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(54) Title: STABILIZATION OF ASPARAGINASE

(57) Abstract: The present invention relates to stabilization of asparaginase enzymes.

STABILIZATION OF ASPARAGINASE

REFERENCE TO SEQUENCE LISTING

This application contains a Sequence Listing in computer readable form. The computer readable form is incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to stabilization of asparaginase enzymes.

BACKGROUND OF THE INVENTION

Any discussion of the prior art throughout the specification should in no way be considered as an admission that such prior art is widely known or forms part of common general knowledge in the field.

It is well known that formation of acrylamide in heated food products can be reduced by reducing the amount of asparagine in the food materials, such as by subjecting the food materials to the action of the enzyme asparaginase (see, e.g., WO2004/026043 (The Procter & Gamble Company)).

For some applications, to fit into the production line of specific food products, the asparaginase treatment should preferentially take place at a relatively high temperature. But asparaginase enzymes may not be stable at the industries' preferred temperatures to apply for the enzyme treatment. Also, asparaginase enzymes may not be stable even at lower temperatures, e.g., when being diluted or when being used continuously, such as for continuous or batch-wise dipping or incubation of potato pieces in asparaginase solution during the production of sliced potato chips or french fries.

The present invention relates to means of stabilizing asparaginase enzymes, especially at high temperatures or when being diluted or when being used continuously.

It is an object of the present invention to overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

SUMMARY OF THE INVENTION

The present inventors have surprisingly found that asparaginase enzymes are more stable at low pH. In particular, asparaginase enzymes are more thermostable at low pH. Therefore, the addition of an acid, such as sodium acid pyrophosphate, monopotassium phosphate or citric acid, to an aqueous solution of asparaginase improves the stability of the enzyme, such as its stability at high temperature, or its stability when being diluted.

Therefore, the invention in one aspect relates to a method for producing a heat-treated food product comprising:

- a) contacting at a temperature of at least 42°C an intermediate form of said food product with asparaginase at a pH which is lower than about pH 6.5,
- b) incubating the intermediate form of the food product for at least 1 minute, and
- c) processing the intermediate form of the food product to obtain the heat-treated food product, wherein the processing comprises heating.

In a further aspect, the present invention provides a method of producing a heat-treated vegetable-based food product comprising:

- a) contacting at a temperature of at least 42°C an intermediate form of said food product with asparaginase at a pH which is lower than about pH 6.5,
- b) incubating the intermediate form of the food product for at least 1 minute, and
- c) processing the intermediate form of the food product to obtain the heat-treated food product, wherein the processing comprises heating;

wherein the contacting in step a) is performed by

- i) the intermediate form of the food product being sprayed with, dipped in or incubated in a solution comprising asparaginase and at least one acid or salt selected among sodium acid pyrophosphate, monopotassium phosphate, citric acid, lactic acid, acetic acid, ascorbic acid, monocalcium phosphate and potassium bitartrate, or
- ii) the intermediate form of the food product being blended with asparaginase and at least one acid or salt selected among sodium acid pyrophosphate, monopotassium phosphate, citric acid, lactic acid, acetic acid, ascorbic acid, monocalcium phosphate and potassium bitartrate.

In a further aspect, the present invention provides a heat-treated vegetable-based food product when prepared by the method according to the present invention.

Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise”, “comprising”, and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to”.

In a preferred embodiment, the contacting in step a) is performed by dipping or incubating the intermediate form of the food product into a solution comprising asparaginase. In an industrial process, such asparaginase solution will typically be reused, e.g., in a continuous process, and therefore enzyme stability is an extremely important parameter. Therefore, the method of the invention is particularly relevant in such processes, as declining asparaginase activity in the solution is presently a problem because of the industries' preferred high temperature, which may be further increased by continuous dipping/incubation of warm intermediate food products, combined with long usage time of the same solution and perhaps leakage of substance from the intermediate food products, such as from potato slices or blanched potato strips. In such applications, an asparaginase solution having a low pH according to the method of the present invention is a huge advantage as it extends the stability of the asparaginase significantly.

In another aspect, the invention relates to an enzyme granulate comprising asparaginase at a concentration of at least 100 ASNU per gram and having a pH which is lower than about pH 6.

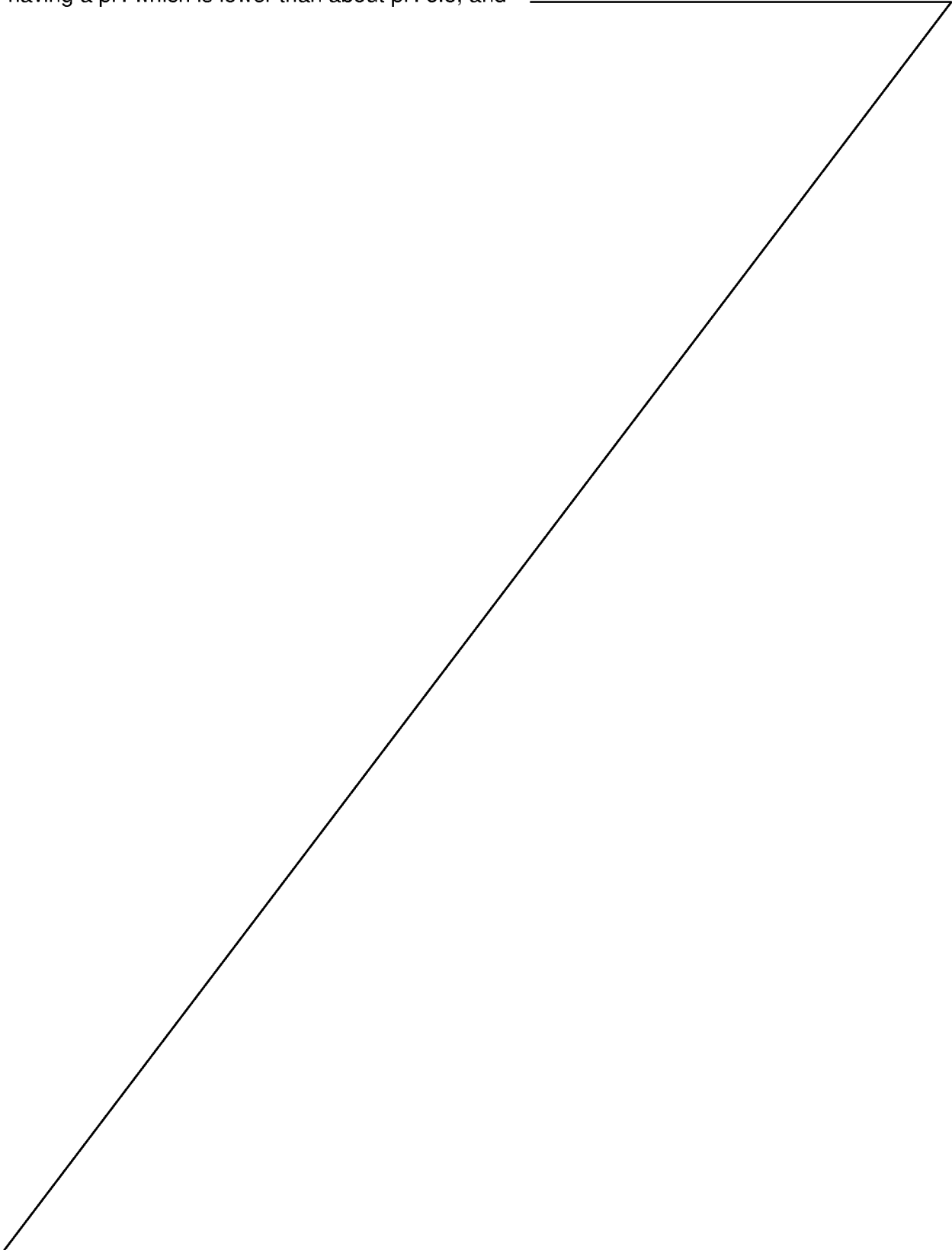
In another aspect, the invention relates to a method for producing an enzyme granulate comprising asparaginase, which method comprises:

- a) making an aqueous solution comprising asparaginase and having a pH which is lower than about pH 6, and
- b) formulating said aqueous solution into an enzyme granulate.

In another aspect, the invention relates to an aqueous stock solution comprising asparaginase at a concentration of 100-2,000 ASNU per gram and having a pH which is lower than about pH 6.5.

In yet another aspect, the invention relates to a method for diluting or dissolving a concentrated composition of asparaginase for applying it into an industrial process, which comprises:

a) diluting or dissolving a concentrated composition comprising asparaginase at a concentration of at least 2,000 ASNU per gram into a stock solution comprising less than half of the asparaginase activity per gram as compared to the concentrated composition and having a pH which is lower than about pH 6.5, and _____



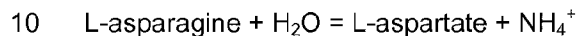
b) applying the stock solution into the industrial process.

These and other aspects of the present invention are further described in the following.

