from Amano's GM strain (*P. camemberti* AE-LGS) is deemed to be identical to the lipase from Amano's non-GM strain (*P. camemberti* AE-LG) that is the subject of GRN 68.

Comparative analysis by sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) shows banding patterns that support no significant differences in protein expression between the self-cloned strain, *P. camemberti* AE-LGS (LG-Y69-001) and Amano's non-GM strain, *P. camemberii* AE-LG (LG-Y67-003) that is the subject of GRN 68. See **Figure 2** below.

Figure 2. SDS-PAGE analysis of lipases derived from *P. camemberti* AE-LG (LG-Y67-003) and *P. camemberti* AE-LGS (self-cloned from *P. camemberti* AE-LG) (LG-Y69-001).



From the left

Maerker, LG-Y67-003, LGS-Y69-001

Gel: Super sep ACE (WAKO pure chmical)

10-20% 17well

3000v 15A Conditions of electrophoresis

Marker: Marker12 Unstained standard (Invitrogen)

Eight-tube for PCR

↓ ← 20 μ L 10000 U-LV/mL

↓ ← 25 μ L

↓ ← 55 μ L

↓ ← Voltex

↓ ← 99 $^{\circ}$ C 10 min Thermal cyler

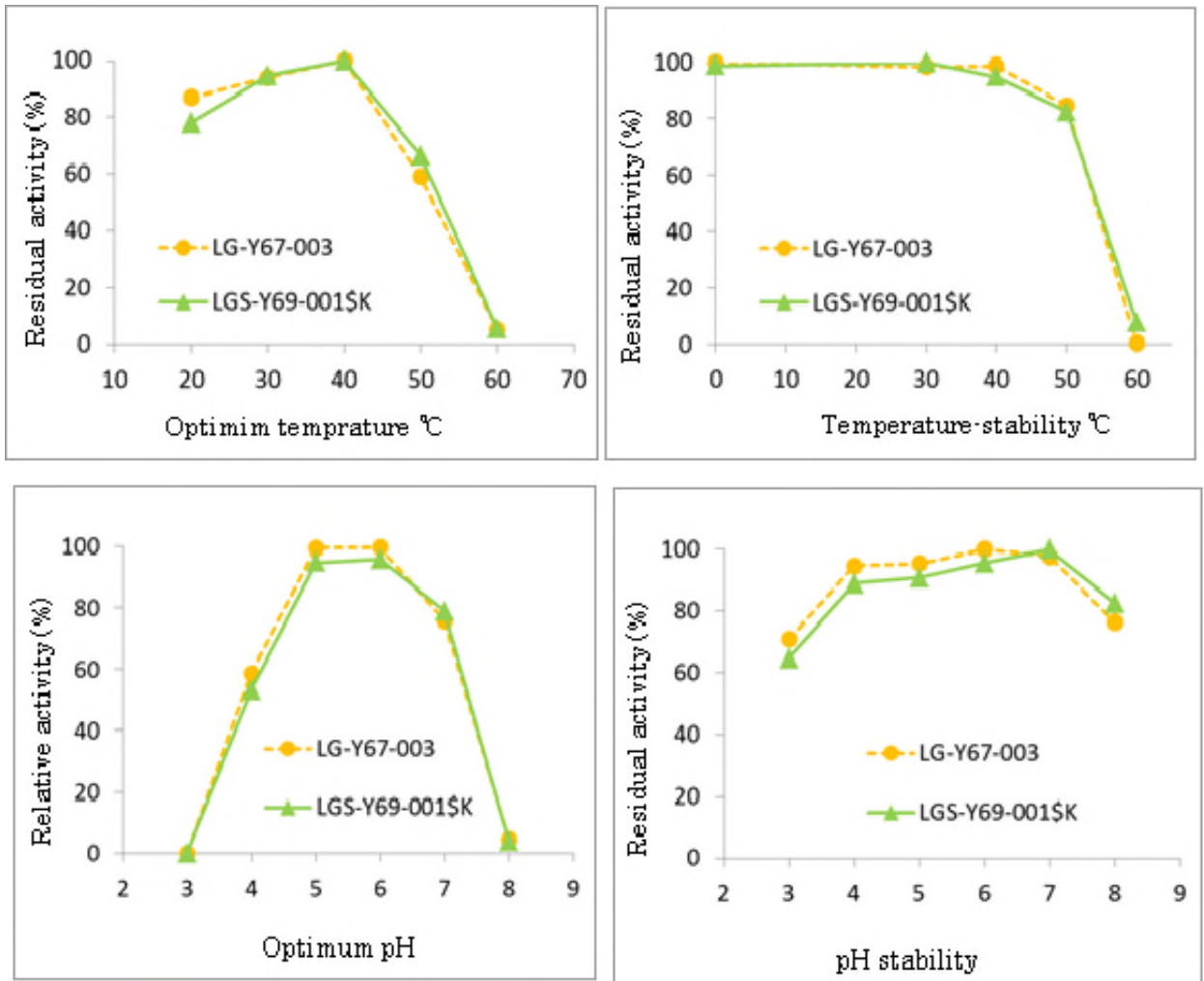
10 μ L electrophoresis

LGS-Y69-001:

Production strain is self cloned microorganism

Optimum temperature, temperature stability, pH stability, and optimum pH were equivalent for the lipase from Amano's GM strain (*P. camemberti* AE-LGS) as compared to the lipase from Amano's non-GM strain (*P. camemberti* AE-LG) that is the subject of GRN 68. See **Figure 3** below.

Figure 3. Optimum temperature, temperature stability, pH stability, and optimum pH of lipases derived from *P. camemberti* AE-LG (LG-Y67-003) and *P. camemberti* AE-LGS (self-cloned from *P. camemberti* AE-LG) (LGS-Y69-001SK).



TOS contents were equivalent for the lipase from Amano’s GM strain (*P. camemberti* AE-LGS) as compared to the lipase from Amano’s non-GM strain (*P. camemberti* AE-LG) that is the subject of GRN 68. Lipase derived from Amano’s GM strain is of a higher purity than that derived from non-GM strains as indicated by activity (U/g) assays. See **Table 2** below.

Table 2. Comparison of lipases derived from *P. camemberti* AE-LG (“LG (Non-GM)”) and *P. camemberti* AE-LGS (self-cloned from *P. camemberti* AE-LG; “LGS (GM)”).

	LGS (GM)	Test article (90 day toxicity study)	LG (Non-GM)			
Batch No.	LGS-Y69-001	LGK-000602	LG-Y64-002	LG-Y65-001	LG-Y65-002	Mean
Ash (%)	2.52	22.2*	1.8	3.1	2.6	2.5
Water (%)	4.9	2.04	4.4	4.3	5.1	4.6
TOS (%)	92.58	75.76	93.80	92.60	92.30	92.9
Activity (Units/g)	913,000	100,222	337,000	140,000	304,000	260,333
Units/mg TOS	986.2	132.3	359.3	151.2	329.4	279.9

* The ash content of the test article samples was high because the liquid before alcohol precipitation was freeze-dried.

2.1(j) Taxonomic classification of the production strains

Super Kingdom	Eukaryote
Kingdom	Fungi
Phylum	Ascomycota
Order	Eurotiales
Class	Eurotiomycetes
Family	Trichocomaceae
Genus	<i>Penicillium</i>
Species	<i>camemberti</i>
Strain	AE-LG (U-150) and AE-LGS (not registered)

2.1(k) Information regarding the source of the notified substance

The lipase production strain, *Penicillium camemberti* AE-LGS, was obtained via self-cloning from *P. camemberti* U-150 (designated internally by Amano as strain AE-LG).

FDA has issued a May 21, 2009 letter indicating that the Agency has “no questions” regarding the GRAS status of lipase derived from *P. camemberti* U-150 for use in the production of ingredients derived from fats and oils as described in Amano’s GRN 68. (The intended uses of the lipase in this GRAS notice are expanded to include (1) dairy processing (i.e., the production of enzyme-modified cheese) and (2) flavoring production (i.e., production of flavor ingredients for a wide variety of foods and drinks) in addition to (3) fats and oil processing (i.e., the production of ingredients derived from fats and oils including, but not limited to, gamma linolenic acid (GLA), docosahexaenoic acid (DHA), and eicosapentaenoic acid (EPA)), which is described in GRN 68.)

P. camemberti AE-LGS contains two genes from *P. camemberti* AE-LG: (1) native lipase gene, *mdlA*, and (2) marker gene, *pyrG* (orotidine-5’-phosphate decarboxylase) for non-toxic nutritional selection of transformed cells with amplified *mdlA* genes.

Using a *pyrG*-deficient strain derived from UV treatment of *P. camemberti* AE-LG as the host, transformation was conducted by the protoplast method to achieve the target transformant. The DNA fragments *mdlA* and *pyrG* were incorporated into the host genome through non-homologous recombination. Transformants were grown on a plate spiked with brilliant green and monoolein, and primary screening was conducted based on the Halo size. Strains with high lipase productivity were selected.

