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(54) **Title**: SPRAY DRIED MYROSINASE AND USE TO PRODUCE ISOTHIOCYANATES

(57) **Abstract**: A spray dried myrosinase/ ascorbate mixture is formed from the steps comprising: providing a source of myrosinase, adding ascorbate to the source of myrosinase, heating the source of myrosinase to a temperature of about 104 °F (about 40 °C) or higher, and spray drying the myrosinase/ ascorbate mixture. The spray dried myrosinase/ ascorbate mixture may be used to prepare isothiocyanates. The spray dried myrosinase/ ascorbate mixture may also be mixed with glucoraphanin and used in an activated tablet or capsule,

SPRAY DRIED MYROSINASE AND USE TO PRODUCE ISOTHIOCYANATES

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application hereby claims the benefit of the provisional patent application Serial No. 61/445,156, filed on February 22, 2011, the disclosure of which is hereby incorporated by reference in its entirety.

BACKGROUND

[0002] Numerous studies have shown that eating certain vegetables, particularly cruciferous vegetables, may reduce one's risk of developing cancer. The origin of this chemoprotective effect is generally attributed to glucosinolates in the vegetables that are converted into isothiocyanates by contact with endogenous myrosinase enzymes when plant cell walls are breached. Some of these isothiocyanates have been shown to be potent Phase II enzyme inducers, which can protect cells against the toxic and neoplastic effects of carcinogens.

[0003] Myrosinase catalyzes the conversion of glucosinolates to isothiocyanates. The rate and yield of the isothiocyanates may be altered by the source and quality of the myrosinase. One well known isothiocyanates is sulforaphane.

[0004] Glucosinolates may be converted to isothiocyanates through the use of myrosinase enzymes. However, during conversion other products may be formed which decreases the amount and purity of isothiocyanate produced.

BRIEF SUMMARY

[0005] A spray dried myrosinase/ascorbate mixture is formed from the steps comprising: providing a source of myrosinase, adding ascorbate to the source of myrosinase to produce a mixture, heating the mixture in a solvent to a temperature of about 104 °F (about 40 °C) or higher, and spray drying the myrosinase/ascorbate mixture.

[0006] In one embodiment, a process for producing spray dried myrosinase/ascorbate mixture comprises the steps of: providing a source of myrosinase, adding ascorbate to the source of myrosinase to produce a myrosinase/ascorbate mixture, heating the mixture in a solvent to a temperature of about 104 °F (about 40 °C) or higher, and spray drying the myrosinase/ascorbate mixture.

[0007] In one embodiment, a process for producing isothiocyanates comprises mixing plant material comprising glucosinolates; spray dried myrosinase/ascorbate mixture; and ascorbate in water at a pH of from about 5 to about 6.5.

[0008] An activated tablet or capsule comprises a spray dried myrosinase/ascorbate mixture and glucoraphanin.

DETAILED DESCRIPTION

[0009] Glucosinolates can be catalytically converted to isothiocyanates by the enzyme myrosinase. Both glucosinolates and myrosinase may be found in many crucifers and are generally higher in concentration in the sprouts and seeds than in the rest of the plant. A well known isothiocyanate is sulforaphane, which is a potent inducer of mammalian detoxification and chemoprotection by inducing Phase 2 enzymatic activity. Glucoraphanin, a glucosinolate, is the precursor to sulforaphane.

[0010] The yield of sulforaphane from glucoraphanin is reduced by epithiospecifier protein (ESP), which is also present in crucifers with myrosinase. ESP catalyzes the formation of sulforaphane nitrile; this alternative reaction pathway competes with the reaction pathway that creates sulforaphane. One way to deactivate ESP is through heating.

[0011] In one embodiment, a spray dried myrosinase/ascorbate mixture is made by mixing a source of myrosinase with ascorbate and heating the mixture to a temperature of about 104 °F (about 40 °C) or higher, and then spray drying the mixture. The resulting spray dried myrosinase/ascorbate mixture has improved properties over other myrosinase. It is more stable; in addition it is more active in producing sulforaphane from

glucoraphanin. Spray dried myrosinase/ascorbate mixture may have an improved yield of sulforaphane, may produce sulforaphane at a more rapid rate, or both.

[0012] In another embodiment the source of myrosinase is heated to a temperature of about 104 °F (about 40 °C) or higher, then mixed with ascorbate, heated to a temperature of about 95 °F (35 °C) or more, and then spray dried. After the ascorbate and the source of myrosinase have been mixed, the mixture may be incubated before it is spray dried.