5 DETAILED DESCRIPTION OF THE INVENTION

Asparaginase

An asparaginase according to the present invention may be an enzyme which is defined according to standard enzyme EC-classification as EC.3.5.1.1 and which catalyzes the following reaction:



The asparaginase may be a microbial asparaginase, e.g., an asparaginase derived from a bacterium, an archaeon or a fungus. The asparaginase may, e.g., be derived from *Archaea*, *Erwinia chrysanthemii*, *Saccharomyces cerevisiae*, *Candida utilis*, *Escherichia coli*, *Aspergillus oryzae*,
15 *Aspergillus nidulans*, *Aspergillus niger*, *Aspergillus fumigatus*, *Fusarium graminearum*, or *Penicillium citrinum*.

In a preferred embodiment, an asparaginase according to the present invention is derived from *Aspergillus*.

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An asparaginase according to the present invention may have the amino acid sequence shown as SEQ ID NO:1 or an amino acid sequence having at least 50%, at least 60%, at least 70%, at least 80%, at least 90% or at least 95% identity to SEQ ID NO:1. Such an asparaginase may preferably be derived from *Aspergillus oryzae* or *Aspergillus niger*, most preferably from *Aspergillus oryzae*.

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For purposes of the present invention, the degree of identity between two amino acid sequences may be determined using the Needleman-Wunsch algorithm (Needleman and Wunsch, 1970, J. Mol. Biol. 48: 443-453) as implemented in the Needle program of the EMBOSS package (EMBOSS: The European Molecular Biology Open Software Suite, Rice et al., 2000, Trends in Genetics 16: 276-277), preferably version 3.0.0 or later. The optional parameters used are gap open penalty of 10, gap extension penalty of 0.5, and the EBLOSUM62 (EMBOSS version of BLOSUM62) substitution matrix. The output of Needle labeled "longest identity" (obtained using the -nobrief option) is used as the percent identity and is calculated as follows:

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35 $(\text{Identical Residues} \times 100) / (\text{Length of Alignment} - \text{Total Number of Gaps in Alignment})$

An asparaginase according to the present invention may be a tetramer in its most active form.

Method for producing a food product

As mentioned above, the invention in one aspect relates to a method for producing a heat-treated food product comprising:

- 5 a) contacting at a temperature of at least 42°C, preferably at least 45°C, at least 50°C or at least 55°C, more preferably at least 60°C, at least 62°C or at least 65°C, an intermediate form of said food product with asparaginase at a pH which is lower than about pH 6.5,
- b) incubating the intermediate form of the food product for at least 1 minute, and
- 10 c) processing the intermediate form of the food product to obtain the heat-treated food product, wherein the processing comprises heating.

Preferably, the incubation in step b) is performed for at least 5 minutes, more preferably for 7-15 minutes.

- 15 In a preferred embodiment, the heat-treated food product is a vegetable-based food product. Preferably, such vegetable-based food product is derived from a vegetable tuber or root such as, but not limited to, the group consisting of potato, sweet potato, yams, yam bean, parsnip, parsley root, Jerusalem artichoke, carrot, radish, turnip, and cassava. A preferred food product produced by the method of the invention is a potato product. A more preferred food product
- 20 produced by the method of the invention is french fries or sliced potato chips. Another more preferred food product produced by the method of the invention is a food product comprising potato granules or potato flakes, e.g., potato-based snacks.

- The intermediate form of a food product to be produced by a method of the invention is any in-
- 25 termediate form which is to be applied to a heat treatment before the final heat-treated food product is obtained. E.g., if the heat-treated food product is french fries, an intermediate form may be the potato strips at any time before the final fry. Alternatively, if the final frying is to be done by the consumer, e.g., at a restaurant or at home, the heat-treated food product produced by the method of the invention is the par-fried french fries, and an intermediate form may be the
- 30 potato strips at any time before the par-frying. If the heat-treated food product is sliced potato chips, an intermediate form may be the sliced potatoes at any time before the final fry. If the heat-treated food product is potato-based snacks made from potato granules or potato flakes, an intermediate form of the food product may be cooked mashed potatoes which are to be processed into potato granules or potato flakes to be used for production of the snacks, or it
- 35 may be a dough or pieces of dough comprising potato granules or potato flakes. If the heat-treated food product is a dough-based baked food product, e.g., bread, or a dough-based fried food product, e.g., tortilla chips, an intermediate form may be the dough or pieces of the dough

at any time before the final baking or the final fry.

In a preferred embodiment, the heat-treated food product is par-fried french fries and an intermediate form of the food product is blanched potato strips at any time before par-frying. In another preferred embodiment, the heat-treated food product is sliced potato chips and an intermediate form of the food product is sliced potatoes at any time before the final fry. In another preferred embodiment, the heat-treated food product is potato-based snacks made from potato granules or potato flakes, and an intermediate form of the food product is cooked mashed potatoes which are to be processed into potato granules or potato flakes to be used for production of the snacks.

The contacting of the intermediate form of the food product with asparaginase at a pH which is lower than about pH 6.5 may be performed by incubation or dipping of the intermediate form of the food product into a solution comprising asparaginase enzyme and having a pH which is lower than about pH 6.5. In that case, the contacting in step a) and the incubating in step b) may be performed as one step, where the intermediate form of the food product is incubated in said solution for at least 1 minute. Such incubation may be longer, e.g., at least 5 minutes, at least 10 minutes, at least 15 minutes, at least 20 minutes or at least 30 minutes.

Alternatively, the dipping or incubation into the solution may be for a shorter time followed by drying of the intermediate form of the food product, e.g., in a drying oven. In that case, the drying step may be important for the asparaginase to work and therefore, if the dip is short, the incubation step b) in the method of the invention may be the drying of the intermediate form of the food product. Such short dipping or incubation into the solution may be, e.g., for between 2 seconds and 1 minute, such as for about 5 seconds, for about 10 seconds, for about 30 seconds or for about 45 seconds. Or the dipping may only be a very short dip with no incubation.

Alternatively, the contacting in step a) may be performed by spraying the intermediate form of the food product at a temperature of at least 42°C with a solution comprising asparaginase and having a pH which is lower than about pH 6.5, followed by incubation, e.g., in a drying oven for at least 1 minute, preferably for at least 5 minutes, more preferably for at least 10 minutes.

The drying may be performed, e.g., at an air temperature of above 60°C, preferably above 70°C, and more preferably of above 80°C, such as at a temperature of about 85-90°C. Alternatively, drying may be performed at lower temperature, e.g., at 40-45°C. Drying may also be performed at any other temperature, e.g., at 45-60°C. Drying may be performed, e.g., for between 5 and 30 minutes. Drying may be performed in an oven where temperature, humidity and/or air

flow can be adjusted to the level(s) desired.

As mentioned above, the incubation step b) in a method of the invention may be the drying of the intermediate form of the food product. It may also be, though, that the intermediate form of the food product is incubated with the enzyme before optionally being dried. The incubation step
5 b) may be any step in the manufacturing process of the heat-treated food product where the asparaginase enzyme is active and in contact with the intermediate form of the food product.

In a preferred embodiment, a solution comprising asparaginase and having a pH which is lower
10 than about pH 6.5 to be used in various embodiments of the method of the invention, i.e. a solution wherein the intermediate form of the food product is dipped and/or incubated or a solution which is sprayed onto the intermediate form of the food product, comprises asparaginase at a concentration of 1,000-50,000 ASNU per litre, preferably 2,000-20,000 ASNU per litre, more preferably 3,000-15,000 ASNU per litre and most preferably 4,000-10,000 ASNU per litre.

15 An asparaginase unit (ASNU) is defined as the amount of enzyme needed to generate 1.0 micromole of ammonia from hydrolysing asparagine in 1 minute at 37°C and pH 7.0. The concentration of asparagine when determining the activity may be 9.6 mg/ml.

20 In a preferred embodiment, a solution comprising asparaginase and having a pH which is lower than about pH 6.5 to be used in various embodiments of the method of the invention, i.e. a solution wherein the intermediate form of the food product is dipped and/or incubated or a solution which is sprayed onto the intermediate form of the food product, comprises at least one acid selected among sodium acid pyrophosphate, monopotassium phosphate, citric acid, lactic acid,
25 acetic acid, ascorbic acid, monocalcium phosphate and potassium bitartrate. Such acid or acids, optionally in combination with other acids, are to be present in the solution in sufficient amount so that the solution has a pH which is lower than about pH 6.5. Alternatively, corresponding bases can be used and pH adjusted as desired using the relevant mixes of acids and corresponding salts or another acid.

30 Preferably, the solution has a pH which is below pH 6.5. In one preferred embodiment, the solution has a pH which is lower than about pH 6, such as a pH which is below pH 6. In another preferred embodiment, the solution has a pH which is lower than about pH 5.8, such as a pH which is below pH 5.8. In another preferred embodiment, the solution has a pH which is lower than
35 about pH 5.7, such as a pH which is below pH 5.7. In another preferred embodiment, the solution has a pH of about pH 5.5.