2.2 Description of the method of manufacture

The lipase enzyme preparation is manufactured under controlled fermentation conditions using a pure culture of *Penicillium camemberti*; specifically, either *P. camemberti* AE-LG (a non-GM strain) or *P. camemberti* AE-LGS (a self-cloned strain). Production of the enzyme complies with FDA’s current good manufacturing practice (CGMP), hazard analysis, and risk-based preventive controls (HARPC) for human food regulations set forth in 21 C.F.R. Part 117. A detailed description of the manufacturing process, which was provided in GRN 68 and is incorporated herein, reflects the current process with the exception of minor changes made to improve process efficiency. See GRN 68 at Appendix I, located at page 13 of GRN 68.² As compared to the previous (conventional) technology, the hours of growth in the main fermentation step have decreased and the enzyme is now harvested at a slightly lower optical density. Additionally, the filtration process was optimized. Specifically, a new course-filtering step was added and the microfiltration steps now employ only the most ideal grade of diatomaceous earth.

Each raw material used in manufacturing lipase derived from *Penicillium camemberti* has an appropriate FDA regulatory status for its intended use and is of a grade suitable for use in producing food. In the future, should Amano choose to modify the raw materials or

² “Specifically identified data and information” are incorporated into Amano’s current GRAS notice by reference to GRN 68 as permitted under 21 C.F.R. § 170.215 (“Incorporation into a GRAS notice”). Amano’s GRN 68 is publicly available on FDA’s GRAS notice inventory at <https://www.accessdata.fda.gov/scripts/fdcc/index.cfm?set=GRASNotices&id=68> and also remains in CFSAN’s files as required for incorporation by reference under Section 170.215.

processing aids used in the production of the lipase enzyme preparation, the Company will ensure that all such components are safe and suitable for their intended use.

2.3 Specifications of the food-grade material

Specifications for the lipase enzyme are in keeping with the requirements of the Food Chemicals Codex (11th Edition) and Joint FAO/WHO Expert Committee on Food Additives (JECFA 2006) monographs for enzyme preparations used in food processing. **Table 3** below identifies the specifications for the lipase enzyme preparation.

Table 3. Specifications for the lipase enzyme preparation.

Item	Requirement	Lot No. LGSQ0552101GK	Lot No. LGSQ0750501GK	Lot No. LGSQ1151401GK
Lead	Not more than 5 mg/kg	0.042 mg/kg	0.037 mg/kg	0.047 mg/kg
Salmonella sp.	Negative, Not detected (ND), in 25 grams	ND in 25g	ND in 25g	ND in 25g
Total coliforms	Not more than 30 CFU/g	<10 CFU /g	<10 CFU /g	<10 CFU /g
Escherichia coli	Negative, Not detected (ND), in 25 grams	ND	ND	ND
Antimicrobial activity	Negative	Negative	Negative	Negative
Mycotoxins	No significant levels*	None detected	None detected	None detected

* Although nonpathogenic and nontoxigenic microorganisms are normally used in the production of enzymes used in food processing, several fungal species traditionally used as sources of enzymes are known to include strains capable of producing low levels of certain mycotoxins under fermentation conditions conducive to mycotoxin synthesis. According to JECFA specifications, the enzyme preparations derived from such fungal species should not contain toxicologically significant levels of mycotoxins that could be produced by these species. There are no concerns for mycotoxins in Amano’s lipase derived from *P. camemberti*. See Part 6.2 below mycotoxin screening of Lipase GS “Amano” 250G and page 6 of GRN 68 regarding mycotoxin screening of Lipase G “Amano” 50, which is incorporated by reference to this GRAS notice. Testing of Lot Nos. LGSQ0552101GK, LGSQ0750501GK, and LGSQ1151401GK showed no mycotoxins were detected at the respective limits of detection listed in Figure 4 below.

2.4 Data and information bearing on the physical or other technical effect

The mode of action of the enzyme is presented at Part 2.1(g) above. This GRAS notice does not otherwise include data and other information bearing on a physical or other technical effect because such data and other information are not necessary to demonstrate safety.

Part 3 – Dietary exposure

As described above in Part 1.4(b), the lipase enzyme preparation is used at levels ranging from 25 to 2,522 mg TOS/kg enzyme-modified food ingredient (EMC); 10 to 1,000 mg TOS/kg flavor ingredient; and 50 to 252 mg TOS/kg fat/oil ingredient.

For calculating the Estimated Daily Intake (EDI) of the lipase enzyme preparation, it is assumed that the maximum potential use levels described in Part 1.4(b) are always employed for each application. Furthermore, the calculation takes into account the expected level of each raw material (*i.e.*, ingredient using Amano’s lipase) in the finished food, and it is assumed that all the TOS will end up in the final food product. The maximum levels of TOS in finished foods are tabulated below.