[0013] A source of myrosinase may be from a cruciferous plant, such as daikon radish, broccoli, and rapeseed. In one embodiment the source of myrosinase may be the seeds, florets, or sprouts of a cruciferous plant. In another embodiment the source of myrosinase may be a broccoli plant. In another embodiment the source of myrosinase may be the seeds of a broccoli plant. The seeds of a broccoli plant may be processed by grinding it into a powder. In another embodiment, the seeds may be crushed or otherwise processed to crack or remove the hull.

[0014] Ascorbate is defined as salts of ascorbic acid. Examples of ascorbate include calcium ascorbate, sodium ascorbate, potassium ascorbate, and magnesium ascorbate. In one embodiment the ascorbate used in the formation of spray dried myrosinase is calcium ascorbate. The amount of ascorbate need not be enough to alter the pH of the aqueous solution. In one embodiment the amount of ascorbate is about 5 grams per 10 L of water. In another embodiment the amount of ascorbate is about 1 to about 5 grams per 10 L of water. In another embodiment the amount of ascorbate may be from about 1 to about 10 grams, about 2 to about 10 grams, or about 3 to about 12 grams per 10 L of water. In one embodiment broccoli seed meal is mixed with calcium ascorbate in water. The mixture is heated to a temperature of about 104 °F (about 40 °C) or higher, and then spray dried.

[0015] The source of myrosinase is heated. Typically the myrosinase is heated to a temperature range of about 104 °F (about 40 °C) or higher. In one embodiment, the myrosinase is heated to about 104 °F to about 225 °F (about 40 °C to about 107 °C); about 110 °F to about 220 °F (about 43 °C to about 104 °C); about 120 °F to about 190 °F (about 49 °C to about 88 °C); about 130 °F to about 180 °F (about 54 °C to about 82 °C); about 135 °F to about 175 °F (about 57 °C to about 79 °C); about 140 °F to about

175 °F (about 60 °C to about 79 °C); about 145 °F to about 175 °F (about 82 °C to about 79 °C); about 150 °F to about 175 °F (about 66 °C to about 79 °C); about 155 °F to about 175 °F (about 68 °C to about 79 °C); about 160 °F to about 175 °F (about 71 °C to about 79 °C); about 164 °F to about 175 °F (about 73 °C to about 79 °C); or about 164 °F (about 73 °C).

[0016] Upon heating the source of myrosinase the ESP is believed to be deactivated. Less time is required at a higher temperature; more time is required at a lower temperature. In one embodiment, the source of myrosinase is heated for about 1 minute or more. It may be heated about 2 minutes or more, 3 minutes or more, 4 minutes or more, 5 minutes or more, 6 minutes or more, 7 minutes or more, or 10 minutes or more.

[0017] The source of the myrosinase and ascorbate may be heated in an aqueous solution. The pH of the aqueous mixture of the source of myrosinase and ascorbate is typically initially between about 4.5 to about 7.5. In one embodiment the pH range is from about 5 to about 7.5, about 5.5 to about 7.5, about 5.5 to about 7.0, about 6.0 to about 7.0, or about 5.0 to about 6.0. After the mixture has been in the aqueous solution the pH may change.

[0018] In one embodiment the heat treated myrosinase/ ascorbate mixture in an aqueous solution is separated from the seed meal or other plant material. In another embodiment the myrosinase may also be filtered. The solution containing myrosinase/ ascorbate mixture is then spray dried. In another embodiment, there is no need to separate the myrosinase/ ascorbate mixture from the seed meal or other plant material, instead it is spray dried homogeneously. In one embodiment, the myrosinase/ ascorbate mixture and the seed meal or other plant material is homogenized then spray dried. In another embodiment the myrosinase/ ascorbate mixture and the seed meal or other plant material is sonicated then spray dried

[0019] The myrosinase/ ascorbate mixture may be mixed with a starch material before spray drying. Examples of starch materials are cyclodextrin, maltodextrin, sucrose, dextrose, corn starch, and vegetable gums. The amount of starch material may be about 10% by weight. The temperature of the air the myrosinase/ ascorbate mixture is sprayed

into may be from about 180 °F to about 215 °F. The method of spray drying is well known to a person of ordinary skill in the art. Typically the material to be spray dried must be dissolved, suspended, or otherwise in a solution. If the heating steps were not performed with the source of myrosinase in a solution, a liquid must be added before the spray drying step.