Sodium acid pyrophosphate ($\text{Na}_2\text{H}_2\text{P}_2\text{O}_7$) is also sometimes referred to as SAPP or disodium pyrophosphate. Monopotassium phosphate (KH_2PO_4) is also sometimes referred to as potassium dihydrogen phosphate, KDP, or monobasic potassium phosphate, MKP. Potassium bitartrate ($\text{KC}_4\text{H}_5\text{O}_6$) is also sometimes referred to as potassium hydrogen tartrate or cream of tartar.

5 Monocalcium phosphate ($\text{Ca}(\text{H}_2\text{PO}_4)_2$) is also sometimes referred to as calcium acid phosphate.

If the intermediate form of the food product is a dough, the dough may be contacted with asparaginase at a pH which is lower than about pH 6.5 by adding asparaginase and any appropriate acid to a liquid ingredient of the dough which is then mixed into the dry ingredients to form the

10 dough, or the asparaginase and an appropriate acid, optionally in a solution, may be added directly to the dry ingredients of the dough before mixing these with the liquid ingredient(s), or the asparaginase and an appropriate acid, optionally in a solution, may be added to the dough or some pre-form of the dough after the dry ingredients or part of the dry ingredients have been mixed with liquid. The asparaginase and the acid do not have to be added to the dough or to

15 ingredients of the dough at the same time and/or from the same solution. It is preferred, though, that the acid is added before or at the same time as the asparaginase. An appropriate acid may be, e.g., at least one acid selected among sodium acid pyrophosphate, monopotassium phosphate, citric acid, lactic acid, acetic acid, ascorbic acid, monocalcium phosphate and potassium bitartrate. The incubation in step b) may take place, e.g., while the dough is being further processed or while the dough is resting.

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In a preferred embodiment, the intermediate form of the food product comprises cooked mashed potatoes. In a more preferred embodiment, the intermediate form of the food product is cooked mashed potatoes. Such cooked mashed potatoes have optionally been cooled. When

25 being contacted with the asparaginase at a pH which is lower than about pH 6.5, such cooked mashed potatoes may have a temperature of at least 42°C , preferably at least 45°C , at least 50°C or at least 60°C , more preferably at least 70°C , at least 75°C or at least 80°C .

Preferably, when the contacting in step a) is performed by blending asparaginase into the intermediate form of the food product at a pH which is lower than about pH 6.5, the concentration of asparaginase in the intermediate form of the food product is 100-10,000 ASNU per kg dry matter, more preferably 250-8,000 ASNU per kg dry matter, more preferably 500-7,500 ASNU per kg dry matter and most preferably 1,000-5,000 ASNU per kg dry matter. Preferably, when the contacting in step a) is performed by blending asparaginase into the intermediate form of

30 the food product, the intermediate form of the food product has a pH which is below pH 6.5. In one preferred embodiment, the intermediate food product has a pH which is lower than about pH 6, such as a pH which is below pH 6. In another preferred embodiment, the intermediate

form of the food product has a pH which is lower than about pH 5.8, such as a pH which is below pH 5.8. In another preferred embodiment, the intermediate form of the food product has a pH which is lower than about pH 5.7, such as a pH which is below pH 5.7. In another preferred embodiment, the solution has a pH of about pH 5.5.

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In step c) in the method of the invention, the intermediate form of the food product is processed to obtain the heat-treated food product, wherein the processing comprises heating. Preferably, such heating is performed by frying or by baking. In a preferred embodiment, the heat-treated food product is par-fried french fries where the heating in step c) is a par-frying, optionally followed by freezing and packing. In that case, the final frying may be done by the consumer, e.g. at a restaurant or at home.

The processing according to step c) may also comprise other steps. If, for example, the intermediate form of the food product is cooked mashed potatoes which are to be processed into potato granules or potato flakes to be used for production of, e.g., potato-based snacks, the cooked mashed potatoes may following step a) and b) be dehydrated, e.g. by drying, and further processed to granules or flakes, and the granules or flakes may later be applied in the production of potato-based snacks. In this example, the heat-treated food product is the potato-based snacks and the heating in step c) is the frying or baking of these.

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In the preferred embodiment where the contacting in step a) is performed by dipping or incubating the intermediate form of the food product into a solution comprising asparaginase, enzyme stability is an extremely important parameter. In an industrial process, such enzyme solution will be reused. I.e., only a small fraction of the asparaginase will stick to the intermediate form of the food product after the dipping or incubation, whereas most of the asparaginase will remain in the solution. Thus the same enzyme solution may be used over a longer time period for the dipping or incubation of a large quantity of intermediate food product, such as, e.g., potato slices or blanched potato strips for the production of sliced potato chips or french fries. In such process, the method of the present invention is particularly relevant, as declining asparaginase activity in the solution is presently a problem because of the industries' preferred high temperature, which is in part caused by a wish to avoid microbial growth, and which may be further increased by continuous dipping/incubation of warm intermediate food products, combined with long usage time and perhaps leakage of substance from the intermediate food products, such as from potato slices or blanched potato strips. In such applications, an asparaginase solution having a low pH according to the method of the present invention is a huge advantage as it extends the stability of the asparaginase significantly.

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Therefore, in a more preferred embodiment, the contacting in step a) is performed by dipping or incubating the intermediate form of the food product into a solution comprising asparaginase and having a pH which is lower than about pH 6.5, and the intermediate form of the food product is subsequently essentially separated from the asparaginase solution. In this context, essentially separated means that the intermediate form of the food product after the dipping/incubation retains at most 10%, such as 4-5%, (wt./wt.) sticking moisture. I.e., the weight of the intermediate food product is increased by at most 10%, such as by 4-5%, because of asparaginase solution sticking to it after the dipping/incubation. Preferably according to this embodiment, the asparaginase solution is used for continuous or batch-wise dipping or incubation. Continuous or batch-wise dipping or incubation in this context means that the same asparaginase solution is used for the dipping or incubation of more than one batch of the food product in its intermediate form. Preferably, the intermediate form of the food product is potato slices or blanched potato strips, and one litre of the asparaginase solution is used for the treatment of at least 2 kg potato substance, more preferably at least 5 kg, and even more preferably at least 10 kg.

In another more preferred embodiment, the contacting in step a) is performed by dipping or incubating the intermediate form of the food product into a solution comprising asparaginase and having a pH which is lower than about pH 6.5, and the asparaginase solution is buffered such that pH is kept below 6.5 after the dipping or incubation of at least 2 kg, preferably at least 5 kg, more preferably at least 10 kg, of food product in its intermediate form per litre of asparaginase solution. Preferably in this embodiment, the intermediate form of the food product is potato slices or blanched potato strips.

In the following, a solution comprising asparaginase and having a pH which is lower than about pH 6.5 is sometimes referred to as an acidic asparaginase solution.

In a typical industrial production of french fries, potatoes are initially washed, sorted, steam peeled and cut. Following cutting, the potato strips are blanched in 2 to 3 sequential steps typically at 65-85°C for 10-30 min. Blanching is done to inactivate the endogenous enzymes in the potato, to partially cook the potato and to leach out reducing sugars to prevent excessive browning of the final product. After blanching, the potato strips may quickly be dipped, e.g. for 30-60 seconds, in a warm phosphate salt solution, e.g. a warm solution of sodium acid pyrophosphate, to prevent greying of the final product. The dip is optionally combined with a dip in glucose to control the final colour. The potatoes may be dried in a drier with hot circulating air at 75-95°C for 5-20 minutes giving a weight loss of 5-25%. Or they may be dried at a lower temperature, e.g., at 40-45°C, in which case the weight loss will be lower. Finally, the potato strips

are par-fried before being quick-frozen and packed. Final frying is done at the restaurant or by consumers.

5 A french fry production method according to the present invention may be performed as described above, except that the intermediate form, i.e., the potato strips, are at some point before the par-frying contacted at a temperature of at least 42°C with an acidic asparaginase solution, such as a solution comprising asparaginase and an acid, preferably sodium acid pyrophosphate or monopotassium phosphate, and incubated for at least 1 minute, preferably for at least 5 minutes. Such contacting and incubation may, e.g., be performed following blanching. I.e., for example after blanching, the potato strips are contacted at a temperature of at least 42°C with an acidic asparaginase solution and incubated for at least 1 minute, preferably for at least 5 minutes. The contacting of the potato strips with the acidic asparaginase solution may be performed by incubation or dipping of the potato strips into a solution comprising asparaginase and, e.g., sodium acid pyrophosphate in one dip bath, and the incubation for at least 1 minute, preferably for at least 5 minutes, may be performed either in the dip bath or in a following optional drying step, preferably for 7-15 min. Or the contacting may be performed by spraying the potato strips with an acidic asparaginase solution at a temperature of at least 42°C followed by incubation in a drier as described above for the typical industrial production of french fries. Following dipping/incubation in or spraying with the acidic asparaginase solution and optionally drying, the potato strips may be par-fried, quick-frozen and packed as described above. The potato strips may optionally be dipped in a glucose solution, e.g. before the contacting and incubation with the acidic asparaginase solution. Alternatively, glucose may be included in the acidic asparaginase solution, so that the potato strips are contacted with asparaginase, glucose and acid such as sodium acid pyrophosphate at the same time.

