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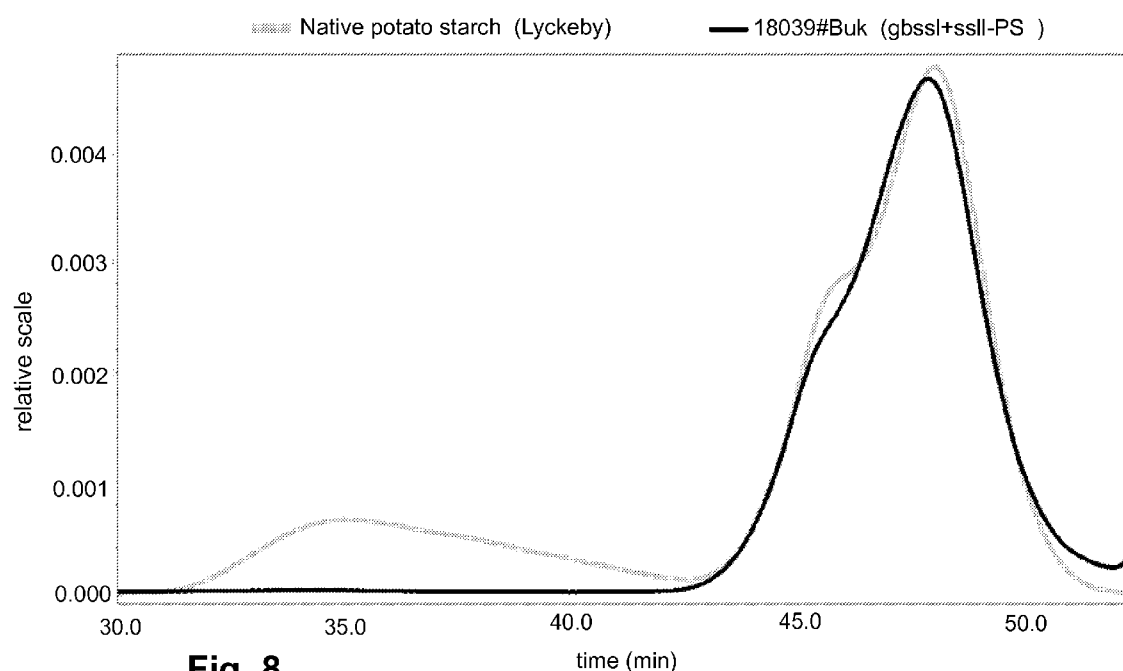
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(54) Title: AMYLOPECTIN POTATO STARCH WITH IMPROVED STABILITY AGAINST RETROGRADATION AND IMPROVED FREEZE AND THAW STABILITY

**Fig. 8**

(57) Abstract: Amylopectin potato starch with improved stability against retro- gradation and improved freeze and thaw stability, wherein it contains more than 99 % amylopectin, preferably 100 % amylopectin, is disclosed, as well as a method for the production of a potato (*Solanum tuberosum*) containing said amylopectin potato starch, wherein said method involves homology- directed mutagenesis using CRISPR/nuclease technology and comprises the following steps: a) provision of potato cells or potato tissue containing potato cells, b) introduction into the nuclei of said potato cells of one or more CRISPR/nuclease complexes each comprising a specific targeting ribonucleotide sequence which is fully or essentially homologous to a target nucleotide sequence located in a DNA sequence immediately upstream of a PAM (5'-NGG-3'protospacer adjacent motif) in a gene coding for a GBSS enzyme and optionally also in



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a gene coding for an SSII enzyme and/or in a gene coding for an SSIII enzyme, wherein said mutagenesis takes place in one or more alleles of the potato genome, wherein when said targeting ribonucleotide sequence identifies the complementary strand of the target nucleotide sequence, said one or more CRISPR/nuclease complexes cut(s) said DNA sequence, leading to a subsequent complete lack of the ability of the potato to produce a functional GBSSI enzyme, optionally also a functional SSII and/or SSIII enzyme, c) wherein step b) optionally is repeated until the potato lacks the ability to produce said functional GBSSI enzyme, optionally also a functional SSII and/or SSIII enzyme, in all of the alleles, preferably 3 times, a potato obtained by said method, a method for the production of said amylopectin potato starch from said potato, and different uses of said amylopectin potato starch.

AMYLOPECTIN POTATO STARCH WITH IMPROVED STABILITY AGAINST
RETROGRADATION AND IMPROVED FREEZE AND THAW STABILITY

Technical field of the invention

The present invention refers to an amylopectin potato starch with improved stability against retrogradation and improved freeze and thaw stability, to a method for the production of a potato containing said amylo-
5 pectin starch, to a potato containing said amylopectin starch, to a method for the production of said amylopectin potato starch, and to uses of said amylopectin potato starch.

Background Art

10 Starch is one of the most used food ingredients in the world. It is primarily used as a thickening agent and thus impart viscosity and texture to food products like soups, sauces, dairy products, fruit preparation etc. It is also used for fat replacement in a large variety of food applications and for many other purposes, e.g. coating of nuts, deep fried foods and as a gelatin
15 replacer in confectionary products, as a stabilizer of oil in water emulsions for liquid emulsions and spray dried functional oils. Starch is found in a large variety of food products in its native state or in a modified form to give the requested performance. Starch is extracted from different botanical sources, e.g. maize, potato, tapioca, wheat, barley, rice etc. and the performance of
20 the starch depends on a number of physical and chemical properties. One of the main characteristics of the starch is the ratio of amylose and amylopectin. The polysaccharide starch is a polymer made from a chemically uniform monomer, the glucose molecule. However, it is a very complex mixture of different forms of molecules which differ with respect to their degree of
25 polymerization and the occurrence of branching of the glucose chains. Starch is therefore not a uniform raw material. A differentiation is made in particular between amylose starch, an essentially unbranched polymer of α -1,4-glycosidically linked glucose molecules, and amylopectin starch, which for its part is a complex mixture of differently branched glucose chains. In typical
30 plants used for starch production, such as maize, potato, wheat, barley, rice,

and tapioca, the synthesized starch consists of about 20%–30% of amylose starch and 70%–80% of amylopectin starch.

For a considerable time amylose was regarded as a linear polymer, consisting of α -1,4-glycosidically linked α -D-glucose monomers. However, 5 research has proven the presence of α -1,6-glycosidic branching points with short chains, called stubs, at the branching points. The chain length of the stubs is defined to be less than 20 DP (STARCH Metabolism and Structure, Nakamura Yasunori, Springer 2015) but other research is also indicating slightly longer stubs (Curá et al, Amylose is not Strictly Linear, Biosynthesis, 10 Nutrition and Biomedical, Vol 47, 1995, 207-209).

Amylopectin consists of a complex mixture of variably branched glucose chains that can be differentiated into A-chains, B-chains with different lengths and C-chain. Unlike amylose, amylopectin is more highly branched. Side chains are linked to the primary chain (the C-chain, consisting of α -1,4- 15 glycosidically linked α -D-glucose monomers) via an α -1,6-glycosidic bond. According to textbook information (Voet and Voet, Biochemistry, John Wiley & Sons, 1990), the α -1,6 branches occur on average every 24 to 30 glucose units. This corresponds to a degree of branching of approx. 3%-4%. The facts regarding the degree of branching vary and depend on the respective starch 20 origin which gives different degrees of branching in between 3-6 % of the amylopectin part of the starch in different botanical sources for the starch. Another fundamental difference between amylose and amylopectin lies in the molecular weight. Depending on the origin of the starch, amylose has a molecular weight (M_w) of approximately 3×10^4 - 10^6 Da, and in the case of 25 amylopectin it is between 10^8 and 10^9 Da. The two macromolecules can be differentiated on the basis of their molecular weights and their different physicochemical properties. In addition to the amylose/amylopectin ratio, the functional characteristics of the starch are strongly influenced by the molecular weight, the side chain distribution pattern and the length of the side 30 chain, the ion content, the lipid and protein content as well as the average starch granular size and its distribution profile. Examples of important functional characteristics are the solubility, the gelatinization behavior, the

granule swelling behavior, the water binding capability, the viscosity and texture properties, the retrogradation property, the film forming properties, and the freeze/thaw stability etc.

5 A water system where the starch has been gelatinized undergoes a process which in general terms is called retrogradation. During the retrogradation process the starch-water system is reorganized and the process leads to syneresis. The starch molecules reform into new crystalline complexes and the water bound to the starch is released. As a consequence the reduced water binding capacity leads to the water being released from the starch-water system, a process called syneresis. At low concentrations this
10 phenomenon will lead to a precipitation of the starch crystalline complexes, and at higher concentrations it leads to gel formation. This behavior is seen in the common starches on the market from maize, potato, tapioca, wheat, barley etc. This is well known by a skilled man in the art and depends on the starch properties which in nature depend on from which natural botanical
15 source it is derived from. (See Jacobson R. et al, Cereal Chemistry, (1997), Volume 74, Number 5, Pages 511-518; Wang et al, Food Science and Food Safety (2015), Volume 14, pages 568–585, Hizukuri S. Carbohydrate research 141, 1985, 295-306; Roulet P Starch 42, 3, 1990 99-100). It has
20 also been shown that the chain length of the amylopectin molecule influences this phenomenon (Hizukuri S, 1985, Kalichevsky M et al, Carbohydrate research 198, 1990, 49-55 and Jane. J et al Cereal Chemistry, (1999), Volume 76, Number 5, Pages 629-637) and also the amylose – amylopectin ratio (Fetches P et al Carbohydrate research 340, (2205), 2563-2568; Miles,
25 M. et al, Carbohydrate research 135, 1985, 271-281; Miles J. Carbohydrate Research, Volume 135, (1985) Pages 271–281).

In most common starches the amylose content is 20-30% whereas in the so-called waxy types the quantity is lower and normally defined as less than 10%. As the presence of amylose in the starch it strongly influences the
30 stability after gelatinization, a lower amount of amylose will have a high impact on the retrogradation behavior.