Table 4. Maximum level of TOS per kilogram of finished food.

Application	Raw Material (RM)	Maximum Recommended Use Level (mg TOS/kg RM)	Final Food	Ratio RM/Final Food	Maximum Level in Final food (mg TOS/kg Food)
Dairy Processing	Enzyme Modified Cheese	2522	Soup, snack foods, processed cheese	0.02	50
Fats and Oil Processing	Edible fats and oils	252	Bread, pastry, and confections	0.3	76

Although the maximum possible level of Amano’s lipase would be 50 mg TOS kilogram in foods made with EMC produced using acylglycerol lipase, it is assumed that all foods and beverages contain 76 mg TOS per kilogram of food (which corresponds to the maximum level in bread, pastry, and confections, *i.e.*, the highest level for any food). Based on this exaggerative assumption, and applying FDA’s standard assumption that an average daily diet consists of 3 kilograms (kg) of food per day (including 1.5 kg of beverages) and body weight of 60 kg, the EDI for Amano’s lipase enzyme preparation is calculated to be:

$$3 \text{ kg/p/day} \times 76 \text{ mg TOS/kg food} \div 60 \text{ kg bw} = \mathbf{3.8 \text{ mg TOS/kg bw/day}}$$

This calculated EDI is highly conservative because of the following exaggerative assumptions:

- All producers of the above mentioned foods use ingredients made with the acylglycerol lipase from *Penicillium camemberti*;
- All producers employ the HIGHEST use level of lipase per application;
- All foods contain the HIGHEST theoretical amount of TOS found in any food;

- The amount of TOS does not decrease as a result of the food production process;
- A person consumes only foods containing the calculated theoretical amount of TOS daily over the course of a lifetime.
- A person consumes 3 kg of solid food per day (which potentially contains ingredients made with acylglycerol lipase), rather than 1.5 kg of solid food and 1.5 kg of beverages (which are not expected to contain ingredients made with acylglycerol lipase).

Part 4 – Self-limiting levels of use

This part does not apply

Part 5 – Experience based on common use in food before 1958

This part does not apply

Part 6 – Narrative

The information provided in Part 2 above on the identity, manufacturing process, and specifications of the lipase derived from *Penicillium camemberti* support Amano's view regarding the equivalence of the lipase derived from a genetically modified strain of *P. camemberti* (i.e., Lipase GS "Amano" 250G derived from *P. camemberti* AE-LGS, a self-cloned derivative of *P. camemberti* AE-LG) to the lipase from the non-genetically modified strain (i.e., Lipase G "Amano" 50 derived from *P. camemberti* AE-LG as described in GRN 68). The information regarding Lipase GS "Amano" 250G in Part 2 of this GRAS notice and the information in GRN 68 regarding Lipase G "Amano" 50, together with the dietary exposure estimate provided in Part 3 above and the information provided in this section on the safety of the production organisms and the safety of the enzyme, including its lack of allergenic and toxigenic potential, provide a basis for Amano's determination that its lipase enzyme preparation derived from *Penicillium camemberti* is GRAS for use in dairy processing, flavoring production, and fats and oil processing as discussed in detail below.

6.1 Safety of *Penicillium camemberti* production strains AE-LG and AE-LGS

Although the production organism is not present in the lipase enzyme preparation, Amano follows the best practice of using nonpathogenic organisms for the production of enzymes intended for use in food applications. *Penicillium camemberti* is well known for its long history of use as a secondary cheese culture for mold surface-ripened cheeses, where it can be used to give a white felt on the surface of Coulommier and Camembert type cheese, as reported by G. Stanley in Encyclopedia of Food Sciences and Nutrition (Second Edition), 2003. A literature search for published reports of health concerns associated with *P. camemberti* (conducted August 23, 2018) indicates no concerns for pathogenicity and possibly a low level of potential concern for workplace allergenicity, not related to dietary exposure. In this regard, as discussed at page 9 of GRN 68, Marchisio et al. (1999) reported a possible case of extrinsic allergic alveolitis caused by exposure of an employee in a salami manufacturing facility to *P. camemberti* by inhalation. After Amano's GRN 68 was provided to FDA in 2001, Merget et al. (2008) reported the details of an employee who experienced progressive work-related asthma, rhinitis, and contact urticaria after contact with mold-cured dry sausages and had specific antiglobulin E antibodies to *P. camemberti*. The circumstances and route of exposure for the reported cases of allergic reactions in workers after repeated contact with high levels of *P. camemberti* used in finishing dried sausages do not raise safety concerns for dietary exposure to low levels of an extracellular lipase enzyme preparation derived *P. camemberti* and not containing the production organism. As discussed in Part 6.3 below, there are no allergenicity concerns for the lipase enzyme preparation.