[0020] Isothiocyanates, such as sulforaphane, may be produced from plant material containing glucosinolates. In one embodiment the source of glucosinolates is glucoraphanin, which can be produced by any method known in the art including the method described in U.S. Publication No. 2009/0081138, which is herein incorporated by reference in its entirety. Other sources of glucosinolates are other crucifer plants, such as cabbage, kale, cauliflower, broccoli, mustard greens, kohlrabi, brussels sprouts, turnips and horseradish root. Typically the sprouts and seeds contain the most glucosinolates, but other parts of the plants may be used.

[0021] In one embodiment glucosinolate and the spray dried myrosinase/ ascorbate mixture are mixed together in water. The mixture may be heated above 95 °F for at least 1 minute. The mixture may be heated for about 70 to 100 minutes. The rate of conversion of glucosinolate to isothiocyanate depends upon the temperature. At a lower temperature the conversion may take longer, at a higher temperature the conversion will take less time. There is no requirement that the mixture be heated above 95 °F. This procedure may be used to convert various glucosinolates to isothiocyanates, such as glucoraphanin to sulforaphane.

[0022] Various solvents may be used for the conversion process. In one embodiment the solvent for the glucosinolate and the spray dried myrosinase/ ascorbate mixture is distilled or deionized water because it is substantially free from iron or zinc ions. In another embodiment the water is not distilled or deionized. In another embodiment, the solvent may be an aqueous solution which comprises water.

[0023] In one embodiment the initial pH of the glucosinolate and the spray dried myrosinase/ ascorbate mixture is about 5 to about 6.5. In one embodiment the pH range is from about 5 to about 7.5, about 5.5 to about 7.5, about 5.5 to about 7.0, about 6.0 to

about 7.0, or about 5.0 to about 6.0. After the mixture has been in the aqueous solution the pH may change.

[0024] In one embodiment the mixture of a source of glucoraphanin and the spray dried myrosinase additionally comprises ascorbate. In one embodiment the amount of ascorbate may be from about 0.1% to about 2%, about 0.5% to about 1.5%, or about 1% by weight.

[0025] After the conversion of glucosinolates to isothiocyanate the solution of isothiocyanates may be spray dried.

[0026] An activated tablet or capsule may comprise the spray dried myrosinase/ ascorbate mixture and a glucosinolate, such as glucoraphanin. Glucoraphanin can be converted to sulforaphane by some people in their intestinal tract, however not all people are able to do this efficiently. A tablet or capsule containing myrosinase and glucoraphanin can be used to convert glucoraphanin to sulforaphane in vivo. This will provide a more certain and consistent dosage of sulforaphane. Sulforaphane is less stable than glucoraphanin and myrosinase, and will decompose. So, a tablet or capsule containing a spray dried myrosinase/ ascorbate mixture and that produces sulforaphane in vivo will have a longer shelf life than a tablet or capsule containing sulforaphane.

[0027] The tablet or capsule may also comprise ascorbate. In one embodiment the tablet or capsule comprises a mixture of ascorbate, glucoraphanin, and spray dried myrosinase/ ascorbate mixture that can produce about 12 to about 20 μmoles of sulforaphane in 2-3 hours. A tablet of this composition is able to produce a fixed dosage of sulforaphane. The amount of sulforaphane produced in vivo will depend upon the amount of glucoraphanin used in the tablet or capsule. In one embodiment, the tablet or capsule comprises about 100 mg of glucoraphanin. The mixture of ascorbate, glucoraphanin, and spray dried myrosinase/ ascorbate mixture used in the tablet or capsule may be mixed in a ratio of 1g of ascorbate, 7.5 g of spray dried myrosinase/ ascorbate mixture, and 100g of glucoraphanin. The ratio of the ingredients may be varied.

[0028] To allow the tablet to pass through the intestinal tract to the small intestine, an enteric coating may be formed over the tablet. In another embodiment the tablet may have a time release coating or controlled-release coating. Spray dried myrosinase/ ascorbate mixture and glucoraphanin particles may be separately or as a mixture coated with enteric coatings. Use of enteric coatings, time release coatings and controlled-release coatings are well known. An enteric coating releases the contents to the intestine. In another embodiment, a capsule may be used. The spray dried myrosinase, glucoraphanin, and the ascorbate may be coated with an enteric coating within the capsule.

[0029] While the present disclosure has illustrated by description several embodiments and while the illustrative embodiments have been described in considerable detail, it is not the intention of the applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications may readily appear to those skilled in the art.