The starch retrogradation process is one of the most important factors when differentiating starches and their use in food applications but also in other applications as non-food. Most native starches must undergo some kind of chemical modification to inhibit the retrogradation process, and this inhibition can be achieved by chemical modification of the starch by coupling functional groups to the starch molecule via covalent bonding. The most common chemical modifications used in the starch industry are esterification and etherification. These chemical modifications prevent the retrogradation process of the starch. Etherification has the highest impact in food usage as the substituent is more bulky in size and can be made to higher substitution levels and still be classified as a food grade modified starch. It is therefore used to render the starch to become freeze/thaw-stable in water pastes. The function of different chemical modifications is well-known and most of the chemical modifications for food usage can be found in JECFA, Modified starches; 57th JECFA (2001) and are published in FNP 52 Add 9 (2001), FDA §172.892 and in the EU food additive directive. Stabilization against retrogradation can also be achieved by alternative methods generally known as non-chemical modification methods. Retrogradation of starch solutions can be prevented by enzymatic modification. Degradation of the starch molecules with alpha-amylase has shown to increase the stability against retrogradation, and degradation with beta-amylase has shown a remarkable increase of the stability. If beta-amylase is allowed to totally degrade the amylose molecule and partly the amylopectin molecule, forming a beta-limit dextrin, the resulting starch solution will be extremely stable against retrogradation. The reason for the extreme improvement in the stability after degradation with beta-amylase is that the remaining amylopectin molecule will have a reduced chain length size, and this has proven to increase the retrogradation stability, as well as the freeze/thaw stability. However, enzymatic stabilization can only be achieved on non-granular starch and this kind of stabilization is therefore not possible to use for the granular starches. In granular starches, the starch texture is built up by hydrated and swollen but still intact granules, generally termed as gelatinized but dispersed starch granules, and is the common way

starch is used in food applications. The enzymatic stabilization is also time consuming and means extra production costs making the starch products more expensive. Besides the enzymatic modifications it is also known that pyrodextrinization and alkaline roasting can be partly used to prevent the retrogradation phenomenon as well as complexing the amylose molecule with mono-diglycerides.

There are also natural varieties of starches which have a remarkable robustness against the retrogradation phenomenon due to their chemical structure. Starches with a smaller amount of amylose, generally known as waxy starches with an amylose content of less than 10% or even as low as less than 2%, can be found in nature, and these starches have a natural robustness against the retrogradation process but only to a limited level. The retrogradation will for this kind of starches be delayed compared to starches with higher amylose contents. Thus there is a clear correlation between the amylose content and retrogradation. (Sasaki T. Cereal Chemistry, (2000), Volume 77, Number 1, Pages 58-63). Further to this, it is well known that naturally occurring starches with an extremely low amylose content, i.e. less than 0.5%, and with a short chain structure of the amylopectin molecule are extremely stable against retrogradation. (Fredriksson H, et al, (1998), Carbohydrate polymers 35, 119-134; Jane J.L, et al, (1999), Cereal chemistry 76, (5), 629-637). One example of starch with an extremely low content of amylose and a short chain structure of the amylopectin which can be found on a commercial basis is the waxy barley starch, crossbred from the 0-amylose mutant line of barley, for example the varieties Cinnamon, Lisen and HB 340.

A starch with improved stability in starch pastes, after partly being gelatinized or after total gelatinization into a starch solution, is also of high interest in non-food applications as it opens up new possibilities of large varieties of products, e.g. as a functional component in production of adhesives, as a functional ingredient in paper industry, both as a wet-end starch but also for surface sizing and coating of paper, as a functional ingredient in emulsions for paper- and paint industry, as a functional

ingredient in construction products, and as a functional ingredient in pharmaceutical production.

Starch retrogradation can be determined by a broad range of analytical methods including analyzing the properties of starch gels at both the macro-
5 scopic and molecular level. Many analytical methods are summarized in Karim A. et al; Food chemistry 71, (2000), 9-36. An easy method for determining the stability of starch is to partly gelatinize the starch, consequently remained in a granular condition as a starch suspension of gelatinized and swollen granules, or totally disrupted into a starch solution in which there are
10 no intact starch granules remaining in the system. The viscosity and texture properties of the starch suspension or solution are analyzed continuously after storage under different conditions which influences the retrogradation behavior. To analyze and determine the freeze/thaw stability the starch paste or solution is frozen and thawed and then centrifuged to rapidly press out
15 liberated liquid. The released water, which is a result of syneresis due to forced retrogradation of the starch molecules, is siphoned off and weighed. The procedure is repeated systematically and the total amount of accumulated water release after each freeze/thaw cycle is measured and corresponds to the starch stability property and thus equals to its robustness against
20 retrogradation.

The behavior of gelatinized starches upon cooling and storage, generally termed as the retrogradation behavior, is of great interest to food scientists and technologists since it strongly affects the quality, acceptability and shelf-life of starch-containing foods. Starch molecules in food pastes or
25 gels are known to associate upon aging, leading to retrogradation which results in effects such as precipitation, gelation, and undesirable changes in texture due to the retrogradation of the starch. Based on these facts regarding retrogradation of starch pastes and its importance in food industry, it is of highest interest to develop starches which are more stable against the
30 retrogradation phenomenon. There is a strong demand to develop starches which are robust against retrogradation without chemical modifications of the structure and thus can meet the demands of stability from these ones for

starch pastes in food applications for storage in refrigerators or freezers without chemical modification of the starch.

It is known that plants can be genetically modified in such a way that they produce starches that can be differentiated from the starch in the
5 corresponding none- genetically modified plant from which they have been manufactured on the basis of physicochemical parameters. A review of various plant species that exhibit a reduction in enzymes involved in starch biosynthesis has been described by Kossmann and Lloyd [1, 2] (2000, Critical Reviews in Plant Sciences 19(3), 171-126), and later by Zeeman et al. (2010,
10 Annual Review of Plant Biology 61, 209-234)).

Potato plants have previously been disclosed in which the activity of the starch granule-bound starch synthase I (GBSSI; "Granule-Bound Starch Synthase I") is reduced (Hovenkamp-Hermelink et al., 1987, Theoretical and Applied Genetics 75, 217-221; Visser et al., 1991, Mol. Gen. Genet. 225, 289-
15 296; Hergersberg, 1988, Dissertation, Universität Köln; WO 92/11376). The GBSSI is involved in the formation of amylose. Inhibition of GBSSI activity leads to synthesis of starch that almost exclusively is comprised of amylopectin. The corresponding GBSSI gene in maize plant is known by the term "waxy" and this is the reason why starches with lower contents of amylose in
20 general terms are called waxy starches, e.g. waxy corn/maize, waxy potato, waxy wheat, waxy tapioca, waxy barley, waxy rice etc.

In US patent application 20120216316 A1 a method for reducing the activity of GBSSI is disclosed. The amylopectin content in the potato produced is described to be of at least 98% and with a phosphate content
25 higher than 0.09%. In US patent 6,940,001 B1, a method for reducing the activity of GBSSI and BE (Branching Enzyme) is disclosed which will lead to a starch with an amylose content below 10% and with an increased phosphate content.

Nevertheless, according to the disclosed methods in these patent
30 documents the activity of GBSSI and BE is not completely eliminated, which is the reason for still having a significant level of amylose in the produced starch. Furthermore, the used technology used to achieve the decreased

activity is based on a method which will lead to a potato with residual exogenous material.

Moreover, potato plants have been described in which the activity of Soluble Starch Synthase III and II (SSIII and SSII) is reduced (Abel et al.,
5 1996, The Plant Journal 10(6), 981-991; Lloyd et al., 1999, Biochemical Journal 338, 515-521; WO 00/08184; WO 96/15248; EP-A 0779363). In comparison with starch isolated from the corresponding wild type plant, starch from such plants exhibits a shift from longer chains to shorter ones in the side chains of the amylopectin (Lloyd et al., 1999, Biochemical Journal 338, 515-
10 521), no change in the amylose content (Abel et al., 1996, The Plant Journal 10(6), 9891-9991) and a reduced end viscosity via a RVA (Rapid-Visco-Analyzer) analysis (Abel, 1995, Dissertation, Freie Universität Berlin).

It has further been discovered that a combined reduction of SSIII and SSII in potato has much greater effect on the starch structure and behavior
15 than was predicted by the reduction of the individual enzyme isoforms (WO 99/66050, Edwards et al, Plant Journal 17, 251-261, 1999). WO 01/19975 discloses plants in which both the GBSSI and the SSII and/or SSIII activity is reduced. Starch from genetically modified potato plants with reduced GBSSI, SSII and SSIII activity exhibits a lower amylose content, changed
20 gelatinization and swelling properties of the starch granule, and an improved freeze/thaw stability in comparison to the starch from the wild type potato plant. The genetic modification technology used in the invention disclosed in WO 01/19975 is dependent on the stable introduction of one or several genetic devices for a continuous suppression to a larger or lesser degree of
25 gene function. This will most often not lead to a complete suppression of the enzymatic activity of GBSSI, SSIII and SSII and therefore the achieved starch properties will still to some extent be influenced by these starch synthesizing enzymes.

In US patent 0080667670 B2 a method for reducing the activity of
30 GBSSI, SSIII and BEI is disclosed which leads to a starch which is defined as having an amylose content of below 10% and a phosphate content at the C6 position of 30-100 nmol per mg of starch (0.09-0.31% phosphorous of starch

DM). Furthermore, this patent describes the starch properties as having freeze and thaw stability of at least 60%. According to the disclosed method in this patent, the activity of GBSSI, SSII and BEI is not completely eliminated, which is the reason for the starch still having a significant level of amylose and that the freeze and thaw stability is only partially affected by the achieved decreased activity of the specific enzymes. It can therefore be concluded that this patent is based on a technology which will only partially decrease the activity of the specific enzymes GBSSI, SSIII, and BEI. Further to this, it can be concluded that the related technology disclosed in the patent will lead to a potato with residual exogenous material.

The effect of partially suppressing the biosynthetic activities of GBSSI, SSII, and SSIII can be found, inter alia, in Jobling et al 2002, wherein it has been shown that a starch modified by partial gene suppression of the GBSSI, SSIII, and SSII will lead to a starch with improved freeze/thaw stability. Thus, this starch has improved stability properties and consequently robustness against the retrogradation phenomenon.

WO 2015/193858 discloses a starch product from a Solanum plant comprising a mutation in each GBSS allele endogenous to said plant.

Kossmann J et al., "Understanding and influencing starch biochemistry", Critical Reviews in Plant Sciences, 2000, vol. 19, no. 3, pages 171-226, discloses that mutants lacking GBSS in potato synthesize amylose-free starch.