While *P. camemberti* strains AE-LG (i.e., U-150) and AE-LGS are not specifically known to have been used in cheese or dry sausage production, the fact that other *P. camemberti* strains have a long history of use in food production with no reports of infection supports the conclusion that the lipase production strains are not pathogenic. Further, a study showed no concerns for pathogenicity based on the histopathology analysis of mice 14 days after the injection into the tail vein of 10^2 , 10^4 , or 10^6 viable

spores of *P. camemberti* AE-LG. See page 6 of GRN 68, discussing the results of the pathogenicity testing reported by Kondo et al. (1994).

6.2 Safety of enzyme preparation from *Penicillium camemberti*

The pivotal safety data in concluding the intended use of Amano's lipase enzyme preparation is GRAS are from a 90-day toxicological study of Lipase G Amano 50 (LGK) in rats reported by Kondo et al. (1994), which was provided to FDA in GRN 68 (incorporated here by reference). No adverse toxicological data were located in an updated review of the toxicological literature conducted on August 23, 2018, aside from reports – discussed briefly below – which indicate that cyclopiazonic acid (CPA) is a mycotoxin of potential concern for some strains of *Penicillium camemberti* under certain environmental conditions.

Le Bars (1979) reported that each of 20 strains of *P. camemberti* isolated from cheese produced CPA at levels greatly dependent on the strain and environmental parameters (medium, temperature, and incubation time). Císarová M et al. (2012) reported that only 2 of 14 strains of *P. camemberti* isolated from samples of 20 different cheeses did not produce CPA under any conditions of the study and that production of CPA by the other 12 isolates varied by strain and was dependent on incubation temperature. No published data were located regarding production of CPA by *P. camemberti* U-150.

While there are no reports of illness linked to consumption of cheese with CPA produced by *P. camemberti*, acute toxicity is a recognized hazard for oral exposure to CPA. See PubChem, Open Chemistry Database, Compound Summary for CID 54682463, available at https://pubchem.ncbi.nlm.nih.gov/compound/cyclopiazonic_acid (accessed July 24, 2018). The toxic potency of CPA is moderate to high, *i.e.*, LD50 Rat oral 36 mg/kg and LD50 Mouse oral 64 mg/kg (see Lewis, R.J. *Sax's Dangerous Properties of Industrial Materials*. 9th ed. Volumes 1-3. New York, NY: Van Nostrand Reinhold, 1996., p. 973). Only one incident of human toxicity, however, has been potentially linked to the consumption of food possibly containing CPA. Namely, Rao and Husain (1985) reported on the detection of *Aspergillus flavus* and *Aspergillus tamaris* (two fungi known to produce CPA) in kodo millet associated with 'kodu poisoning' in humans and cattle in India. The possible link of human illness to CPA potentially present in food contaminated with two fungi that are not closely related to *P. camemberti* is not directly relevant to the safety analysis of the enzyme preparation derived from *P. camemberti*.

Based on an exhaustive review of the published research on CPA, Ostry et al. (2018) concluded:

CPA is a potentially serious mycotoxin and its toxicity to several animal species warrant further chronic toxicity and carcinogenicity studies. The results of chronic toxicity and carcinogenicity studies, recent consumption data, and the occurrence of CPA in foodstuffs are required for the assessment of toxicity severity and estimation of human dietary exposure and health risk assessment.

CPA was not detected in the enzyme preparations derived from *P. camemberti* AE-LG (i.e., U-150), as reported in GRN 68, or in *P. camemberti* AE-LGS, which was analyzed for a broad range of mycotoxins by high pressure liquid chromatography with fluorescence detection (HPLC/FD), liquid chromatography- tandem mass spectrometry (LC-MS/MS), or solid phase extraction (SPE) with LC-MS/MS with the results set forth in **Figure 4** below.

Figure 4. Mycotoxin screening of enzyme preparation derived from *Penicillium camemberti* AE-LGS.