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In a typical industrial production of potato flakes, cooked mashed potato is dried on a drum drier with applicator rolls. The dried sheet is then ground into flakes and packed. Such flakes may be applied in the production of heat-treated potato-based food products, e.g., potato-based snacks. To introduce an asparaginase treatment in this process, the cooked mash must be cooled down sufficiently to not inactivate the enzyme. However, if the cooked mash is contacted with the asparaginase at acidic pH according to the method of the present invention, the asparaginase will be stabilized and less cooling required before addition of the enzyme. To accommodate asparaginase action, the mash may be held for a time of 5-25 minutes after it has been contacted with the asparaginase at a pH which is lower than about pH 6.5.

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In a typical industrial production of potato granules, cooked mashed potatoes of approximately 80% moisture are mixed with previously dried granules (often referred to as add-back) to give a

moist mix, which after holding and drying can be granulated to a fine powder. The mix which has around 25-30% moisture is conditioned at 25-40°C for 0.3-1 hour. It is then dried to 6-10% moisture and screened. 10-15% of the product is removed and packed, the remainder used as add-back. Utilizing the time during conditioning for asparaginase treatment is optimal. However, as above, the cooked mash must be cooled down sufficiently to not inactivate the enzyme. Performing the asparaginase treatment at a pH which is lower than about pH 6.5 will improve enzyme stability and allow for enzyme addition at higher temperatures.

Potato granules or potato flakes to be applied for production of heat-treated food products, which are made from cooked mashed potatoes having been contacted and incubated with asparaginase at a pH which is lower than about pH 6.5 according to the method of the present invention, may still comprise active enzyme when packed. In that case, when such granules or flakes are used, e.g. in a dough, the asparaginase may still be active in the dough. Therefore, in addition to the incubation in the cooked potato mash before drying, further incubation with the asparaginase may take place in the dough before frying or baking to produce the potato-based snacks.

In another aspect, the present invention relates to a method for producing a heat-treated food product comprising:

- a) contacting at a temperature of at least 42°C, preferably at least 45°C, at least 50°C or at least 55°C, more preferably at least 60°C, at least 62°C or at least 65°C, an intermediate form of said food product with asparaginase in the presence of an inorganic salt of phosphate or pyrophosphate,
- b) incubating the intermediate form of the food product for at least 1 minute, and
- c) processing the intermediate form of the food product to obtain the heat-treated food product, wherein the processing comprises heating.

Preferably, the incubation in step b) is performed for at least 5 minutes.

In the context of the present invention, an inorganic salt of phosphate or pyrophosphate may be any inorganic salt of phosphate or pyrophosphate including any salt of PO_4^{3-} , HPO_4^{2-} , H_2PO_4^- and $\text{P}_2\text{O}_7^{4-}$. Suitable examples may, e.g., be K_3PO_4 , K_2HPO_4 , KH_2PO_4 , Na_3PO_4 , Na_2HPO_4 , NaH_2PO_4 , $(\text{NH}_4)_3\text{PO}_4$, $(\text{NH}_4)_2\text{HPO}_4$, $(\text{NH}_4)\text{H}_2\text{PO}_4$, $\text{K}_4\text{P}_2\text{O}_7$, $\text{K}_3\text{HP}_2\text{O}_7$, $\text{K}_2\text{H}_2\text{P}_2\text{O}_7$, $\text{KH}_3\text{P}_2\text{O}_7$, $\text{Na}_4\text{P}_2\text{O}_7$, $\text{Na}_3\text{HP}_2\text{O}_7$, $\text{Na}_2\text{H}_2\text{P}_2\text{O}_7$, $\text{NaH}_3\text{P}_2\text{O}_7$, $(\text{NH}_4)_4\text{P}_2\text{O}_7$, $(\text{NH}_4)_3\text{HP}_2\text{O}_7$, $(\text{NH}_4)_2\text{H}_2\text{P}_2\text{O}_7$, $(\text{NH}_4)\text{H}_3\text{P}_2\text{O}_7$. However, this aspect of the invention is not limited to the salts of phosphate or pyrophosphate listed here.

In a preferred embodiment, the inorganic salt of phosphate or pyrophosphate is an acidic salt.

In a more preferred embodiment, the inorganic salt of phosphate or pyrophosphate is sodium acid pyrophosphate or monopotassium phosphate. In a more preferred embodiment, the inorganic salt of phosphate or pyrophosphate is sodium acid pyrophosphate.

In a preferred embodiment, the heat-treated food product is a vegetable-based food product. Preferably, such vegetable-based food product is derived from a vegetable tuber or root such as, but not limited to, the group consisting of potato, sweet potato, yams, yam bean, parsnip, parsley root, Jerusalem artichoke, carrot, radish, turnip, and cassava. A preferred food product produced by the method of the invention is a potato product. A more preferred food product produced by the method of the invention is french fries or sliced potato chips. Another more preferred food product produced by the method of the invention is a food product comprising potato granules or potato flakes, e.g. potato-based snacks.

Preferably, the inorganic salt of phosphate or pyrophosphate is present at a concentration which stabilizes the asparaginase. More preferably, the inorganic salt of phosphate or pyrophosphate is present at a concentration which stabilizes the asparaginase at high temperature, e.g. 42°C, 45°C, 50°C, 55°C, 60°C, 62°C or 65°C.

“Stabilizes the asparaginase” in the context of the present invention may mean that the half-life of the asparaginase is extended by at least a factor of 1.5, preferably by at least a factor of 2, more preferably by at least a factor of 3, and even more preferably by at least a factor of 5, when the inorganic salt of phosphate or pyrophosphate is present as compared to when it is not.

Half-life in the context of the present invention is the time after which the activity of the enzyme is reduced by 50% when being incubated under the relevant conditions. It may be determined as described in the Examples of the present application.

In a preferred embodiment, the contacting in step a) is performed by spraying a solution comprising asparaginase and an inorganic salt of phosphate or pyrophosphate onto the intermediate form of the food product.

In another preferred embodiment, the contacting in step a) is performed by dipping or incubating the intermediate form of the food product into a solution comprising asparaginase and an inorganic salt of phosphate or pyrophosphate.

In another preferred embodiment, the incubating in step b) is performed by drying the intermediate form of the food product at an air temperature of above 50°C.

- 5 In another preferred embodiment, the contacting in step a) and the incubating in step b) is performed as one step, where the intermediate form of the food product is incubated in a solution comprising (i) asparaginase and (ii) an inorganic salt of phosphate or pyrophosphate for at least 1 minute.
- 10 Preferably, such solution wherein the intermediate form of the food product is dipped and/or incubated, or which is sprayed onto the intermediate form of the food product, comprises asparaginase at a concentration of 1,000-50,000 ASNU per litre, more preferably 2,000-20,000 ASNU per litre, even more preferably 3,000-15,000 ASNU per litre and most preferably 4,000-10,000 ASNU per litre. Preferably, such solution comprises inorganic salt of phosphate or pyrophosphate, preferably sodium acid pyrophosphate or monopotassium phosphate, more preferably sodium acid pyrophosphate, at a concentration of 0.1-250 mM, more preferably 1-100 mM, even more preferably 5-50 mM.
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- Preferably, such solution wherein the intermediate form of the food product is dipped and/or incubated, or which is sprayed onto the intermediate form of the food product, has a pH which is lower than about pH 6.5, such as a pH which is below pH 6.5. In one preferred embodiment, the solution has a pH which is lower than about pH 6, such as a pH which is below pH 6. In another preferred embodiment, the solution has a pH which is lower than about pH 5.8, such as a pH which is below pH 5.8. In another preferred embodiment, the solution has a pH which is lower than about pH 5.7, such as a pH which is below pH 5.7. In another preferred embodiment, the solution has a pH of about pH 5.5.
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In a preferred embodiment, the food product is french fries or sliced potato chips.

- 30 In another preferred embodiment, the contacting in step a) is performed by blending asparaginase and an inorganic salt of phosphate or pyrophosphate into the intermediate form of the food product. Preferably, the concentration of asparaginase in the intermediate form of the food product is 100-10,000 ASNU per kg dry matter and the concentration of inorganic salt of phosphate or pyrophosphate is 0.05-5%.

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Preferably, when the contacting in step a) is performed by blending asparaginase and an inorganic salt of phosphate or pyrophosphate into the intermediate form of the food product, the in-

intermediate form of the food product has a pH which is lower than about pH 6.5, such as a pH which is below pH 6.5. In one preferred embodiment, the intermediate food product has a pH which is lower than about pH 6, such as a pH which is below pH 6. In another preferred embodiment, the intermediate form of the food product has a pH which is lower than about pH 5.8,
5 such as a pH which is below pH 5.8. In another preferred embodiment, the intermediate form of the food product has a pH which is lower than about pH 5.7, such as a pH which is below pH 5.7. In another preferred embodiment, the solution has a pH of about pH 5.5.

10 In a preferred embodiment, the intermediate form of the food product comprises cooked mashed potatoes.

In some embodiments, the heating in step c) is performed by frying or par-frying. In other embodiments, the heating in step c) is performed by baking.