US 6,600,093 (B1) discloses genetically engineered potato plants producing essentially amylose-free starch and no detectable GBSS activity.

The method used in the above-mentioned WO 01/19975 and Jobling et al 2002 is based on stable integration of gene silencing constructs in the potato. As a consequence of this technology, the enzyme activity, e.g. of GBSSI and/or SSII etc., is not totally abolished or suppressed, and therefore the effect of proposed change will not reflect the effect on the starch properties to a 100% suppression. This means that, if for instance GBSSI is blocked or inhibited, small amounts of amylose starch will still be present in the starch component. In the case of blockage of the SSIII and SSII by

genetically modification of the potato, it will not lead to a complete suppression of the chain length synthesized by these enzymes, and thus a small activity of SSIII and SSII is still present and small amounts of longer chains will be found in the starch material from such genetically modified
5 plants.

Another drawback with the known technologies, e.g. in related patents, is that the achieved changes in the species are based on the stable introduction of genetic devices for the continuous suppression of the gene function. Thus, the continuous stable function of the introduced gene suppressing
10 device can efficiently be affected by various external factors, such as biotic or abiotic factors, wherein the modified plant cell material will contain residual exogenous material.

To summarize, there is clearly a need for the provision of a potato starch having improved stability against retrogradation and improved freeze-
15 thaw stability, as well a need for a method for the production of potatoes having the ability to express and produce such a potato starch without having any residual exogenous genetic material.

Summary of the Invention

An object of the present invention is to fulfill the above-mentioned
20 need. This object is reached with an amylopectin potato starch having the characteristics defined in claim 1. This object is also achieved with a method for the production of a potato containing said amylopectin starch, with a potato containing said amylopectin starch, with a method for the production of said amylopectin potato starch, and with uses of said amylopectin potato
25 starch.

More precisely, in one aspect the present invention refers to an amylopectin potato starch with improved stability against retrogradation and improved freeze and thaw stability, wherein it contains more than 99 % amylopectin, preferably 100 % amylopectin.

30 In another aspect the present invention refers to a method for the production of a potato (*Solanum tuberosum*) containing the amylopectin potato starch according to claims 1-3, wherein said method involves

homology-directed mutagenesis using CRISPR/nuclease technology and comprises the following steps:

- a) provision of potato cells or potato tissue containing potato cells,
- b) introduction into the nuclei of said potato cells of one or more
5 CRISPR/nuclease complexes each comprising a specific targeting
ribonucleotide sequence which is fully or essentially homologous to a
target nucleotide sequence located in a DNA sequence immediately
upstream of a PAM (5'-NGG-3' protospacer adjacent motif) in a gene
coding for a GBSS enzyme and optionally also in a gene coding for an
10 SSII enzyme and/or in a gene coding for an SSIII enzyme, wherein
said mutagenesis takes place in one or more alleles of the potato
genome, wherein when said targeting ribonucleotide sequence
identifies the complementary strand of the target nucleotide sequence,
said one or more CRISPR/nuclease complexes cut(s) said DNA
15 sequence, leading to a subsequent complete lack of the ability of the
potato to produce a functional GBSSI enzyme, optionally also a
functional SSII and/or SSIII enzyme,
- c) wherein step b) optionally is repeated until the potato lacks the ability
to produce said functional GBSSI enzyme, optionally also a functional
20 SSII and/or SSIII enzyme, in all of the alleles.

In a further aspect the present invention refers to a potato obtained with the inventive method.

25 In still another aspect the present invention refers to a method for the
production of amylopectin potato starch by extraction from said inventive
potato.

In still another aspect the present invention refers to different uses of
said amylopectin potato starch of said potato.

30 The different aspects of the present invention also appear in the inde-
pendent claims, and further embodiments are disclosed in the accompanying
dependent claims.

Brief Description of the Drawings

Fig. 1 shows schematically genes of *Solanum tuberosum*, more precisely A) the GBSSI gene, B) the SSII gene, and C) the SSIII gene.

Fig. 2 shows schematically the results of the determination of allelic variation of Kuras, more precisely A), exon 8 of the GBSSI gene, B) exon 1 of the SSII gene and C) exon 3 of the SSIII gene.

Fig. 3 shows constructs designed for CRISPR/Cas9 mediated induction of mutations in the GBSSI, SSII, and SSIII gene.

Fig. 4 shows diagrams of the result of high resolution fragment analysis of CRISPR/Cas9 mediated induction of mutations of the GBSSI gene, more precisely A) line with at least one allele mutated having a one bp deletion, B) line with at least two alleles mutated having one and six bp deletions, C) a line with all four alleles mutated having 2 and 8 bp deletions and D) parental line

Fig. 5 shows the results of genotyping of individual alleles with induced mutations in GT1, GT2, GT3, GT4, S2T1, S2T2, S3T1, S3T2 and S3T3 target regions.

Figs. 6-9 show results of analyses of a starch composition isolated from a number of individual mutated lines by use of a HPSEC system.

Detailed description of Preferred Embodiments

In one aspect the present invention relates to a method of changing the starch biosynthetic process in potato species by using a homology-directed mutagenesis for the continuous suppression of the gene function, wherein no integrated residual exogenous material is maintained in the genome of the derived potato plants. In the inventive method, the potato starch synthetic process is changed in the potato plant cell which leads to the synthesis of an amylopectin starch with no previously known properties, i.e. a novel structure, composition, and branching pattern. This is achieved by disrupting the physical gene context of genes which encode the enzymes that are involved in the synthesis of amylose and of the side chains in the amylopectin molecule. The specific disruption of the genes achieves a complete abolishment of the activities of the specific enzymes involved in the specific starch synthesis,

by which starch properties and functionalities that goes beyond the state of art are obtained. With the inventive method a complete blocking of the production of one or more of the active forms of the enzymes GBSSI, SSIII, SSII is achieved, which leads to a novel starch with properties and functionalities never disclosed in literature or related patents before.

Below some definitions of some terms and expressions used throughout the application text are presented.

The term "GBSSI" is to be understood to mean any enzyme that belongs to the class of starch Granule-Bound Starch Synthases of the isoform I. Consequently the term "GBSSI gene" is to be understood to mean a nucleic acid molecule or polynucleotide (DNA, cDNA) that codes for GBSSI.

The terms "SSIII" and "SSII" are to be understood to mean a class of Soluble Starch Synthases. Soluble Starch Synthases catalyze a glycosylation reaction in which glucose moieties of the ADP-glucose substrate are transferred to an α -1,4-linked glucan chain with formation of new α -1,4-linkages, wherein the different classes synthesize chains of different lengths. For example, SSIIIs are described by Marshall et al. (1996, The Plant Cell 8, 1121-1135), Li et al. (2000, Plant Physiology 123, 613-624), Abel et al. (1996, The Plant Journal 10(6), 981-991) and in WO 00/66745. SSIIIs are described by Edwards A. et al (Plant Journal 8, 283-294).

The terms "SSIII gene" and "SSII gene" are to be understood to mean a nucleic acid molecule or polynucleotide (DNA, cDNA) that codes for SSIII and SSII respectively. Polynucleotides coding for Soluble Starch Synthases have been described for various plant species. For potato it is disclosed by Abel et al (1996, The Plant Journal 10(6), 981-991). The term "SSIII gene" preferably means a nucleic acid molecule or polynucleotide (cDNA, DNA) that codes for SSIII in potato plants, and the term "SSII gene" preferably means a nucleic acid molecule or polynucleotide (cDNA, DNA) that codes for SSII in potato plants.

The expression "homology-directed mutagenesis" is to be understood to mean that the target sequence to be mutated in the genome is found and marked for mutagenesis by a ribonucleic acid sequence.

The term "potato" is understood to mean any potato plant belonging to the species *Solanum tuberosum*.

The expression "potato tissue" is understood to mean any part of the potato plant during any stage of its development that contains potato plant
5 cells susceptible to the inventive method. Examples of a potato tissue are a tuber, a shoot, a leaf, a stem, and a flower.

The expression "protoplast" is understood to mean cells from any potato tissue.

The expression "CRISPR/nuclease technology" means that several
10 variants of nucleases may be used together with CRISPR for the production of amylopectin potato starch according to the present invention. Examples of nucleases are Cas, such as Cas9, and Cpf1.

Cas9 is used in the embodiments disclosed below.

The expression "target nucleotide sequence" is understood to mean
15 the specific nucleotide sequence located in the DNA of the potato genome to be identified with the inventive method. In the case of the use of Cas9, as nuclease, in the CRISPR/Cas complex, the target nucleotide sequence consists of 20 bp immediately upstream of a 5'-NGG-3' protospacer adjacent motif (PAM) in the cell genome.

20 The expression "targeting ribonucleotide sequence" is understood to mean a RNA sequence which is fully or essentially homologous to a sequence (the so called target nucleotide sequence) in the gene which is to be mutated by the method according to the invention. If type II Cas9 is used, the targeting ribonucleotide sequence preferably is 20 bp. The targeting
25 ribonucleotide sequence is fully or essentially homologous to the target sequence, which is to be understood as being more than 75% homologous, preferably more than 85% homologous, more preferably more than 95% homologous to the target sequence. In other words, the targeting ribonucleotide sequence is able to hybridize with the complementary strand of
30 the target sequence and in this way locate the Cas to introduce a double strand break (DSB) in the DNA strand.

The expression “essentially homologous” is to be understood to mean that said targeting ribonucleotide sequence may differ from the fully homologous one as to sequence length and base identity but only in such a way that the desired mutation still is obtained.

- 5 The expression “completely lacking amylose” used to define the “amylopectin potato starch” is understood to mean that no amylose at all has been produced in the potato plant due to the complete abolishment of the GBSSI enzyme activity.