Mycotoxin	Detection Method	Result*
Aflatoxin B1	HPLC/FD	<0.2 µg/kg
Aflatoxin B2	HPLC/FD	<0.2 µg/kg
Aflatoxin G1	HPLC/FD	<0.2 µg/kg
Aflatoxin G2	HPLC/FD	<0.2 µg/kg
Total Aflatoxin	NA	<0.8 µg/kg
Ochratoxin	HPLC/FD	<0.5 µg/kg
Deoxynivalenol (DON)	LC-MS/MS	<10.0 µg/kg
Fusarium (HT-2)	LC-MS/MS	<10.0 µg/kg
Trichothecene (T-2)	LC-MS/MS	<10.0 µg/kg
Zearalenone (ZON)	LC-MS/MS	<2.0µg/kg
Fumonisin FB1	SPE with LC-MS/MS	<5.0 µg/kg
Fumonisin FB2	SPE with LC-MS/MS	<5.0 µg/kg
Sterigmatocystin	LC-MS/MS	<10.0 µg/kg
Patulin	LC-MS/MS	<10.0 µg/kg
Cyclopiazonic acid (CPA)	LC-MS/MS	<7.5 µg/kg
Citrinin	LC-MS/MS	<7.5 µg/kg
Penicillic acid	LC-MS/MS	<7.5 µg/kg

* No mycotoxins were detected; results are reported as “<” the limits of detection stated.

In addition to no CPA (or other mycotoxins) being detected in Amano’s lipase from *P. camemberti*, the enzyme preparation also tested negative for antimicrobial activity. In this regard, Larsen and Knochel (1997) attributed antimicrobial activity by *P. camemberti*, which was found in 10 of 13 strains tested, to volatile compounds, including ethanol and 3-methylbutanol. Volatile compounds, if any, would be vaporized under the processing conditions in manufacture of the lipase and production of food ingredients made using the lipase.

The results of mycotoxin screening of the lipase enzymes (discussed above), in combination with the publicly available toxicological data, support Amano’s conclusion that lipases from *P. camemberti* AE-LG and AE-LGS are not known or expected to contain toxins, antibiotics, or other substances that are not suitable for use in food. In this regard, *P. camemberti* AE-LG has been used with no reports of safety issues for more than ten years to produce the lipase enzyme preparation as described in GRN 68. See FDA’s “No Questions” letter dated May 29, 2001. Further, toxicological testing reported by Kondo et al. (1994) of Lipase G Amano 50 (LGK) produced by the commercial

process without the final purification and dilution steps, as discussed at pages 5-6 of GRN 68, support Amano's determination that its lipase enzyme preparation derived from *P. camemberti* is not mutagenic and presents no safety concerns when used as intended.

The no-observed-adverse-effect level (NOAEL) for LGK (the concentrated enzyme) administered by gavage to Sprague-Dawley rats in the 90-day study (discussed in detail in GRN 68) was determined to be the high dose level, 2000 mg/kg body weight. Based on the total organic solids (TOS) content of the LGK (*i.e.*, 75.76%), the NOAEL for the lipase enzyme preparation may be expressed as 1515 mg/kg body weight TOS ($2000 \text{ mg/kg bw} \times 0.7576 = 1515 \text{ mg/kg bw}$). The safety margin between the NOAEL and the EDI for Amano's lipase (*i.e.*, 3.8 mg TOS/kg bw/day) is calculated to be 399-fold ($1515 \text{ mg/kg bw NOAEL} \div 3.8 \text{ mg TOS/kg bw/day} = 398.7$).

Safety margins greater than 100 support the conclusion that the toxicological data demonstrate the safety of the proposed uses for Amano's food production enzyme. Therefore, even with the conservative assumptions employed in estimating the daily intake of the enzyme, there are still adequate safety margins for potential dietary exposure to the enzyme when Amano's lipase derived from *P. camemberti* is used as intended in dairy processing, flavoring production, and fats and oil processing. Further, the lack of enzyme activity in the food ingredients further diminishes the risk of any toxicity as well.

6.3 No allergenicity concerns for enzyme preparation from *Penicillium camemberti*

In contrast to most known food allergens, which are naturally present in a narrow range of foods, a wide variety of enzyme classes (and structures), are naturally present in many foods. Further, enzymes have a long history of safe use in food processing, with no indication of adverse effects or reactions. Such is the case with acylglycerol lipase. Additionally, Amano found no matches in comparing the amino acid sequence of the acylglycerol lipase to the primary sequences of known allergens based on a search of the Structural Database of Allergenic Proteins, including a search for $\geq 35\%$ homology over a sliding "window" of 80 amino acids, and an exact match of 8 contiguous amino acids.