EXAMPLES

Example 1 (Spray dried myrosinase)

[0030] Broccoli seed (200 g) containing myrosinase was milled to a powder. The powdered seed was mixed with distilled water (200 mL) at 95 °F (35 °C). The mixture was rapidly mixed for 5 minutes, then heated to 165-175 °F (74 °C-79 °C) and held at that temperature for 5 minutes. Calcium ascorbate (10 mg) was added to the mixture, which was then incubated for 24 hours at 98 °F (37 °C). The mixture was strained and the liquid homogenized. The homogenized liquid was then spray dried.

Example 2 (Convert glucoraphanin to sulforaphane)

[0031] Broccoli seeds containing high levels of glucoraphanin (sulforaphane glucosinolate) were crushed in an extruder at 270 °F (132 °C). The crushed seed was defatted by means of super critical extraction using super critical CO_2 to produce glucoraphanin powder.

[0032] Spray dried myrosinase/ ascorbate mixture (100 mg) from Example 1, glucoraphanin powder (1 g, 130 μm glucoraphanin/g), and calcium ascorbate (10 mg) were mixed together in distilled water (500 mL) at 99.5 °F (37.5 °C). After 70 to 100 minutes the liquid was filtered, and spray dried to produce sulforaphane (62 μm).

Example 3

[0033] Broccoli seeds, which contain glucoraphanin (sulforaphane glucosinolate), were crushed in an extruder at 270 °F (132 °C). The crushed seed was defatted by means of super critical extraction using super critical CO_2. Water was added to the seed meal (5:1 water: seed meal).

[0034] A source of myrosinase enzyme, broccoli seed, was milled. The milled seed was hydrated in water (5:1 water: milled seed by weight). The mixture was heated to 135 °F - 145 °F (57 °C - 63 °C) for 3-5 minutes, then cooled to around 90 °F. Ascorbate (0.01g / g milled seed meal) was added to the hydrated milled seed. The pH of this mixture was about 5.9 to 6.1. The mixture was allowed to incubate for 24 hours at 99.5 °F (37.5 °C).

[0035] The myrosinase mixture was added to the glucoraphanin mixture (1:100 myrosinase: glucoraphanin by weight) at 99.5 °F (37.5 °C). After 70 to 100 minutes the liquid is filtered, and spray dried to produce sulforaphane.

Example 4

[0036] Glucoraphanin powder and deionized water (1:5 to 1:10 weight ratio) were mixed at a temperature of 135 °F for 15 minutes. The mixture was cooled to 95 °F - 100 °F (35 °C - 38 °C) and calcium ascorbate (0.01:1 of ascorbate to myrosinase by weight) was added to the mixture. Spray dried myrosinase/ ascorbate mixture (0.1:1 of myrosinase to glucoraphanin by weight) from Example 1 was added to the mixture and incubated at 95 °F - 100 °F (35 °C - 38 °C) for 1 hour.

Example 5 (spray dried myrosinase)

[0037] Broccoli seed (100 g) was ground and added to distilled water (10 L) at 73 °C (164 °F). Ascorbate (5 g) was added and the mixture was stirred for 7 minutes then cooled. The mixture was kept at 35 °C (95 °F) for 24 hours. The liquid was decanted

and spray dried with 10% by weight maltodextrin. Four samples were made using this procedure. The ascorbate used is shown in the table below. Sample 3 was decanted after the mixture was cooled; unlike the other samples, it was not kept at 35 °C (95 °F) for 24 hours. All the samples of spray dried myrosinase were tested for the rate and amount of sulforaphane they were able to produce; see the table below. A sample of 1 gram was tested from a mixture of ascorbate (1 g), spray dried myrosinase (7.5 g), and glucoraphanin (100 g).

[0038] The spray dried myrosinase/ ascorbate was able to produce sulforaphane more rapidly than spray dried myrosinase. See Samples 1 and 3, which at three hours produced 30.2 and 47.7 μmol sulforaphane, respectively. These Samples generated more sulforaphane at three hours in comparison to myrosinase that was not mixed with ascorbate (25.2 μmol sulforaphane) and myrosinase that was mixed with ascorbic acid (20.79 μmol sulforaphane). A rapid generation of sulforaphane in three hours is more important than an overall yield because the glucoraphanin will not remain in the gastrointestinal tract for 24 hours, when the complete conversion of glucoraphanin to sulforaphane has taken place.