- 10 The expression “100 % amylopectin” and “0 % amylose” is understood to mean the same. However, as trace amounts of amylose at least theoretically can happen to be included in an amylopectin potato starch, e.g. due to contamination from the surroundings, the expressions “more than 99 % amylopectin” and “more than 99.5 % amylopectin” is presented with a view to covering such a situation. Nevertheless, amylopectin potato starch containing
15 99 % or more of amylopectin is not known before. The inventive method for achieving the obstruction of the desired ones among the enzymes GBSSI, SSIII, and SSII uses a method for targeted homology-directed mutagenesis. Thus, the method according to the present invention provides targeted editing of the plant genome without leaving any residual exogenous genetic material
20 in the resulting plant. This technology is more precisely directed to disrupting the gene context where earlier methods have been dependent on the physical insertion of a genetic device intended for the modulation of the gene expression or translation, respectively. As defined above, with homology-directed mutagenesis is meant that the target region to be mutated is found
25 and marked for mutagenesis in the cell nucleus by a targeting ribonucleotide sequence which identifies the complementary strand of the target nucleotide sequence. In the inventive method the obstruction of the starch synthesis enzymes in question is made by the action of a sequence-specific RNA/-nuclease protein complex which is translocated to the nucleus and which acts
30 to precisely cut the DNA at a predetermined locus of a chromosome in a potato plant cell. Error-prone repair of the cut permits the introduction of mutations and a loss of function of the gene, and thus a mutation is achieved

without introducing any exogenous genetic material. In this way the disclosed technology can be used to modify plant cell material without having any residual exogenous material integrated or left in the cell. In one embodiment of the method according to the present invention for achieving said introduction of a homology-directed mutation in a plant cell, genetic material, by a sequence-specific RNA/nuclease protein complex is obtained by using the technology CRISPR/Cas9 (clustered regularly interspaced short palindromic repeats / CRISPR associated protein 9). (Doubna and Charpentier, 2014; Mahfouz et al 2014). The most widely used CRISPR/Cas originates from Streptococcus pyogenes [3], where it plays a role as a part of the adaptive immune system of this bacterium taking care of invading viruses or other nucleic acids. In nature, CRISPR consists of an array of sequence repeats separated by protospacers from the target genome. The resulting rather long transcript is then processed into short non-coding RNAs which can form a complex with a type II Cas9 protein. The complex binds to the corresponding region which is complementary to the protospacer region in the invading nucleic acid and makes a double strand digestion in the target region, thus inactivating the invading RNA or DNA. The adapted method for directed gene mutations uses a short single guide RNA (sgRNA), containing a 20 bp guide sequence, i.e. the targeting ribonucleotide sequence used in the inventive method, a promoter and an sgRNA scaffold, which in combination with a Cas9 [3] can induce mutations in more or less any target of choice. The target sequence in the gene is 20 bp for the type II Cas9 and must be located immediately upstream a 5'-NGG-3' protospacer adjacent motif (PAM) in the cell genome. The genes which are targeted according to the present invention contain several PAMs, located both in introns and in exons. Thus, several different targeting ribonucleotide sequences may be anticipated by the disclosed invention.

Furthermore, the present invention is not limited to the targeting ribonucleotide sequence being 20 bp. In some cases the targeting ribonucleotide sequence may be shorter or longer than 20 bp, depending on i.a. the specific

target sequence. Also, if another type of Cas is used, the targeting ribo-nucleotide sequence may be shorter or longer than 20 bp. The resulting double strand break (DSB) is repaired by the cells own repair mechanism, either through non-homologous end joining (NHEJ) or homologous recombination (HR). The repair mechanisms are error prone and often lead to inserts or deletions (indels), which may cause a gene knockout by introducing a stop codon into the gene, leading to the production of a truncated non-functional enzyme. The indels are random in size, even though small indels seem to be most common. The repair mechanisms may also lead to a frame shift, which may lead to the production of a truncated enzyme or a defect enzyme having a decreased or abolished enzyme activity. The repair mechanism may also lead to a changed number of codons, which may lead to a defect enzyme having a decreased or abolished enzyme activity. According to the present invention, no active or functional enzyme is produced in the resulting potato.

This can be verified by measuring the enzyme activity by methods well known in the art, such as enzyme kinetics, histochemical studies or different biochemical studies (e.g. Zymogram, ELISA and PAGE). The presence of a mutation can be verified by conventional techniques such as PCR. Also, the absence of a functional enzyme may be verified by analyzing the composition of the produced starch, e.g. by the staining method described in Example 6 below.

If desired, base shifts or insertions can be tailor made by introduction of a repair template [4, 5], increasing the applications from only generating gene knockouts to also involve gene enhancement. The *Streptococcus pyogenes* Cas9 coding sequence can be used as such or may be codon adapted for plants or codon adapted to other organism classes or species [6] [7].

The choice of promoter driving the sgRNA has been shown to impact the efficiency of generating mutations. In a study on soybean by Sun et al. 2014, a U6 promoter from soybean (*Glycine max* L.) was compared with the more generally used [8] U6 promoter from *Arabidopsis thaliana* and an

increase in mutation efficiency was found when using the endogenous promoter [9] . However, it has also been shown that the strength of the promoter can have an effect on off-targets, and high concentrations of SgRNA-Cas9 transcripts can increase off-target mutations [10, 11], i.e undesired mutations.

5 The method according to the present invention, in which the CRISPR/Cas, preferably CRISPR/Cas 9, is used in one embodiment including a specific targeting ribonucleotide sequence as the guide sequence, will lead to 100% elimination, or inhibition, of the targeted enzyme activity in question. Thus, in the specific species, the consequence will be that the
10 targeted biosynthetic process is totally blocked. This means that if the GBSSI gene is obstructed in the potato by the used technology there will not be any amylose synthesized in the potato and as a consequence the starch composition will be constituted by at least 99 % amylopectin, preferably 100%, in view of the definition above. As suggested above, the difference
15 between a 100 % amylopectin starch and starch containing e.g. 2% or 1 % amylose is substantial in view of such properties as stability and improved freeze and thaw stability. Furthermore, the impact of eliminating also the soluble starch synthase activities SSIII and or SSII will also lead to a so far unknown amylopectin starch with unique properties. The consequence of
20 reducing the SSIII and/or SSII enzyme activities is known to lead to shorter chains of the amylopectin molecule.

Some target regions and the corresponding target nucleotide sequences of particular relevance in connection with the present invention are the following, which also are disclosed in more detail in Example 2.

25

GT1: 5'-GATATTAGAATCACATAGGG-3'	SEQ. ID. NO. 1
GT2: 5'-TGTTGACAAGGGTGTGAAT- 3'	SEQ. ID. NO. 2
GT3: 5'-GCTACCATTGTTTGTGGA-3'	SEQ. ID. NO. 3
GT4: 5'-GACAAGAAGATCCCTTTGAT-3'	SEQ. ID. NO. 4
30 S2T1: 5'-GTGCTAAAAGGGGTAAGTTG-3'	SEQ. ID. NO. 5
S2T2: 5'-GGGGTGCCCTTTCATCGGCC-3'	SEQ. ID. NO. 6
S2T3: 5'-GCTCCAGTAGAGAGCAAATG-3'	SEQ. ID. NO. 7

S3T1: 5'-GAACATCTGAACCAAATTTTC-3'	SEQ. ID. NO. 8
S3T2: 5'-GAGGTGGCAATGGACCCAGG-3'	SEQ. ID. NO. 9
S3T3: 5'-GGAAACTAATGCCAGTAGCA-3'	SEQ. ID. NO. 10

5 In one embodiment of the present invention the production of the GBSSI enzyme is abolished, or inhibited, which leads to a potato which produces more than 99 %, preferably 100%, amylopectin starch.

 In another embodiment of the invention the enzyme activity of GBSSI and SSIII are eliminated, which leads to a potato that produces, more than
10 99%, preferably 100%, amylopectin starch, wherein the structure of such an amylopectin molecule is not known before. In a preferred embodiment of the invention the enzyme activity of all of GBSSI, SSIII, and SSII is eliminated, which leads to a potato which produces more than 99 %, preferably 100%, amylopectin starch and in which the amylopectin structure in several aspects
15 is totally different from the potato amylopectin structure that can be found in conventional cropped potatoes. More precisely, the structure of such an amylopectin chain can be defined as a short-chained, highly branched amylopectin, and these characteristics are known from other crops than potato to give improved stability and robustness against retrogradation.

20 In order to fully abolish the production of an active enzyme in a potato, the corresponding gene must be mutated in all alleles in such a way that no protein with enzyme activity is produced, that a truncated enzyme having no enzyme activity is produced or that a mutated enzyme having no enzyme activity is produced. Importantly, according to the present invention, the
25 mutation may or may not be the same in all alleles. Thus, different parts of the gene may be mutated in different alleles. The same part of the gene may also be mutated in different ways in different alleles. Potato genotypes having 2 or more alleles, most commonly 4 alleles, are known.

 Thus, with the method according to the present invention four different
30 varieties of potato may be produced, wherein also four different starch qualities may be synthesized, namely "gbssl-potato starch", "gbssl/ssIII-potato starch", "gbssl/ssII-potato starch" and "gbssl/ssII/ssIII-potato starch",

all with individual characteristics as to the composition of amylose and amylopectin ratio and as to the amylopectin structure. As a consequence thereof, its function in food and non-food applications is correlated to the solution stability from the altered starch composition.

5 Thus, in one aspect the present invention refers to an amylopectin potato starch which in one embodiment contains at least 99 % amylopectin, preferably 100 % amylopectin, and which in another embodiment additionally is provided with shorter chains and a higher degree of branching in the amylopectin molecule compared to native potato amylopectin.

10 More precisely, the fact that the amylopectin chains in the amylopectin potato starch according to the present invention in average are shorter than the chains of potato amylopectin means that the amylopectin chains in the amylopectin potato starch according to the present invention in average automatically also have a higher degree of branching than the chains in
15 native potato amylopectin. More precisely, the degree of branching is more than 5%, preferably more than 6%.

 The amylopectin potato starch according to the present invention may in its most preferred embodiments (two or three enzymes eliminated) be defined and differentiated compared to conventional amylopectin potato
20 starches by a freeze/thaw stability test (in which less than 30 % syneresis is obtained after 2-4, preferably 2, repeated freeze/thaw cycles, alternatively less than 15 % syneresis after 4 repeated freeze/thaw cycles. This test is presented in a poster at the V International Oat Conference & VII International Barley Genetics Symposium July 30 – August 6, 1996 at the University of
25 Saskatchewan, Saskatoon, Canada, by Å. Ståhl, G. Persson, L-Å Johansson, and H. Johansson with the poster “Breeding barley for functional food-starch”.