Regarding potential impurities, the manufacturing process for the subject lipase enzyme preparations employ standard materials that are routinely used in the enzyme industry. No target protein was detected at a maximum limit of detection of 1.4 ppm in representative batches of Lipase GS "Amano" 250G and Lipase G "Amano" 50 that were tested by enzyme-linked immunosorbent assay (ELISA) for ingredients used in production of the enzymes that contain protein derived from one of the "major food allergens" designated by the Food Allergen Labeling and Consumer Protection Act (FALCPA), *i.e.*, milk, eggs, fish, Crustacean shellfish, tree nuts, peanuts, wheat, and soybeans. Furthermore, the production media will be consumed by the microorganism as the nutrient in the fermentation process.

Additional indicators of a lack of allergenic potential for the lipase from *Penicillium camemberti* are noted as follows:

- Bindslev-Jensen *et al.* (2006) concluded that food allergy is not likely to be a concern regarding ingestion of food enzymes in general based on a study of enzymes produced by wild-type and genetically modified strains, as well as wild-type enzymes and Protein Engineered variants in 400 patients diagnosed with allergies to inhalation allergens, food allergens, bees, or wasps.
- An expert group convened by the Association of Manufacturers & Formulators of Enzyme Products (AMFEP), *i.e.*, the AMFEP Working Group on Consumer Allergy Risk from Enzyme Residues in Food, evaluated the existing scientific data and concluded that for exposure by ingestion, as opposed to exposure by inhalation, enzyme proteins are not potent allergens and sensitization to ingested enzymes is rare.
- Wüthrich (1996) published a list of enzymes that are often ingested daily over many years as digestive aids, at much higher amounts compared to enzymes present in food (up to 1 million times more), and concluded that such enzymes are not potent allergens by ingestion.

Thus, scientific data do not indicate that small amounts of enzymes in food can sensitize or induce allergic reactions in consumers. Additional considerations supporting the conclusion that allergenicity is not a concern for ingestion of enzymes in foods are outlined as follows:

- Most proteins are not food allergens and based on previous experience, the enzyme industry is not aware of any enzyme proteins used in food that are homologous to known food allergens.
- Whereas food enzymes are used in small amounts during food processing, resulting in very small amounts of the enzyme protein, if any, in the final food, we noted that a high concentration generally equals a higher risk of sensitization, whereas a low level in the final food equals a lower risk. *See e.g.*, Goodman *et al.* (2008) and the World Health Organization (WHO; 2001).
- Where proteins are denatured, as is lipase used to produce food or food ingredients in this case, the tertiary conformation of the enzyme molecule is destroyed, which is an alteration in protein conformation that is generally associated with a decrease in the antigenic reactivity in humans in the vast majority of investigated cases where denatured proteins are found to be much less immunogenic than the corresponding native proteins. *See e.g.*, Kikuchi *et al.* (2006), Nakazawa *et al.* (2005), Takai *et al.* (1997), and Valenta (2002a and 2002b).

6.4 Pariza and Johnson decision tree analysis

The enzyme preparation derived from *Penicillium camemberti* AE-LGS may be “accepted” for the intended use per an analysis using the Pariza and Johnson decision tree (Pariza and Johnson, 2001) as presented in **Figure 5** below.

Figure 5. Pariza and Johnson decision tree analysis of the lipase from *P. camemberti* AE-LGS

1. *Is the production strain genetically modified?*

YES; *Penicillium camemberti* AE-LG (U-150) (the recipient strain) was transformed using a protoplast method by the insertion of the lipase gene (mdIA) and a marker gene (pyrG, i.e., orotidine-5'-phosphate decarboxylase) from *Penicillium camemberti* AE-LG (U-150) (the donor strain), yielding the lipase production strain, *Penicillium camemberti* AE-LGS.

If yes, go to 2. If no, go to 6.

2. *Is the production strain modified using rDNA techniques?*

NO; *Penicillium camemberti* AE-LGS does not contain DNA from a different species (as it is self-cloned from *P. camemberti* AE-LG).

If yes, go to 3. If no, go to 5.

5. *Is the production strain sufficiently well characterized so that one may reasonably conclude that unintended pleiotropic effects, which may result in the synthesis of toxins or other unsafe metabolites, will not arise due to the genetic modification method that was employed?*

YES; the base production strain is non-pathogenic and non-toxicogenic. Moreover, the final enzyme product is highly purified, such that the production organism is not present. *Penicillium camemberti* is well known for its long history of safe use in cheese-making where it is used to give a white felt on the surface of Coulommier and Camembert type cheese, as reported by G. Stanley in Encyclopedia of Food Sciences and Nutrition (Second Edition), 2003. Further, traditional toxicological studies have been performed that support the safety of the product.

If yes, go to 6. If no, go to 7.