15 Stabilized asparaginase composition at high temperature

In another aspect, the invention relates to an aqueous composition having a temperature of at least 42°C, preferably at least 45°C, at least 50°C or at least 55°C, more preferably at least 60°C, at least 62°C or at least 65°C, which comprises (i) asparaginase and (ii) an inorganic salt of phosphate or pyrophosphate.

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In one preferred embodiment, the inorganic salt of phosphate or pyrophosphate is an inorganic salt of pyrophosphate, preferably sodium acid pyrophosphate. In another preferred embodiment, the inorganic salt of phosphate or pyrophosphate is monopotassium phosphate or sodium acid pyrophosphate.

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Preferably, the aqueous composition comprises an inorganic salt of phosphate or pyrophosphate, preferably sodium acid pyrophosphate or monopotassium phosphate, more preferably sodium acid pyrophosphate, at a concentration which stabilizes the asparaginase. More preferably, the inorganic salt of phosphate or pyrophosphate, preferably sodium acid pyrophosphate
30 or monopotassium phosphate, more preferably sodium acid pyrophosphate, is present at a concentration which stabilizes the asparaginase at high temperature, e.g. 42°C, 45°C, 50°C, 55°C, 60°C, 62°C or 65°C.

In a preferred embodiment, the aqueous composition comprises asparaginase at a concentration of 1,000-50,000 ASNU per litre, preferably 2,000-20,000 ASNU per litre, more preferably 3,000-15,000 ASNU per litre and most preferably 4,000-10,000 ASNU per litre. In another preferred embodiment, the aqueous composition comprises an inorganic salt of phosphate or pyro-

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phosphate, preferably sodium acid pyrophosphate or monopotassium phosphate, more preferably sodium acid pyrophosphate, at a concentration of 0.1-250 mM, preferably 1-100 mM, more preferably 5-50 mM.

- 5 In another aspect, the invention relates to a method for making a heated aqueous composition, which comprises:
- a) adding to water (i) asparaginase and (ii) an inorganic salt of phosphate or pyrophosphate, and
 - b) heating to a temperature of at least 42°C, preferably at least 45°C, at least 50°C or at least
- 10 55°C, more preferably at least 60°C, at least 62°C or at least 65°C, wherein step a) is performed before, during or after step b).

It is to be understood that "adding to water" in step a) of such method does not necessarily mean adding to pure water. "Adding to water" includes adding to tap water with whatever ions, etc., are present in tap water. It also includes adding to any kind of water which has been purified or otherwise treated, e.g. deionised water, etc. It also includes adding to any aqueous solution which after step a) becomes an aqueous composition comprising asparaginase and an inorganic salt of phosphate or pyrophosphate.

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- 20 The heating in step b) may be performed before adding the asparaginase and the inorganic salt of phosphate or pyrophosphate, it may be performed during the addition of asparaginase and the inorganic salt of phosphate or pyrophosphate, it may be performed after the addition of asparaginase and the inorganic salt of phosphate or pyrophosphate, it may be performed after the addition of the inorganic salt of phosphate or pyrophosphate but before addition of the asparaginase or it may be performed after the addition of asparaginase but before addition of the inorganic salt of phosphate or pyrophosphate, although this last option is less preferable as the enzyme may be inactivated in the heated water before the addition of phosphate/pyrophosphate. The heating of the water need not take place in the tank where the asparaginase and the inorganic salt of phosphate or pyrophosphate are applied. The water may be heated before filling it into the tank.
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The asparaginase may be added before, at the same time or after the addition of the inorganic salt of phosphate or pyrophosphate. Preferably, the asparaginase is added after the addition of the inorganic salt of phosphate or pyrophosphate.

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In one preferred embodiment, the inorganic salt of phosphate or pyrophosphate is an inorganic salt of pyrophosphate, preferably sodium acid pyrophosphate. In another preferred embodi-

ment, the inorganic salt of phosphate or pyrophosphate is monopotassium phosphate or sodium acid pyrophosphate.

5 Preferably, the inorganic salt of phosphate or pyrophosphate is added at a concentration which stabilizes the asparaginase. More preferably, the inorganic salt of phosphate or pyrophosphate is added at a concentration which stabilizes the asparaginase at high temperature, e.g. 42°C, 45°C, 50°C, 55°C, 60°C, 62°C or 65°C.

10 Preferably, asparaginase is added at a concentration of 1,000-50,000 ASNU per litre, more preferably 2,000-20,000 ASNU per litre, even more preferably 3,000-15,000 ASNU per litre and most preferably 4,000-10,000 ASNU per litre. Preferably, the inorganic salt of phosphate or pyrophosphate is added at a concentration of 0.1-250 mM, more preferably 1-100 mM, and even more preferably 5-50 mM.

15 A heated asparaginase composition wherein the asparaginase has been stabilized with, e.g., monopotassium phosphate or sodium acid pyrophosphate, or with another acid, such as, e.g., citric acid, lactic acid, acetic acid, ascorbic acid, monocalcium phosphate or potassium bitartrate, may be useful, e.g., in the food industry, where, for various reasons, asparaginase treatment of food products before heating of these should preferentially take place at a relatively
20 high temperature to fit into an existing production line. In such processes, the asparaginase may be unstable especially in the start-up phase of a continuous process. When the asparaginase is added to fairly pure tap water, which is optionally heated, its activity may be reduced, in which case the present inventors have surprisingly found that lowering the pH stabilizes the enzyme and gives a higher activity in an aqueous solution, especially in an aqueous solution having a
25 high temperature.

When the continuous process is running more or less in a steady-state, for example a continuous process of french fries where potato strips are dipped continuously in a hot solution of asparaginase, leakage of solubles from the potato strips may contribute to stabilization of the asparaginase enzyme and therefore even though further addition of, e.g., enzyme and water may
30 be needed along the continuous process to maintain a steady-state level, the level of acid may be allowed to be reduced to a lower level at this stage as compared to the start-up phase.

Therefore, in one aspect, the invention relates to a method for starting up a continuous industrial process, which comprises:

a) making an aqueous solution of asparaginase having a pH which is lower than about pH 6.5, and

b) heating to a temperature of at least 42°C, preferably at least 45°C, at least 50°C or at least 55°C, more preferably at least 60°C, at least 62°C or at least 65°C, wherein step a) is performed before, during or after step b).

- 5 In a preferred embodiment, the continuous industrial process is a process for producing par-fried french fries where potato strips are continuously dipped or incubated in a solution comprising asparaginase.

Preferably, also for this aspect, asparaginase is added at a concentration of 1,000-50,000
10 ASNU per litre, more preferably 2,000-20,000 ASNU per litre, even more preferably 3,000-15,000 ASNU per litre and most preferably 4,000-10,000 ASNU per litre.

Preferably, also for this aspect, the aqueous asparaginase solution having a pH which is lower than about pH 6.5 comprises at least one acid selected among sodium acid pyrophosphate,
15 monopotassium phosphate, citric acid, lactic acid, acetic acid, ascorbic acid, monocalcium phosphate and potassium bitartrate. Such acid or acids, optionally in combination with other acids, are to be present in the solution in sufficient amount so that the solution has a pH which is lower than about pH 6.5. Preferably, the solution has a pH which is below pH 6.5. In one preferred embodiment, the solution has a pH which is lower than about pH 6, such as a pH which is
20 below pH 6. In another preferred embodiment, the solution has a pH which is lower than about pH 5.8, such as a pH which is below pH 5.8. In another preferred embodiment, the solution has a pH which is lower than about pH 5.7, such as a pH which is below pH 5.7. In another preferred embodiment, the solution has a pH of about pH 5.5.

25 Concentrated asparaginase composition

In one aspect, the present invention relates to a concentrated composition of asparaginase comprising (i) asparaginase at a concentration of at least 100 ASNU per gram and (ii) an inorganic salt of phosphate or pyrophosphate at a concentration of at least 0.1 mM, preferably at least 1 mM, more preferably at least 5 mM.

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Stabilization of asparaginase may be advantageous already at the stage of its production. I.e., an inorganic salt of phosphate or pyrophosphate, preferably an acidic inorganic salt of phosphate or pyrophosphate, such as sodium acid pyrophosphate or monopotassium phosphate, may be added during fermentation of a microorganism expressing asparaginase. Or it may be
35 added after fermentation to the fermentation broth comprising the asparaginase.

Optionally, the asparaginase may be purified. In that case, a stabilizing compound such as an

acid, e.g., sodium acid pyrophosphate or monopotassium phosphate, may be added to the asparaginase before or after it has been purified.