 As disclosed above, the starch biosynthetic process in a potato plant is changed in the inventive method by targeted mutagenesis using the CRISPR/Cas method, preferably the CRISPR/Cas9 method, which introduces
30 mutations in the gene loci encoding the GBSSI, SSIII and SSII enzymes. The achieved mutation/mutations lead(s) to a complete disruption of the activity of the GBSSI, SSIII, and SSII enzymes in the potato plant cell, which leads to a

new potato genotype which synthesizes a starch consisting of, more than 99 %, preferably 100%, amylopectin type molecules with unique properties compared to the parental potato it is derived from.

For the production of the CRISPR/Cas9 complexes the transcription
5 unit for sgRNA and encoding Cas9 can reside on the same or separate physical DNAs. The gene constructs are not limited to the sgRNA and the Cas9 disclosed above. In the case of other variants of Cas, the target nucleotide sequence may be shorter or longer than 20 bp.

In one embodiment of the inventive method, gene constructs encoding
10 sgRNA and Cas9 nuclease are transfected to potato protoplasts. The DNA encoding sgRNA and Cas9 is transiently expressed in the cell and is not transferred to later generations, thus not leaving any residual exogenous DNA in the resulting potato.

In a second embodiment, sgRNA and Cas9 protein are produced
15 outside the potato cell and are introduced by e.g. microinjection. According to this embodiment, no exogenous DNA is introduced into the cell, and thus there will be no residual exogenous DNA in the resulting potato.

In a third embodiment, T-DNAs encoding sgRNA and Cas9 are stably
20 introduced by particle bombardment or Agrobacterium mediated transformation, using Agrobacterium tumefaciens. Agrobacterium introduction of T-DNA can be performed by well-known transformation methods in the art, e.g. leaf disc or stem transformation or by agroinfiltration. DNA encoding sgRNA and Cas9 nuclease can in a preferred embodiment be transiently operating in the potato cell or be stably introduced in the potato genome. Stably introduced
25 DNA can subsequently be separated from introduced mutations by crossing, leading to a potato having no residual exogenous DNA. Importantly, the introduced mutation is stably transferred across the generations, thus giving rise to a new potato in which GBSSI and SSII and/or SSIII do not show any enzyme activity.

30 The cultivated potatoes are normally tetraploid and such potatoes are preferably used for the introduction of mutations. However, the methods and means disclosed here are also applicable for potato genotypes of higher or

lower ploidy level, e.g. for diploid genotypes. There are several methods well known in the art to change the ploidy level of potato cells.

sgRNAs, i.e. the targeting ribonucleotide sequences, targeting one or several locations in the same gene as well as sgRNAs targeting several
5 different genes and optionally different locations of these genes can be applied in one and the same introduction of mutational constructs or assemblies. Thus, one or more locations in the same gene can be targeted in the same step and/ one or more genes can be targeted in the same step.

Different methods can be used for the identification of successfully
10 mutated genes. Identifications of mutations can preferably be performed by PCR and fragment analysis for identification of indels via high resolution capillary electrophoresis.

Several methods for the identification of mutations in specific loci are known in the art such as PCR coupled to melting point analysis of an applied
15 probe, PCR and sequencing of amplified fragments spanning the targeted region for mutation or detection using CAPS, a method based on the loss of function of a restriction site located in the predicted cleavage site in the target region.

The methods disclosed can be applied in multiple rounds of application
20 to introduce mutations in all alleles of a gene or to introduce mutations in more than one gene or to introduce additional mutations in additional genes where application of targeting several genes has occurred. More specifically, already mutated genotypes can be stably transformed or agroinfiltrated, or used for production of protoplasts and transfected or microinjected for
25 introduction of additional mutations.

In one embodiment of the invention at least one allele of one gene is mutated in one application of the CRISPR/Cas9 complex. In a more preferred embodiment mutations are introduced into several alleles of one or several genes in one application of the CRISPR/Cas9 complex. In an even more
30 preferred embodiment of the invention all alleles of a gene or several genes are mutated in one application of mutation method. Importantly, to reach

mutations in all alleles of a gene, additionally rounds of application of the CRISPR/Cas9 complex might be needed.

Starch from the potato, in which the enzyme activities of GBSSI and/or SSIII, and/or SSII have been eliminated according to the above description, is
5 extracted and purified by washing the potato with water at room temperature in a rotating washing drum. The potatoes are grinded/rasped with cell disintegrators to liberate the starch granules from the cells. The potato mash obtained containing granular starch, fibers, and proteins is further screened using mesh sizes in the area from 60-160 μm of the screen so that the fiber
10 material is separated from the starch granules and the solubilized protein fraction. The starch suspension is further processed using screening equipment in which the potato fruit juice, consisting of solubilized potato protein and other nutritional components, is separated from the starch. The starch is mixed with fresh water and washed clean using hydrocyclone equipment,
15 decanter or washing centrifuge in which the water is changed and the starch is thereby washed until the protein level in the refined starch is less than 0.2% measured by the Kjeldahl nitrogen content method, with a conversion factor of 6.25. The starch slurry is dewatered on a rotating vacuum filter to a dry matter (DM) of 55-65%. The starch suspension is dried in a flash drier to
20 approx. 78-82% w/w DM. The purified starch is collected and stored at room temperature. The disclosed invention is not limited to the described extraction and purification method although it is considered to be basic knowledge and for a skilled man in the art how starch from potato tubers are produced.

Before drying, the starch can be separated into different granular sizes
25 giving one fraction with small granules of less than 25 μm , one fraction with large granules, i.e. 25-60 μm , or very large granules of more than 60 μm . Alternatively, it can be fractionated dry into different granular sizes. The present invention is not limited to the extraction processing of the starch from the potato, as this is considered to be common knowledge in starch
30 manufacturing.

The purified inventive starch may be inhibited by alkaline roasting or bleaching reaction with oxidizing agents. It may also be pre-gelatinized and

further dried with spray drying or drum drying to a dry content of more than 80% w/w DM, preferably more than 85% w/w DM, even more preferably more than 90% w/w DM. It may also be degraded to a molecular weight of 100 000 – 1 000 000 Da, preferably 300 000 – 800 000 Da, even more preferably
5 500 000 – 700 000 Da, with enzymatic modification or acid treating or pyrodextrinization or oxidation degradation, or combinations thereof.

Consequently, the achieved starch based on the obstruction of the production of the GBSSI and/or SSIII and/or SSII enzymes is freeze/thaw stable and has an extremely enhanced stability, i.e. robustness against
10 retrogradation, after being partly or totally gelatinized in a liquid suspension and preferably, but not exclusively, in the use for food applications.

In another aspect of the present invention the inventive amylopectin potato starch may be used in several different applications. In one embodiment, the purified novel amylopectin potato starch may be used in food
15 applications in its native state. The starch may alternatively be used in a modified state, wherein the starch has been modified by anyone of the modification methods known by a skilled man in the art. The most common modification methods are cross-linking, phosphorylation, acetylation, hydroxypropylation, 2-octenylsuccinylation with both the sodium and the aluminium
20 salt forms, succinylation, cationization, oxidation, enzymatic modification, acid treatment of starch, pyro-dextrinization and alkaline roasting of starches as well as combinations thereof. The present invention is not limited to the modification methods disclosed, as chemical or non-chemical modifications are considered as basic know-how. Thus, all kinds of modifications described
25 in literature and publications can be applied on the inventive amylopectin potato starch products.

The applications in which the purified inventive amylopectin potato starch can be used are common food applications in which starch and modified starches normally are used and can be found in literature. The
30 common applications are, but not limited to: fruit preparations, soups and sauces, confectionary, dairy products like yoghurt, crème fraiche, processed cheese, as a stabilizer of oil in water (O/W) emulsions as well as water in oil

(W/O) emulsions in liquid products and spreads and/or emulsions which are spray dried into a powder, e.g. spray dried functional oils like DHA, ARA, vitamin E etc. Further to this, the product can be used in coating applications like batters and breading's for deep fried potatoes, vegetables, chicken, beef
5 etc.

To conclude, the purified amylopectin starch may be used in the following food applications:

- as a texturizer in liquid formulations, wherein the starch concentration is 0.05-15 % w/w, preferably 0.5-10 % w/w, more preferably 1.5-6 %
10 w/w,
- as a texturizer in formulations wherein the food product is additionally frozen,
- preferably in coating applications in which a vegetable or animal derived food product is coated with the starch and/or starch in a
15 formulation with other ingredients, and followed by additional deep frying.
- as a stabilizer of water-in-oil (W/O) emulsions in liquid products and spreads, or
- as an emulsion stabilizer for oil-in-water (O/W) emulsions in a liquid
20 state and in applications where the oil-in-water emulsion is additionally spray dried to a powder, wherein said amylopectin potato starch first has been modified with sodium octenyl succinate or aluminium octenyl succinate.

25 Further, the purified amylopectin starch may also be used in paper applications, preferably for surface sizing and coating of paper, or as a wet-end starch in paper production.

In a further aspect, the present invention also encompasses a product containing said amylopectin potato starch, wherein the nature of said product
30 is related to any one of the above mentioned uses.

Experiments

Example 1 – Sequencing of target genes

Information about the GBSSI, SSII, and SSIII genes are shown in Fig. 1, wherein A represents the *Solanum tuberosum* GBSSI gene (GenBank accession No. A23741.1), in which 13 exons are marked with arrows. Sequencing primers covering 508 bp of exon 8 and splice regions are marked with StGBSSExf and StGBSSExr. Target regions are marked with GT1, GT2, GT3, and GT4. Fig 1B represents the *Solanum tuberosum* SSII gene (GenBank accession No. NW_006238930.1), in which 8 exons are marked with arrows. Sequencing primers covering 1352 bp of exon 1 and splice regions are marked StSSExon f and StSS2Exon r. Target regions are marked with S2T1, S2T2 and S2T3. Fig 1C represents the *Solanum tuberosum* SSIII gene (GenBank accession No. NW_006239023.1), in which 15 exons are marked with arrows. Sequencing primers covering 966 bp of exon 3 and splice regions are marked StSS3Exf and StSS3Exr. Target regions are marked with S3T1, S3T2 and S3T3.

Allelic variation of parts of the GBSS, SSII, and SSIII genes in the tetraploid potato variety Kuras was determined as described below. The results of a determination of single exons of the target genes are shown in Fig. 2 A-C.