Making the Spray Dried Myrosinase

Sample	Ascorbate	Initial pH	pH after stirring	pH after 24 h
1	calcium ascorbate	6.3	5.43	5.66
2	ascorbic acid	6.3	5.33	5.54
3	calcium ascorbate	6.2	4.82	-
4	-	6.3	5	4.6

Testing the Spray Dried Myrosinase

Sample	Initial pH	pH at 1h	sulforaphane at 1h (μmol)	pH at 3h	sulforaphane at 3h (μmol)	pH at 24h	sulforaphane at 24h (μmol)
1	5.3	5.3	12.4	5.2	30.2	4.8	83
2	5.3	5.3	11	5.2	20.79	4.5	83.6
3	5.4	5.2	20	5	47.7	4.5	87
4	5.3	5.21	17	5.21	25.2	4.86	85.3

CLAIMS

What is claimed is:

1. A spray dried myrosinase/ ascorbate mixture formed from the steps comprising:
providing a source of myrosinase,
adding ascorbate to the source of myrosinase,
heating the source of myrosinase to a temperature of about 104 °F (about 40 °C) or higher, and
spray drying the myrosinase/ ascorbate mixture after heating.

2. The spray dried myrosinase/ ascorbate mixture of claim 1, wherein the ascorbate is added to the source of myrosinase before the heating step.

3. The spray dried myrosinase/ ascorbate mixture of claim 1, wherein the ascorbate is added to the source of myrosinase after the heating step.

4. The spray dried myrosinase/ ascorbate mixture of any of the preceding claims, wherein the source of myrosinase is broccoli seeds.

5. The spray dried myrosinase/ ascorbate mixture of any of the preceding claims, wherein the ascorbate is calcium ascorbate.

6. The spray dried myrosinase/ ascorbate mixture of any of the preceding claims, wherein the source of myrosinase is heated for at least 7 minutes.

7. The spray dried myrosinase/ ascorbate mixture of any of claims 1, 2, 4-6, wherein the source of myrosinase and ascorbate are added to an aqueous solution, the aqueous solution with the source or myrosinase and ascorbate is heated to a temperature of about 104 °F to about 225 °F (about 40 °C to about 107 °C), the aqueous solution is separated from the residual solids, and spray dried.

8. The spray dried myrosinase/ ascorbate mixture of any of the preceding claims, wherein the mixture is homogenized before it is spray dried.

9. The spray dried myrosinase/ ascorbate mixture of any of the preceding claims, wherein the water has a pH of from about 4.5 to about 7.5.

10. A tablet or capsule comprising the spray dried myrosinase/ ascorbate mixture of any of the preceding claims and a source of glucoraphanin.

11. The tablet or capsule of claim 10, wherein the source of glucoraphanin is broccoli seeds.

12. The tablet or capsule of any of claims 10-11, additionally comprising ascorbate.

13. The tablet or capsule of any of claims 10-12, wherein the spray dried myrosinase and the source of glucoraphanin are encapsulated in an enteric coating.

14. The tablet or capsule of any of claims 10-13, wherein the tablet or capsule is able to produce about 12 to about 20 μmoles of sulforaphane in 2-3 hours after dissolving in water.

15. A process for producing isothiocyanate comprising mixing the spray dried myrosinase/ ascorbate mixture of any of the preceding claims, with a source of glucosinolate in an aqueous solution.

16. The process of claim 15, wherein aqueous solution comprises ascorbate.

17. The process of any of claims 15-16, wherein the aqueous solution is heated to a temperature of at least about 90 °F (about 32 °C).

18. A process for producing spray dried myrosinase/ ascorbate mixture comprising the steps of:
providing a source of myrosinase,
adding ascorbate to the source of myrosinase,
heating the source of myrosinase to a temperature of about 104 °F to about 225 °F (about 40 °C to about 107 °C), and
spray drying the myrosinase/ ascorbate mixture.

19. The process of claim 18, wherein the source of myrosinase is broccoli seeds.

20. The process of any of claims 18-19, wherein the ascorbate is calcium ascorbate.

21. The process of any of claims 18-20, wherein the source of myrosinase is heated for at least 7 minutes.

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/026036

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61K38/47 A61K9/16 A61K36/31
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, BIOSIS, CHEM ABS Data, Sequence Search, EMBASE, NAPRALERT

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 10 2005 033616 A1 (BIOPRO AG BIOLOG PRODUCTS [DE]; NIG NAHRUNGS INGENIEURTECHNIK [DE]) 25 January 2007 (2007-01-25) paragraph [0025]; claims 1,2,7,13,14; example 4 -----	1-21

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
11 April 2012	26/04/2012

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102005033616 A1	25-01-2007	NONE	