The term "purified" as used herein covers asparaginase preparations where the preparation has
5 been enriched for the asparaginase enzyme. Such enrichment could for instance be: the removal of the cells of the organism from which the asparaginase was produced, the removal of non-protein material by a protein specific precipitation or the use of a chromatographic procedure where the asparaginase is selectively adsorbed and eluted from a chromatographic matrix. The asparaginase may have been purified to an extent so that only minor amounts of other proteins are present. The expression "other proteins" relate in particular to other enzymes.
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Therefore in one aspect, the present invention relates to an aqueous composition comprising (i) asparaginase at a concentration of at least 100 ASNU per gram and (ii) an inorganic salt of phosphate or pyrophosphate, preferably an acidic inorganic salt of phosphate or pyrophosphate, such as sodium acid pyrophosphate or monopotassium phosphate, at a concentration of
15 at least 0.1 mM, preferably at least 1 mM, more preferably at least 5 mM.

Such aqueous composition of asparaginase which has been stabilized, e.g., with sodium acid pyrophosphate or monopotassium phosphate according to the present invention comprises asparaginase at a concentration of at least 100 ASNU per gram, preferably at least 1000 or at least 2000 ASNU per gram, more preferably at least 3000 ASNU per gram, such as about 3500 ASNU per gram.
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In a preferred embodiment, such aqueous composition comprising asparaginase and an inorganic salt of phosphate or pyrophosphate has been formulated to further stabilize the asparaginase. In another preferred embodiment, such aqueous composition comprising asparaginase and an inorganic salt of phosphate or pyrophosphate comprises glycerol, preferably at a concentration of 40-60%.
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Such aqueous composition comprising asparaginase and an inorganic salt of phosphate or pyrophosphate may be stored as a liquid composition until the asparaginase is to be applied by industry, e.g. for industrial production of a food product, such as a heat-treated food product.
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Alternatively, an aqueous asparaginase composition comprising a stabilizing compound such as an acid, e.g., sodium acid pyrophosphate or monopotassium phosphate, may be formulated into an enzyme granulate, e.g. by spray-drying.
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Therefore in one aspect, the present invention relates to an enzyme granulate comprising (i) asparaginase at a concentration of at least 100 ASNU per gram and (ii) an inorganic salt of phosphate or pyrophosphate, such as sodium acid pyrophosphate or monopotassium phosphate, at a concentration of at least 0.1 mM, preferably at least 1 mM, more preferably at least 5 mM . The term "enzyme granulate" as used herein is a granular formulation of the asparaginase enzyme. The enzyme granulate may also comprise other enzymes.

In another aspect, the present invention relates to an enzyme granulate comprising asparaginase at a concentration of at least 100 ASNU per gram and having a pH which is lower than about pH 6.

In the context of the present invention, the pH of an enzyme granulate means the pH of an aqueous solution or slurry of such enzyme granulate in deionised water.

Such enzyme granulate may comprise at least one acid selected among sodium acid pyrophosphate, monopotassium phosphate, citric acid, lactic acid, acetic acid, ascorbic acid, monocalcium phosphate and potassium bitartrate.

An enzyme granulate of the present invention comprises asparaginase at a concentration of at least 100 ASNU per gram, preferably at least 1000 or at least 2000 ASNU per gram, more preferably at least 3000 ASNU per gram, such as about 3500 ASNU per gram.

In one aspect, the invention relates to a method for producing an enzyme granulate comprising asparaginase, which method comprises:

- a) adding an inorganic salt of phosphate or pyrophosphate, such as sodium acid pyrophosphate or monopotassium phosphate, to an aqueous solution comprising asparaginase, and
- b) formulating said aqueous solution into an enzyme granulate.

Preferably, the inorganic salt of phosphate or pyrophosphate is added at a concentration of at least 0.1 mM, more preferably at least 1 mM, and even more preferably at least 5 mM.

In one aspect, the invention relates to a method for producing an enzyme granulate comprising asparaginase, which method comprises:

- a) making an aqueous solution comprising asparaginase and having a pH which is lower than about pH 6, and
- b) formulating said aqueous solution into an enzyme granulate.

Preferably, the aqueous solution has a pH which is below pH 6. In one preferred embodiment, the solution has a pH which is lower than about pH 5.8, such as a pH which is below pH 5.8. In another preferred embodiment, the solution has a pH which is lower than about pH 5.7, such as a pH which is below pH 5.7. In another preferred embodiment, the solution has a pH of about pH 5.5.

Preferably, following step a), the asparaginase is allowed to "age" in the acidic solution, e.g. for 0.5 to 10 hours, before the solution is formulated into an enzyme granulate. Without wishing to be bound by any theory, it may be that the enzyme is more active in a multimeric form, e.g. as a dimer or a tetramer, and such aging may allow the multimers to assemble thus rendering the enzyme granulate more active and more stable.

Sodium chloride, NaCl, is often added to purified enzyme liquid before granulation. However, NaCl may destroy the activity of the asparaginase enzyme. Therefore, the methods of the present invention of making a stabilized asparaginase granulate may be especially relevant in the situation where the asparaginase granulate also comprises NaCl.

Stock solution of asparaginase

Stabilization of asparaginase according to the present invention may be advantageous at the stage where the concentrated formulated composition of asparaginase is to be applied into an industrial process, e.g. for production of a heat treated food product. At this stage, the industrial food processors in many cases wish to make a stock solution of the enzyme having a suitable concentration to apply into their production line. However, such stock solution of asparaginase may lose its activity when being stored, especially at elevated temperatures, such as at room temperature or higher.

The present inventors have surprisingly found that lowering the pH stabilizes the asparaginase in such stock solution.

For example, in production of dough-based biscuits or snacks, asparaginase will typically be added with the liquid and mixed into the dry ingredients or added directly to the dry ingredients before mixing of the dough. However, to facilitate correct dosing, it might be optimal to have an enzyme stock solution of lower activity than the formulated, concentrated enzyme product. To ensure enzyme stability of this intermediate stock solution during processing in potentially warm industrial facilities an acid may be added according to the present invention.

Therefore, in one aspect, the present invention relates to an aqueous stock solution comprising

asparaginase at a concentration of 100-2,000 ASNU per gram and having a pH which is lower than about pH 6.5.

5 Preferably, the aqueous stock solution has a pH which is below pH 6.5. In one preferred embodiment, the solution has a pH which is lower than about pH 6, such as a pH which is below pH 6. In another preferred embodiment, the solution has a pH which is lower than about pH 5.8, such as a pH which is below pH 5.8. In another preferred embodiment, the solution has a pH which is lower than about pH 5.7, such as a pH which is below pH 5.7. In another preferred embodiment, the solution has a pH of about pH 5.5.

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In another aspect, the present invention relates to a method for diluting or dissolving a concentrated composition of asparaginase for applying it into an industrial process, which comprises:

- 15 a) diluting or dissolving a concentrated composition comprising asparaginase at a concentration of at least 2,000 ASNU per gram into a stock solution comprising less than half of the asparaginase activity per gram as compared to the concentrated composition and having a pH which is lower than about pH 6.5, and
- b) applying the stock solution into the industrial process.

20 The concentrated composition comprising asparaginase may be an aqueous composition, in which case it is diluted into a stock solution, or it may be an enzyme granulate, in which case it is dissolved into a stock solution.

25 Preferably, also in this aspect of the invention, the aqueous stock solution has a pH which is below pH 6.5. In one preferred embodiment, the solution has a pH which is lower than about pH 6, such as a pH which is below pH 6. In another preferred embodiment, the solution has a pH which is lower than about pH 5.8, such as a pH which is below pH 5.8. In another preferred embodiment, the solution has a pH which is lower than about pH 5.7, such as a pH which is below pH 5.7. In another preferred embodiment, the solution has a pH of about pH 5.5.

30 In a preferred embodiment, the stock solution is diluted by at least a factor of 2 (w/w) when applying it into the industrial process. In a more preferred aspect, the stock solution is diluted by at least a factor of 5 (w/w), more preferably by at least a factor of 10 (w/w), when applying it into the industrial process.

35 Preferably, at least a part of the stock solution is stored for at least 6 hours before applying it into the industrial process.

Preferably, in step a), the concentrated composition comprising asparaginase is diluted or dissolved into a stock solution comprising less than 20%, more preferably less than 10%, of the asparaginase activity per gram as compared to the concentrated composition.

- 5 In yet another aspect, the present invention relates to a method for diluting or dissolving a concentrated composition of asparaginase for applying it into a dough, which comprises:
- a) diluting or dissolving a concentrated composition comprising asparaginase at a concentration of at least 2,000 ASNU per gram into a stock solution comprising less than half of the asparaginase activity per gram as compared to the concentrated composition and having a pH
- 10 which is lower than about pH 6.5, and
- b) applying the stock solution into the dough.

Preferably, the dough is to be heat-treated, such as by baking or by frying.

- 15 Preferably, also in this aspect of the invention, the stock solution has a pH which is below pH 6.5. In one preferred embodiment, the solution has a pH which is lower than about pH 6, such as a pH which is below pH 6. In another preferred embodiment, the solution has a pH which is lower than about pH 5.8, such as a pH which is below pH 5.8. In another preferred embodiment, the solution has a pH which is lower than about pH 5.7, such as a pH which is below pH 5.7. In
- 20 another preferred embodiment, the solution has a pH of about pH 5.5.