The GBSS gene

Genomic DNA from the potato variety Kuras was used to amplify a 508 bp fragment of the GBSS gene, covering exon 8 as well as adjacent introns (StGBSSExf and StGbSSExr, see Fig. 1A). Genomic DNA from leaf tissue of Kuras was extracted using a Gene Jet Plant Genomic DNA Purification Mini Kit (Thermo Fisher Scientific, Waltham USA). 250 ng DNA was used as template in a PCR reaction with 0.5 µmol of primers StGBSSExf and StGBSSExr (Sigma- Aldrich, Saint Louis, USA), Phusion HF polymerase, dNTP, and HF buffer (Thermo Fisher Scientific, Waltman, USA) according to the suppliers instructions.

The primers used were;

StGBSSExf: 5'-CCTCTTCTCAATCTTCCTGATGAATTCAG-3' SEQ. ID. NO. 11

StGBSSExr: 5'-AGAGCCTCCTTTAGTAAAGGTTTTGCGTC-3' SEQ. ID. NO. 12

The amplification was performed with the following cycling conditions:

1. 98° 1 min
- 5 2. 98° 10 s
3. 64° 10 s
4. 72° 15 s
5. Step 2-4 30 cycles
6. 72° for 10 minutes

10

The PCR products were ligated to pJET1.2/blunt using a CloneJET PCR Cloning Kit (Thermo Fisher Scientific, Waltham, USA) following transformation to One Shot® TOP10 Chemically Competent *E. coli* (Invitrogen, Carlsbad, USA). After 1 night incubation at 37°C on LB plates containing 100 µg/mL ampicillin, randomly picked colonies were subjected to DNA isolation and sequenced by Sanger sequencing (GATC Biotech, Konstanz, Germany).

The sequenced alleles of exon 8 (marked StG1-StG4) in the GBSS gene were compared to each other and the results showed that all alleles were highly homologous (See Fig. 2), and that only one allele had a sequence variation in exon 8 with an adenine (A) → guanine (G) shift at one position (marked with a box in Fig. 2 A showing 244 bp of the 508 bp fragment). The results also showed that the 3 identical alleles (StG1-StG3) had a 100% homology to a published GBSS gene (GenBank accession No. A23741.1).

25

The SSII gene

Genomic DNA from the potato variety Kuras was used to amplify a 1352 bp fragment of the SSII gene, covering exon 1 as well as adjacent introns (StSS2Exon f and StSS2Exon r). Genomic DNA from leaf tissue of Kuras was extracted using Gene Jet Plant Genomic DNA Purification Mini Kit (Thermo Fisher Scientific, Waltham USA). 250 ng DNA is used as template in a PCR reaction with 0.5 µmol of primers (Sigma-Aldrich, Saint Louis, USA),

30

Phusion HF polymerase, dNTP, and HF buffer (Thermo Fisher Scientific, Waltham, USA) according to the suppliers instructions.

The primers used were;

StSS2Exon f: 5'-TGCTTCACAATCCCTAATTCTC-3' SEQ. ID. NO. 13

5 StSS2Exon r: 5'-ATCCAAAAGTGTCTCTTGACTG-3' SEQ. ID. NO. 14

Amplification was performed with the following cycling conditions;

1. 98° 1 min
2. 98° 20s
3. 63° 30s
- 10 4. 72° 30s
5. Step 2-4 30 cycles
6. 72° for 10 minutes

The PCR product was ligated to pJET1.2/blunt using a CloneJET PCR
 15 Cloning Kit (Thermo Fisher Scientific, Waltham, USA) following transforma-
 tion to One Shot® TOP10 Chemically Competent *E. coli* (Invitrogen,
 Carlsbad, USA). After 1 night incubation at 37 °C on LB plates containing 100
 µg/mL ampicillin, randomly picked colonies were subjected to DNA isolation
 and sequenced (GATC Biotech, Konstanz, Germany). The sequenced alleles
 20 of exon 1 (marked StS2_exon1- StS2_exon4) in the SSII gene were com-
 pared to each other. Base shift variations were found at two positions (Figure
 2B), one position with an adenine (A) → cytosine (C) shift and one position
 had a guanine (G) → thymine (T) shift (marked with boxes in Figure 2B
 showing 252 bp of the 1352 bp fragment).

25 The SSIII gene

Genomic DNA from leaf tissue of Kuras was extracted using a Gene
 Jet Plant Genomic DNA Purification Mini Kit (Thermo Fisher Scientific,
 Waltham USA). 250 ng DNA was used to isolate a 966 bp gene fragment
 covering exon 3 as well as adjacent introns of SSII (StSS3Exf and StSS3Exr,
 30 see Fig. 1 C). A PCR reaction was performed with 0.5 µmol of primers
 StSSExf and StSSExr (Sigma Aldrich, Saint Louis, USA), Phusion HF

polymerase, dNTP, and HF buffer (Thermo Fisher Scientific, Waltman, USA) according to the supplier's instructions.

The primers used were;

StSS3Exf: 5'-GCTTAGAGAAGCGGCTATGCGTG-3' SEQ. ID. NO. 15

5 StSS3Exr: 5'-TCCATCATATATGCATCCAATGGAACC-3' SEQ. ID. NO. 16

Amplification was performed with the following cycling conditions;

1. 98° 1 min
2. 98° 10s
3. 64° 10s
- 10 4. 72° 15s
5. Step 2-4 30 cycles
6. 72° for 10 minutes

The PCR product was ligated to pJET1.2/blunt using a CloneJET PCR
15 Cloning Kit (Thermo Fisher Scientific, Waltham, USA) following transforma-
tion to One Shot® TOP10 Chemically Competent E. coli (Invitrogen,
Carlsbad, USA). After 1 night incubation at 37 °C on LB plates containing 100
µg/mL ampicillin, randomly picked colonies were subjected to DNA isolation
and sequenced (GATC Biotech, Konstanz, Germany).

20 The sequenced SSIII alleles of exon 3 (marked StS1-StS4) were
compared to each other. Two of the four sequenced SSIII alleles were found
having base shift variations (Figure 2C) in exon 3 with an adenine (A) →
guanine (G) shift in one allele and cytosine (C) → thymine (T) in two of the
alleles (marked with boxes in Figure 2C showing 271 bp of the 966 bp
25 fragment).

Example 2 – Constructs targeting the GBSSI, SSII, and SSIII genes

The different target regions in the GBSSI, SSII, and SSIII genes are
shown in Fig. 1.

Fig. 3 is a schematic drawing of a construct designed for
30 CRISPR/Cas9 mediated induction of mutations in the GBSS, SSII, and SSIII
genes. From left to right; terminator (poly-T), sgRNA scaffold, target regions
(either of GT1, GT2, GT3, GT4, S2T1, S2T2, S2T3, S3T1, S3T2, or S3T3),

U6 promoter of either *Arabidopsis thaliana* or *Solanum tuberosum* origin, 35S promoter of cauliflower mosaic virus origin (CaMV), nuclear localization sequence (NLS), plant codon optimized Cas9(Cas9) gene, NLS and terminator (NOS).

5 Constructs targeting the GBSSI gene

Four target regions for inducing mutations in the GBSS gene were selected and named GT1, GT2, GT3 and GT4 (see Fig. 1A), each target region consisting of 20 bp located directly upstream a 5'-NGG-3' PAM site and with, except for GT2, the nucleotide G in the 5' end. The target regions
10 were identified and selected using a CRISPR-design web based tool (<http://crispr.mit.edu/>). GT1 and GT2 are located within exon 8, with GT1 spanning a region with an allelic variation, while GT3 is located in exon 1 and GT4 is located in exon 9 (GenBank accession no. A23741.1). The four target sequences are all located on the positive strand in the GBSS gene.

15 Target sequences;

GT1: 5'-GATATTAGAATCACATAGGG-3'	SEQ. ID. NO. 1
GT2: 5'-TGTTGACAAGGGTGTTGAAT-3'	SEQ. ID. NO. 2
GT3: 5'-GCTACCATTGTTTGTGGAAA-3'	SEQ. ID. NO. 3
GT4: 5'-GACAAGAAGATCCCTTTGAT-3'	SEQ. ID. NO. 4

20 A fragment containing a promoter, a guide sequence, i.e. the targeting ribonucleotide sequence homologous to the target sequence, and a sgRNA scaffold were synthetically produced for each of the four guide RNAs and were received cloned in a pEx-A2 vector (Eurofins Genomics, Ebersberg, Germany). A U6 promoter of *Arabidopsis thaliana* (GenBank accession no. X52527.1 or *Solanum tuberosum* origin (GenBank accession No. Z17290.1)
25 was chosen for driving the expression of the guide sequence and the sgRNA scaffold (see Fig. 3). The fragments had an additional XhoI site synthesized at the 5' end of the fragment. Since the U6 promoter is dependent on a G nucleotide at the 5' end of the guide sequence to initiate transcription, a G
30 was synthetically added at position 1 of the GT2 targeting nucleotide sequence. The synthesized fragments were cloned together with a Cas9 gene driven by a 35S promoter in the standard Gateway® entry vector

pENTR11 (Invitrogen, Carlsbad, USA) using 3-fragment cloning (see Fig. 3). All constructs were transformed to One Shot® TOP10 Chemically Competent *E. coli* (Invitrogen, Carlsbad, USA). Additionally, Cas 9 and target guide GT1 expression cassettes in their original vectors were transformed to One Shot® TOP10 Chemically Competent *E. coli* (Invitrogen, Carlsbad, USA) for co-expression.

Constructs targeting the SSII gene

Three target regions for SSII were selected and named S2T1, S2T2 and S2T3 (See Fig. 1B), both located directly upstream a 5'-NGG-3' PAM site and with the nucleotide G in the 5' end of a 20 bp fragment adjacent the PAM site. The target regions were identified using the CRISPR-design web based tool (<http://crispr.mit.edu/>). S2T1 is located on the negative strand and S2T3 on the positive strand within exon 1, and S2T2 is located on the negative strand in exon 2 (GenBank accession no. NW_006238930.1).