6. *Is the production strain derived from a safe lineage, as previously demonstrated by repeated assessment via this evaluation procedure?*

YES

*If yes, the test article is **ACCEPTED**. If no, go to 7.*

While the lipase enzyme preparation derived from *P. camemberti* may be considered safe (i.e., **ACCEPTED**) by analysis stopping at step 6 under the Pariza and Johnson decision tree, we note that the organism is not pathogenic (step 7), is free of antibiotics (step 8), is free of oral toxins so known to be produced by other members of the same species

(step 9, which leads to skipping step 10), and the NOAEL for the test article in an appropriate oral study is sufficiently high to ensure safety (step 11, which results in concluding the test article is ACCEPTED).

6.5 Conclusion

Based on the documentation provided in this GRAS notification, and as discussed above, Amano has concluded that its lipase enzyme preparation derived from *Penicillium camemberti* is GRAS via scientific procedures for use as a processing aid in (1) dairy processing (*i.e.*, the production of enzyme-modified cheese), (2) flavoring production (*i.e.*, production of flavor ingredients for a wide variety of foods and drinks), and (3) fats and oil processing (*i.e.*, the production of ingredients derived from fats and oils including, but not limited to, gamma linolenic acid (GLA), docosahexaenoic acid (DHA), and eicosapentaenoic acid (EPA)).

Part 7 – List of supporting data and information

7.1 References

Amano Enzyme Inc., GRN 68, Lipase from *Penicillium camembertii*, filed January 31, 2001, closed with “no questions” from FDA on May 29, 2001.

Císarová M, Tančinová D, Barboráková Z, Mašková Z, Felšöciová S, Kučerková V (2012) Potential production of cyclopiazonic acid by *Penicillium camemberti* strains isolated from Camembert type cheese. *Journal of Microbiol, Biotechnol and Food Science*, 2(2) 434-445.

FDA’s Final Rule, 60 Fed. Reg. 36595 (July 17, 1995).

Kondo M, Ogawa T, Matsubara Y, Mizutani A, Murata S, Kitagawa M (1994) Safety evaluation of lipase G from *Penicillium camembertii*, *Fd Chem Toxic*; 32(8) 685-696.

Larsen AG and Knochel S (1997) Antimicrobial activity of food-related *Penicillium* sp. against pathogenic bacteria in laboratory media and a cheese model system. *Journal of Applied Microbiology*; 83, 111–119.

Le Bars J (1979) Cyclopiazonic acid production by *Penicillium camemberti* Thom and natural occurrence of this mycotoxin in cheese. *Appl Environ Microbiol*; 38(6):1052-5.

Marchisio VF, Sulotto F, Botta GC, Chiesa A, Airaudi D, Anastasi A (1999) Aerobiological analysis in a salami factory: a possible case of extrinsic allergic alveolitis by *Penicillium camemberti*. *Med Mycol*;37:285–289.

Merget R, Sander I, Rozynek P, Heinze E, Imoehl M, Raulf-Heimsoth M, Bruening T (2008) Occupational Immunoglobulin E-Mediated Asthma due to *Penicillium camemberti* in a Dry-Sausage Packer. *Respiration*; 76:109-111.

Ostry V, Toman J, Grosse Y, Malir F (2018) Cyclopiazonic acid: 50th anniversary of its discovery. *World Mycotoxin Journal*; 11 (1): 135-148.

Rao LB, Husain A (1985) Presence of cyclopiazonic acid in kodo millet (*Paspalum scrobiculatum*) causing kodua poisoning in man and its production by associated fungi. *Mycopathologia* 89: 177-180.

Stanley G. (2003) “Cheeses | Starter Cultures Employed in Cheese-Making,” *Encyclopedia of Food Sciences and Nutrition* (Second Edition).

7.2 Tables

Table 1 Comparison of TOS content of lipases derived from *P. camemberti* AE-LG and *P. camemberti* AE-LGS (self-cloned from *P. camemberti* AE-LG).

Table 2 Specifications for the lipase enzyme preparation.

Table 3 Maximum level of TOS per kilogram of finished food.

7.3 Figures

Figure 1 Amino acid sequence of lipase from *Penicillium camemberti*

Figure 2 SDS-PAGE analysis of lipases derived from *P. camemberti* AE-LG and *P. camemberti* AE-LGS (self-cloned from *P. camemberti* AE-LG).

Figure 3 Optimum temperature, temperature stability, pH stability, and optimum pH of lipases derived from *P. camemberti* AE-LG and *P. camemberti* AE-LGS (self-cloned from *P. camemberti* AE-LG).

Figure 4 Mycotoxin screening of enzyme preparation derived from *Penicillium camemberti* AE-LGS

Figure 5 Pariza and Johnson decision tree analysis of lipase from *Penicillium camemberti*