In a preferred aspect, the stock solution is diluted by at least a factor of 2 (w/w) when applying it into the dough. In a more preferred aspect, the stock solution is diluted by at least a factor of 5 (w/w), more preferably by at least a factor of 10 (w/w), when applying it into the dough.

25

Preferably, at least a part of the stock solution is stored for at least 6 hours before applying it into the dough.

- 30 Preferably, in step a), the concentrated composition comprising asparaginase is diluted or dissolved into a stock solution comprising less than 20%, more preferably less than 10%, of the asparaginase activity per gram as compared to the concentrated composition.

- In another aspect, the invention relates to an aqueous stock solution of asparaginase comprising (i) asparaginase at a concentration of at least 100 ASNU per gram and (ii) an inorganic salt
- 35 of phosphate or pyrophosphate, preferably sodium acid pyrophosphate or monopotassium phosphate, at a concentration of at least 0.1 mM. In a preferred aspect, such stock solution comprises asparaginase at a concentration of 100-2,000 ASNU per gram. In another preferred

aspect, such stock solution comprises an inorganic salt of phosphate or pyrophosphate at a concentration of at least 1 mM, preferably at least 5 mM.

In another aspect, the present invention relates to a method for diluting or dissolving a concentrated composition of asparaginase for applying it into an industrial process, which comprises:

- 5 a) diluting or dissolving a concentrated composition comprising asparaginase at a concentration of at least 2,000 ASNU per gram into a stock solution comprising less than half of the asparaginase activity per gram as compared to the concentrated composition and further comprising at least 0.1 mM, preferably at least 1 mM, more preferably at least 5 mM of an inorganic salt
- 10 of phosphate or pyrophosphate, and
- b) applying the stock solution into the industrial process.

In yet another aspect, the present invention relates to a method for diluting or dissolving a concentrated composition of asparaginase for applying it into a dough, which comprises:

- 15 a) diluting or dissolving a concentrated composition comprising asparaginase at a concentration of at least 2,000 ASNU per gram into a stock solution comprising less than half of the asparaginase activity per gram as compared to the concentrated composition and further comprising at least 0.1 mM, preferably at least 1 mM, more preferably at least 5 mM of an inorganic salt of phosphate or pyrophosphate, and
- 20 b) applying the stock solution into the dough.

EXAMPLES

METHODS AND MATERIALS (EXAMPLES 1-8)

25

ENZYME STABILITY IN WATER OF DIFFERENT QUALITY, IN SOLUTIONS CONTAINING SAPP, KH_2PO_4 , AND GLUCOSE

ASNU MICROTITER ASSAY (as used in Examples 1-8)

30 Enzyme activity was determined in a buffer assay at 37°C, pH 7.0 using asparagine as substrate. 1 ASNU is defined as the amount of enzyme releasing one micromole of ammonium from hydrolysis of asparagine per minute at the above conditions.

The produced ammonium is combined with alpha-ketoglutarate to form glutamic acid, whereby
35 NADH is oxidised to NAD^+ . The consumption of NADH is measured with time at 340 nm. Activity is determined relative to known standards.

Reagents:MOPS Buffer:

0.1M MOPS, pH 7.00, 0.01% Triton X-100

Adjust pH to 7.00 +/-0.05 using 4M NaOH before adding Triton X-100

5

Reagent A:

10 mg/ml L-Asparagine in MOPS buffer

0.44 mg/ml NADH

2.52 mg/ml alpha-ketoglutarate

10 2.24 mg/ml GIDH (>65 Units/ml)

Weigh out L-asparagine and dissolve in MOPS buffer.

Weigh out NADH, alpha-ketoglutarate and GIDH and dissolve in MOPS buffer.

Mix the two solutions and fill to volume using MOPS buffer.

15

Standards:

0.5 – 1.0 – 1.5 – 1.9 – 2.5 – 3.0 – 3.4 ASNU/ml.

Samples:

20 Unknown samples are diluted in MOPS buffer to approximately 1-3 ASNU/g.

Procedure:

Use a 96 well microtiter plate

Adjust temperature in the ELISA reader so that the liquid temperature in the wells is 37°C.

25 240 µL reagent A is added to each well and the plate preheated for 10 min.

10 µL sample or standard is added

After 30 sec. standing, the plate is shaken for 30 sec. and measurement started at 340 nm.

Measurements are recorded every 10 sec. for a total time of 6 min. (readings started 1 min. after enzyme addition). Blind samples are run using 10 µL MOPS buffer instead of sample.

30

Absorbance (OD₃₄₀) vs. time is depicted for each standard and sample and the slope (decay) calculated based on data from readings at t=4 min to t=6 min. The slope represents the drop in NADH which is directly proportional to the NH₄⁺ produced by the asparaginase action.

35 A standard curve based on the calculated slopes is made showing the slope vs. enzyme activity in ASNU/ml. Activity in the unknown samples are determined from the calculated slope by comparison to the standard curve.

THERMOSTABILITY ASSAY (as used in Examples 1-8)**Procedure:**

Enzyme was incubated in the relevant solution at a dosage of 10 ASNU/g, and a temperature of
 5 25, 55, and 60°C unless otherwise stated. The 25°C sample was made as a control ensuring
 that enzyme activity was not altered significantly in the presence of the compounds tested.
 Samples were taken out right after enzyme addition and mixing (30 sec.) and subsequently after
 30, 60, 90, 120, and 150 min. and held on ice until activity analysis.

10 Enzyme activity measured in the solution (ASNU/ml) at the different conditions is shown in the
 following. Enzyme stability is given as the estimated half-life using a computed best fit exponen-
 tial decay curve, i.e. $E = E_0 \cdot \exp(-\ln(2)/T_{1/2} \cdot t)$, where E_0 = enzyme activity at time 0, $T_{1/2}$ = half-
 life equivalent to the time where activity is 50% of initial, and t = time.

15 EXAMPLE 1*Stability in deionised water*

	ASNU/ml		
Time (min)	25°C	55°C	60°C
0.5	9.6	9.4	8.9
30	9.5	9.2	6.0
60	9.4	8.7	4.4
90	8.1	8.2	3.4
120	10.1	8.2	2.6
150	8.4	7.7	2.1

Enzyme stability in deionised water is very good at 55°C showing an estimated half-life of 535
 20 min. At 60°C, stability is lower with a half-life of 70 min.

EXAMPLE 2*Stability in tapwater*

	ASNU/ml

Time (min)	25°C	55°C	60°C
0.5	9.2	0.08	0.09
30	8.7	0.11	0.11
60	8.6	0.10	0.07
90	8.5	0.09	0.08
120	8.3	0.05	0.06
150	8.0	0.06	0.05

Enzyme stability in tap water is very poor. Practically no activity at all is detected at 55 and 60°C, even in samples taken after only 0.5 min. Activity at 25°C show a slight drop with time.

5 EXAMPLE 3

Stability in tapwater (25°C, 40°C and 50°C)

Time (min)	ASNU/ml		
	25°C	40°C	50°C
0.5	8.52	7.92	0.39
30	7.72	2.43	0.09
60	7.44	0.96	0.09
90	7.64	0.49	0.08
120	7.06	0.33	0.08
150	6.74	0.26	0.08

At lower temperature, enzyme stability in tap water is improved slightly. At 40°C some activity can be detected until 60 min. and estimated half-life is approximately 20 min, while little if any activity is detected at 50°C. Activity at 25°C shows a slight drop with time.

EXAMPLE 4

Stability in deionised water with 22.5 mM SAPP (0.5%)

15

	ASNU/ml

Time (min)	25°C	55°C	60°C
0.5	9.36	9.80	9.69
30	8.95	9.33	8.67
60	8.35	9.38	7.93
90	8.78	8.94	7.52
120	8.59	9.22	7.71
150	8.52	9.20	7.14

Addition of 22.5 mM Sodium Acid Pyrophosphate (SAPP) to deionised water increases enzyme stability at 60°C significantly. Half-life is estimated to be 375 min. compared to the 70 min. observed in deionised water. At 55°C half-life also increased to approximately 1800 min.

5

EXAMPLE 5

Stability in deionised water with 4.5 mM SAPP (0.1%)

	ASNU/ml		
Time (min)	25°C	55°C	60°C
0.5	8.87	9.01	8.70
30	8.46	8.80	7.61
60	8.70	8.72	7.04
90	8.84	8.60	6.69
120	8.62	8.50	6.23
150	8.67	8.38	5.95

10 Increases in stability were also observed when the amount of SAPP used was reduced to 4.5 mM. Half-life at 60°C was approximately 285 min. and at 55°C approximately 1520 min.

EXAMPLE 6

Stability in tapwater with 22.5 mM SAPP (0.5%)

15

	ASNU/ml

Time (min)	25°C	55°C	60°C
0.5	9.50	10.36	9.61
30	9.00	9.43	8.09
60	8.63	9.59	7.59
90	8.73	9.31	6.96
120	8.79	9.49	6.88
150	8.66	9.55	6.60

Addition of SAPP also increased enzyme stability significantly in tapwater. Half-life at 60°C rose to 297 min. compared to activity being non-detectable in tapwater without SAPP. At 55°C half-life increased to 1735 min. again from a non-detectable level in tapwater.