Target sequences;

S2T1: 5'-GTGCTAAAAGGGGTAAGTTG-3'	SEQ. ID. NO. 5
S2T2: 5'-GGGGTGCCCTTTCATCGGCC-3'	SEQ. ID. NO. 6
S2T3: 5'-GCTCCAGTAGAGAGCAAATG-3'	SEQ. ID. NO. 7

A fragment containing a promoter, a guide sequence, i.e. the targeting ribonucleotide sequence homologous to the target sequence, and a sgRNA scaffold were synthetically produced for the three guide RNAs (Eurofins Genomics, Ebersberg, Germany). A U6 promoter of *Arabidopsis thaliana* (X52527.1) origin was used for driving the expression of the guide sequence and the sgRNA (see Fig. 3). The fragments had an additional XhoI site synthesized at the 5' end. The synthesized fragments were cloned together with a Cas9 gene driven by a 35S promoter in the standard Gateway® entry vector pENTR11 (Invitrogen, Carlsbad, USA) using 3-fragment cloning (Figure 3). All constructs were transformed to One Shot® TOP10 Chemically Competent *E. coli* (Invitrogen, Carlsbad, USA).

Constructs targeting the SSIII gene

Three target regions for SSIII were selected and named S3T1, S3T2 and S3T3 (see Fig. 1C), each located directly upstream a 5'-NGG-3' PAM site

and with the nucleotide G in the 5' end of a 20 bp fragment adjacent the PAM site. The target regions were identified using the CRISPR-design web based tool (<http://crispr.mit.edu/>). S3T1 is located on the negative strand and S3T2 is located on the positive strand within exon 4 and S3T3 is located on the positive strand in exon 1 (GenBank accession no. NW_006239023.1).

Target sequences:

S3T1: 5'-GAACATCTGAACCAAATTTC-3'	SEQ. ID. NO. 8
S3T2: 5'-GAGGTGGCAATGGACCCAGG-3'	SEQ. ID. NO. 9
S3T3: 5'-GGAACTAATGCCAGTAGCA-3'	SEQ. ID. NO. 10

A fragment containing a promoter, a guide sequence, i.e. the targeting ribonucleotide sequence homologous to the target sequence, and a sgRNA scaffold were synthetically produced for each of the guide RNAs (Eurofins Genomics, Ebersberg, Germany). A U6 promotor of *Arabidopsis thaliana* (X525origin was used for driving the expression of the guide sequence and the sgRNA (see Fig. 3). The fragments had an additional XhoI site synthesized at the 5'. The synthesized fragments were cloned together with a Cas9 gene driven by a 35S promoter in the standard Gateway® entry vector pENTR11 (Invitrogen, Carlsbad, USA) using 3-fragment cloning (see Fig. 3). All constructs were transformed to One Shot® TOP10 Chemically Competent *E. coli* (Invitrogen, Carlsbad, USA).

Example 3 - gRNA synthesis and design of RNA-Protein complex (RNP)

One target region each for inducing mutations in GBSS (GT4), SSII (S2T3) and SSIII (S3T2) were selected to produce gRNA using GeneArt™ Precision gRNA Synthesis Kit (Thermo Fisher Scientific, Waltham, USA) according to the supplier's instructions.

Primers;

GT4+T7f	TAATACGACTCACTATAGACAAGAAGATCCCTTTGAT	SEQ.ID.NO. 39
GT4+trRNAr	TTCTAGCTCTAAACATCAAAGGGATCTTCTTGT	SEQ.ID.NO. 40
S3T2+T7f	TAATACGACTCACTATAGAGGTGGCAATGGACCCAGG	SEQ.ID.NO. 41
S3T2+trRNAr	TTCTAGCTCTAAACCCTGGGTCCATTGCCACCT	SEQ.ID.NO. 42
S2T3+T7f	TAATACGACTCACTATAGCTCCAGTAGAGAGCAAATG	SEQ.ID.NO. 43
S2T3+trRNAr	TTCTAGCTCTAAACCATTGCTCTCTACTGGAG	SEQ.ID.NO. 44

The respective gRNAs were composed of a U6 promoter, a guide sequence and a RNA scaffold/tracer RNA. Respective gRNA was incubated with GeneArt™ Platinum™ Cas9 Nuclease (Thermo Fisher Scientific, Waltham, USA) for 10 minutes at room temperature before transfected to
5 purified protoplast.

Example 4 – PEG mediated protoplast transfection and regeneration

Table 1 below shows results of a protoplast transfection experimental setup. The experiments are numbered P1000 - P21000. Targeting nucleotide sequences, PEG (%), DNA (µg), transfection time (min), and the number of
10 protoplasts used was varied and defined for each experiment. The mutation frequency (%) is calculated for each experiment based on mutated lines detected, using high resolution fragment analysis, of the total number of regenerated lines analyzed. The frequency of lines with more than 1 allele mutated (%) is calculated based on multiple mutated alleles detected, using
15 high resolution fragment analysis and Sanger sequencing, of all mutated lines found in experiment.

The potato cultivar Kuras was propagated in 1 x Murashige and Skoog (MS) medium including vitamins (pH 5.8) including 3% sucrose, 8 µM silver thiosulphate (STS), and 0.7% phytoagar (Duchefa, Haarlem, The
20 Netherlands) in a controlled environmental chamber at 24°C for 16h in light and 20°C for 8h in dark.

Homology-directed induction of mutations was made in, 1) GBSSI, 2) GBSSI + SSIII, 3) GBSSI + SSII, and 4) GBSSI + SSII + SSIII, by transfection of one, two or three of the above described constructs or RNPs in protoplasts
25 isolated from top leaf tissue of five to six weeks old potato plantlets. Transient expression was preferred over traditional transformation to avoid stable integration of DNA in the genome. However, stable transformation following crossings and segregation of inserted genetic material is also used with the aim to induce targeted mutations in said genes. Transfection quality DNA,
30 isolated from above described constructs, were purified with a Qiagen Plasmid Mini Kit (Qiagen, Hilden, Germany) according to manufacturer's instructions.

Transient expression of the sgRNA-Cas9 constructs with the targeting ribonucleotide sequences homologous to the target regions GT1, GT2, GT3, GT4, S2T1, S2T2, S2T3, S3T1, S3T2, and S3T3 as well as expression of the targeting ribonucleotide -complex and Cas9 from separate vectors, were made through a PEG-mediated transfection method. Furthermore, RNP of GT4, GT4+S3T2, and GT4+S3T2+S2T2 was delivered to protoplasts using the same PEG-mediated transfection method. The protoplast isolation and transfection method was based on a method described by Nicolia et al 2014 [12], adapted for the CRISPR/Cas9 method. The transfection was performed at room temperature using 1.0×10^5 or 1.6×10^5 protoplasts in 100 μ l, 12.5, 25 or 40% PEG4000 (Sigma-Aldrich, Saint Louis, USA) and 5, 10 or 15 μ g of purified DNA during an incubation time of 3 or 30 min (Table 1). After transfection, the protoplasts were embedded in alginate (Sigma-Aldrich, Saint Louis, USA) and were incubated at 25 °C in dark until the first cell division took place. During the following 2 weeks the light was stepwise increased and reached full light (Memmert, Schwarbach, Germany) when callus visible to naked eye was formed. Approximately four weeks after transfection, each callus was released and incubated in liquid media for additionally two to four weeks for further callus development and shoot induction. The enlarged calli were then transferred to solid medium for shoot development.

Regeneration, i.e development of shoots from the enlarged calli,, was found in all of the different experimental setups used (see Table 1 in Example 5 below). The first shoot emerged approximately 3 months after transfection and up to 25% of all calli had developed a shoot after 6 months.

Example 5 – Mutational screening using high resolution fragment analysis

Screening for induced mutations of a large number of pooled calluses or regenerated plants was made using a high resolution fragment analysis based on 96-format DNA extraction, PCR amplification and capillary electrophoresis. Individual lines were numbered consecutively based on the experiment, e.g P1001, P1002 etc (see also Fig. 5). Callus or a leaf sample of approximately 5 x 5 mm in diameter from a 2-4 weeks old plantlet of each regenerated shoot was homogenized in 500 μ l lysis buffer (100 mM Tris, 50

mM EDTA and 1% SDS, pH 9.0) in a Retsch Mixer Mill MM400 for 30 s at 30 Hz (Retsch, Haan, Germany). DNA was extracted from 200 µl cleared lysate in a Qiacube HT extraction robot using a QIAamp 96 DNA QIAcube HT Kit utilising the standard DNA extraction protocol provided by the supplier

5 (Qiagen, Hilden, Germany) with addition of RNase A to a final concentration of 0.1 mg/ml in the elution buffer. PCR amplification was made on 0.5 µl isolated DNA using Phusion HF polymerase (Invitrogen, Carlsbad, USA) according to the manufacturer's instructions. The forward primers were labelled at the 5' end with the fluorescent dyes FAM, NED or PET (Thermo

10 Fisher Scientific, Waltham USA) depending on the target gene.

Primers:

GT1 and GT2

StGBSSexon1f: FAM-5'-ACTGGATGAAGGCTGGGATA-3' SEQ. ID. NO. 17

15 StGBSSexon1f: VIC-5'-ACTGGATGAAGGCTGGGATA-3' SEQ. ID. NO. 17

StGBSSexon1r: 5'-ATTTGTCAGTCGCTGGGTTC-3' SEQ. ID. NO. 18

GT3

StGBSS(GT3)f: FAM-5'-AGGAACCATACTCTGACTCAC-3' SEQ. ID. NO. 19

20 StGBSS(GT3)f: VIC-5'-AGGAACCATACTCTGACTCAC-3' SEQ. ID. NO. 19

StGBSS(GT3)f: 5'-TTTTGCTCCAAGGACCAAC-3' SEQ. ID. NO. 20

GT4

StGBSS(GT4)f: FAM-5'-TCTCTATACAGGTCATGGACG-3' SEQ. ID. NO. 21

25 StGBSS(GT4)f: VIC-5'-TCTCTATACAGGTCATGGACG-3' SEQ. ID. NO. 21

StGBSS(GT4)f: 5'-GCAGCAACAAGAATATCTGAAC-3' SEQ. ID. NO. 22

S2T1

StSS2(S2T1)f: PET-5'-TGGAATCAGTTCCACCCC-3' SEQ. ID. NO. 23

30 StSS2(S2T1)f: VIC-5'-TGGAATCAGTTCCACCCC-3' SEQ. ID. NO. 23

StSS2(S2T1)r: 5'-CATGGCTAAAACCTTTTGTCTC-3' SEQ. ID. NO. 24

S2T2

StSS2(S2T1)f: PET-5'-CGATAAAAATACACCGCCTGC-3' SEQ. ID. NO. 25

StSS2(S2T1)f: VIC-5'-CGATAAAAATACACCGCCTGC-3' SEQ. ID. NO. 25

StSS2(S2T1)r: 5'-TCTGGAGGGACATTCAACG-3' SEQ. ID. NO. 26

5

S3T1 and S3T2

StSS3(S3T1,S3T2)f: NED-5'-ATCCAAGCTGGAAGCAGTGT-3' SEQ. ID. NO. 27

StSS3(S3T1,S3T2)f: VIC-5'-ATCCAAGCTGGAAGCAGTGT-3' SEQ. ID. NO. 27

StSS3(S3T1,S3T2)r: 5'-GACATGGGTGCCATTTTCAG-3' SEQ. ID. NO. 28

10

S3T3

StSS3(S3T3)f: NED-5'-TGATGACAAGGATGCTGTAAAG-3' SEQ. ID. NO. 29

StSS3(S3T3)f: VIC-5'-TGATGACAAGGATGCTGTAAAG-3' SEQ. ID. NO. 29

StSS3(S3T3)r: -5'-TCAACATCCACCTGCAATATC-3' SEQ. ID. NO. 30

15

The amplification was performed with the following cycling conditions;