5

EXAMPLE 7

Stability in deionised water with 50 mM KH₂PO₄, pH = 5

	ASNU/ml	
Time (min)	25°C	60°C
0.5	9.85	8.19
60	9.93	7.75
120	9.41	7.31
150	9.73	7.12

10 Also phosphate (50 mM) stabilises the enzyme significantly at 60°C.

EXAMPLE 8

Stability in deionised water with 1% glucose

	ASNU/ml		
Time (min)	25°C	55°C	60°C
0.5	9.53	10.14	9.48
30	8.99	10.15	6.09

60	9.10	9.46	4.73
90	9.29	9.36	3.74
120	9.95	9.16	2.94
150	9.12	9.37	2.46

Addition of extra dry matter in the form of 1% glucose did not affect enzyme stability in deionised water. Estimated half-life at 55°C is 1015 min and at 60°C it is 60 min.

5 METHODS AND MATERIALS (EXAMPLES 9-11)

ENZYME STABILITY IN SOLUTIONS CONTAINING SAPP OR CITRIC ACID AT DIFFERENT PH

10 ASNU ASSAY (as used in Examples 9-11)

Enzyme activity was determined in a buffer assay at 37°C, pH 7.0 using asparagine as substrate. 1 ASNU is defined as the amount of enzyme releasing one micromole of ammonium from hydrolysis of asparagine per minute at the above conditions. The produced ammonium is quantified using Nessler's reagent. Absorbance is measured at 436 nm. Activity is determined relative to known standards.

Reagents

Tris Buffer

35 mM Tris, pH 7,00, 0,01% Triton X-100

20

Asparagine

25 mg/ml L-Asparagine in Tris buffer

TCA

25 1.5 M Trichloroacetic acid

Standards

0 – 2 – 4 – 8 - 10 ASNU/ml.

30 **Procedure**

Activity assay

Mix 3.75 ml buffer and 0.5 ml asparagine solution in a glass tube and preheat in a water bath at

37 °C for 5-10 min. Add 0.5 ml standard or sample and incubate at 37°C for 10 min. Add 0.25 ml TCA to stop the reaction.

Ammonia determination

- 5 Take out 0.05 ml of the solution above; add 0.85 ml MQ water, 0.1 ml Nessler's reagent and mix. After 10 min the absorbance is read in a spectrophotometer at 436 nm.

A standard curve showing absorbance vs. enzyme concentration in the standards is made and activities in the unknown samples calculated from this.

10

THERMOSTABILITY ASSAY (as used in Examples 9-11)

Procedure

- 15 Enzyme was incubated in the relevant solution at a concentration of 10 ASNU/ml, and a temperature of 25 and 60°C unless otherwise stated. The 25°C sample was made as a control ensuring that enzyme activity was not altered significantly in the presence of the compounds tested.

- 20 For initial screening of enzyme stability, samples were taken out 5 min after enzyme addition and held on ice until activity analysis. For determination of enzyme half-life ($T_{1/2}$) samples were taken out after 5, 40, 80, 120 min.

- 25 Enzyme activity measured in the solution at the different conditions is shown in the following. Enzyme stability is given as the estimated half-life using a computed best fit exponential decay curve, i.e. $E = E_0 \cdot \exp(-\ln(2)/T_{1/2} \cdot t)$, where E_0 = enzyme activity at time 0, $T_{1/2}$ = half-life equivalent to the time where activity is 50% of initial, and t = time.

EXAMPLE 9

Activity after 5 min holding in 0.5% SAPP in deionised water at different pH

pH	25°C	60°C
5	9.8	9.0
6	9.6	7.0
7	9.4	0.7
8	8.8	0.7

30

Enzyme stability at 60°C in 0.5% SAPP in deionised water is clearly dependent upon pH. At 25°C enzyme activity drops slightly after 5 min holding at pH > 7, while at 60°C nearly all activity

is lost after 5 min holding at pH >6.

EXAMPLE 10

Stability in 0.5% SAPP in deionised water, pH 5

5

Time (min)	ASNU/ml			
	25°C	50°C	60°C	65°C
5	10.6	10.6	9.9	5.7
40		10.4	9.1	0
80		9.7	8.7	0
120	10.2	9.5	8.5	0

Enzyme is stable for more than 120 min when held at a temperature of maximum 60°C and pH 5. Estimated half-life is 8 hrs. At 65°C activity drops very fast, showing no activity at all after 40 min.

10

EXAMPLE 11

Stability in 20 mM citric acid in deionised water, pH 5

Time (min)	ASNU/ml		
	25°C	60°C	65°C
5	9.4	11.0	10.8
40		10.9	8.9
80		10.8	8.1
120	10.7	10.5	7.4

15 In the presence of citric acid, pH 5, the enzyme is stable also at 65°C, having an estimated half-life of approximately 3 hrs.

CLAIMS

1. A method of producing a heat-treated vegetable-based food product comprising:
 - a) contacting at a temperature of at least 42°C an intermediate form of said food product with asparaginase at a pH which is lower than about pH 6.5,
 - b) incubating the intermediate form of the food product for at least 1 minute, and
 - c) processing the intermediate form of the food product to obtain the heat-treated food product, wherein the processing comprises heating;
wherein the contacting in step a) is performed by
 - i) the intermediate form of the food product being sprayed with, dipped in or incubated in a solution comprising asparaginase and at least one acid or salt selected among sodium acid pyrophosphate, monopotassium phosphate, citric acid, lactic acid, acetic acid, ascorbic acid, monocalcium phosphate and potassium bitartrate, or
 - ii) the intermediate form of the food product being blended with asparaginase and at least one acid or salt selected among sodium acid pyrophosphate, monopotassium phosphate, citric acid, lactic acid, acetic acid, ascorbic acid, monocalcium phosphate and potassium bitartrate.
2. The method according to claim 1, wherein the food product is a potato product.
3. The method according to claim 1 or claim 2 wherein the incubating in step b) is performed by drying the intermediate form of the food product at an air temperature of above 50°C.
4. The method according to claim 1, wherein the contacting in step a) and the incubating in step b) is performed as one step, where the intermediate form of the food product is incubated in the solution for at least 1 minute.
5. The method according to any one of claims 1 to 4, wherein the solution comprises asparaginase at a concentration of 1,000-50,000 ASNU per litre or wherein the concentration of asparaginase in the intermediate food product is 100-10,000 ASNU per kg dry matter.
6. The method according to any one of claims 1 to 5, wherein the food product is french fries or sliced potato chips.

7. The method according to any one of claims 1 to 5, wherein the intermediate form of the food product comprises cooked mashed potatoes.
8. The method according to any one of claims 1 to 7, wherein the heating in step c) is performed by frying or par-frying.
9. The method according to any one of claims 1 to 7, wherein the heating in step c) is performed by baking.
10. A heat-treated vegetable-based food product when prepared by the method according to any one of claims 1 to 9.
11. A method according to any one of claims 1 to 9 or the heat-treated vegetable-based food product according to claim 10, substantially as herein described with reference to any one or more of the examples but excluding comparative examples.

SEQUENCE LISTING

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<120> Stabilization of asparaginase

<130> 11533.204-WO

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<212> PRT

<213> *Aspergillus oryzae*

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35 40 45

Thr Thr Leu Pro Asn Val Thr Ile Phe Ala Thr Gly Gly Thr Ile Ala

50 55 60

Gly Ser Ser Ala Asp Asn Thr Ala Thr Thr Gly Tyr Lys Ala Gly Ala

65 70 75 80

Val Gly Ile Gln Thr Leu Ile Asp Ala Val Pro Glu Met Leu Asn Val

85 90 95

Ala Asn Val Ala Gly Val Gln Val Thr Asn Val Gly Ser Pro Asp Ile

100 105 110

Thr Ser Asp Ile Leu Leu Arg Leu Ser Lys Gln Ile Asn Glu Val Val

115 120 125

Cys Asn Asp Pro Thr Met Ala Gly Ala Val Val Thr His Gly Thr Asp

130 135 140

Thr Leu Glu Glu Ser Ala Phe Phe Leu Asp Ala Thr Val Asn Cys Arg

145 150 155 160

Lys Pro Val Val Ile Val Gly Ala Met Arg Pro Ser Thr Ala Ile Ser

165 170 175

Ala Asp Gly Pro Leu Asn Leu Leu Gln Ser Val Thr Val Ala Ala Ser

180 185 190

Pro Lys Ala Arg Asp Arg Gly Ala Leu Ile Val Met Asn Asp Arg Ile

195 200 205

Val Ser Ala Phe Tyr Ala Ser Lys Thr Asn Ala Asn Thr Val Asp Thr

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260 265 270

Tyr Glu Asp Met His Asn Asp Thr Leu Tyr Ser Ala Ile Asp Asn Gly

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Ala Lys Gly Ile Val Ile Ala Gly Ser Gly Ser Gly Ser Val Ser Thr

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Pro Phe Ser Ala Ala Met Glu Asp Ile Thr Thr Lys His Asn Ile Pro

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