1. 98° 1 min
2. 98° 10s
3. 64° 10s
- 20 4. 72° 15s
5. Step 2-4 30 cycles
6. 72° for 10 minutes

0.5 µl of the PCR product (diluted 1:20) was mixed with 0.5 µl wild type
 25 control PCR fragment (diluted 1:20) and 9.0 µl Hi-Di™ Formamide (Thermo
 Fisher Scientific, Waltham USA), incubated at 95° for 3 minutes and chilled
 on ice. The wild type control fragment, amplified under the same PCR
 conditions but using a diverging labelled primer (VIC-labelled), was added to
 each sample in order to distinguish alleles with indels from non-mutated
 30 alleles (see Fig. 4). High resolution fragment separation was performed on a
 3500 Genetic analyser (Thermo Fisher Scientific, Waltham USA) according to
 the manufacturer's instructions. Data was handled with a 3500 Series Data

Collection Software 3. Mutated alleles were identified by the presence of more than one peak in the obtained raw data (see Fig. 4).

Fig. 4 shows the results of a high resolution fragment analysis of CRISPR/Cas9 mediated mutations of the GBSSI gene, exemplified by lines mutated in the GT1 target region. A represents Line P1003 with 1 mutated allele detected, B represents Line P1004 with 2 mutated alleles detected, C represents Line P10084 with 4 mutated alleles detected verified by lack of wild type allele and D represents the wild type GBSS gene fragment.

The results show that mutations were induced using all transfection conditions used. The results also show that mutations are induced using any of the target regions described (see Table 1 below). Inserts and deletions (indels) down to 1 bp were detected with the described method. Multiple alleles with induced indels differing in size were distinguished by visible multiple peaks (see Fig. 4).

Table 1

Experiment	Target sequence	Promoter	PEG (%)	DNA (ug)	Transfection time (min)	Number of protoplasts	Lines analyzed	Mutated lines	Mutation frequency (%)	Lines with >1 allele mutated	Frequency of lines >1 allele mutated
P1000	GT1	At	25	5	3	160000	85	7	8,2	3	42,9
P2000	GT1	At	25	5 + 5	3	160000	130	3	2,3	1	33,3
P3000	GT2	At	25	5	3	160000	214	2	0,9	0	0,0
P5000	GT1	At	12,5	10	3	160000	149	7	4,7	2	28,6
P6000	GT1	At	40	15	30	100000	17	4	23,5	1	25,0
P7000	GT2	At	12,5	10	3	160000	208	11	5,3	1	11,1
P8000	GT2	At	40	15	30	100000	36	2	5,6	1	50,0
P9000	GT3	St	40	15	30	100000	71	1	1,4	1	100
P10000	GT4	St	12,5	10	3	160000	157	9	5,7	3	37,5
P11000	GT4	St	40	15	30	100000	118	2	1,7	1	50,0

P12000	GT1	At	25	5 + 5	3	100000	30	5	16,7	3	60,0
P12000	S3T1	At	25	5 + 5	3	100000	30	1	3,33	1	100
P13000	GT2	At	25	5 + 5	3	100000	38	4	10,5	1	25,0
P13000	S3T1	At	25	5 + 5	3	100000	38	0	0	0	0
P14000	GT1 + GT2	At	25	5 + 5 + 5	3	100000	57	8	14,0	4	50,0
P14000	S3T1	At	25	5 + 5 + 5	3	100000	57	1	1,8	1	100
P15000	GT1+GT2	At	25	5 + 5	3	100000	41	4	9,8	0	0
P17000	GT3	At	40	6,5+15	30	100000	10	1	10,0	0	0
P17000	S3T3	At	40	6,5+15	30	100000	10	2	20,0	0	0
P18000	GT4	At	40	15+15	30	100000	20	6	30,0	1	16,7
P18000	S3T2	At	40	15+15	30	100000	20	4	20,0	0	0
P19000	GT3	At	40	6,5+15+15	30	100000	19	2	10,5	0	0
P19000	S2T1	At	40	6,5+15+15	30	100000	19	7	36,8	5	71,4
P19000	S3T2	At	40	6,5+15+15	30	100000	19	3	15,8	1	33,3
P20000	GT4	At	40	15+1,8+15+1 5	30	100000	21	3	14, 3	0	0
P20000	GT3	At	40	15+1,8+15+1 5	30	100000	21	0	0	0	0
P20000	S2T2	At	40	15+1,8+15+1 5	30	100000	21	1	4,8	0	0
P20000	S3T3	At	40	15+1,8+15+1 5	30	100000	21	1	4,8	0	0
P21000	GT4	At	40	15+15+15	30	100000	16	1	6,25	0	0
P21000	S2T2	At	40	15+15+15	30	100000	16	1	6,25	0	0
P21000	S3T2	At	40	15+15+15	30	100000	16	5	31,3	4	80,0

Table 2 shows the results of a high resolution fragment analysis of RNP CRISPR/Cas9 mediated mutations of the GBSSI gene, SSII gene, and SSIII gene on a pool of calluses.

Table 2

RPN	No of calli	Indels detected
GT4	4	-4,-2,0
GT4	3	-9,-6,-4,0,1
S3T2	3	-4,-2,-1
GT4	10	-5,-4,-2,0
S3T2	10	-2,0
GT4	10	-15,-6,-5,-3,-2,0
S3T2	10	-6,-3,-2,0,1

Example 6 – Analysis of mutations

Fig. 5 shows the results of genotyping of individual alleles with induced mutations in GT1, GT2, GT3, GT4, StT1, S2T2, S3T1, and S3T3 target regions. P1000-P21000 are individual lines. Deleted nucleotides are shown with hyphens, and inserted nucleotides are shown in bold. The PAM site is underlined in each wild type (WT) fragment.

Lines of mutations identified with the high resolution fragment analysis method were subjected to genotyping to determine the exact size and location of the mutation. PCR amplification covering the respective target region in the individual lines were cloned and analyzed by DNA sequencing (Eurofins Genomics, Ebersberg, Germany). Fragments spanning the predicted Cas9-cut site was amplified using 0.5 µl isolated DNA (described under Example 4), 0.25 µM of each forward and reverse primer and with Phusion polymerase (Invitrogen, Carlsbad, USA) according to the manufacturer's instructions.

Primers:

GT1 and GT2

StGBSSexon1f: 5'-ACTGGATGAAGGCTGGGATA-3' SEQ. ID. NO. 17

StGBSSexon1r: 5'-ATTTGTCAGTCGCTGGGTTC-3' SEQ. ID. NO. 18

GT3

StGBSS(GT3)f: 5'-AGGAACCATACTCTGACTCAC-3' SEQ. ID. NO. 19

StGBSS(GT3)r: 5'-TTTTGCTCCAAGGACCAAC-3' SEQ. ID. NO. 20

GT4

StGBSS(GT4)f: 5'-TCTCTATACAGGTCATGGACG-3' SEQ. ID. NO. 21

StGBSS(GT4)f: 5'-GCAGCAACAAGAATATCTGAAC-3' SEQ. ID. NO. 22

5

S2T1

StSS2(S2T1)f: 5'-TGGAAATCAGTTCCACCCC-3' SEQ. ID. NO. 23

StSS2(S2T1)r: 5' - CATGGCTAAAACCTTTTTGCTC-3' SEQ. ID. NO. 24

10 S2T2

StSS2(S2T1)f: 5'-CGATAAAAATACACCGCCTGC-3' SEQ. ID. NO. 25

StSS2(S2T1)r: 5'-TCTGGAGGGACATTCAACG-3' SEQ. ID. NO. 26

S3T1 and S3T2

15 StSS3(S3T1,S3T2)f: 5'-ATCCAAGCTGGAAGCAGTGT-3' SEQ. ID. NO. 27

StSS3(S3T1,S3T2)r: 5' -GACATGGGTGCCATTTTCAG-3' SEQ. ID. NO. 28

S3T3

StSS3(S3T3)f: 5'-TGATGACAAGGATGCTGTAAAG-3' SEQ. ID. NO. 29

20 StSS3(S3T3)r: -5'-TCAACATCCACCTGCAATATC-3' SEQ. ID. NO. 30

The amplification was performed with the following cycling conditions;

1. 98° 1 min
2. 98° 10s
- 25 3. 64° 10s
4. 72° 15s
5. Step 2-4 30 cycles
6. 72° for 10 minutes

30 The PCR products were ligated to pJET1.2/blunt using a CloneJET PCR Cloning Kit (Thermo Fisher Scientific, Waltham, USA) following transformation to One Shot® TOP10 Chemically Competent E. coli (Invitrogen,

Carlsbad, USA). After 1 night incubation at 37 °C on LB plates containing 100 µg/mL ampicillin, randomly picked colonies were sequenced (GATC Biotech, Konstanz, Germany).

The results confirm that mutations are induced in the GBSSI, SSII and
5 SSIII genes. The results also show that mutations are induced in multiple genes when constructs targeting two or three genes are co-transfected (Table 1, Fig. 5). The results also confirmed that mutations were induced using any experimental conditions used. Furthermore, mutations are induced in one or multiple alleles, independent of the experimental conditions and the targeting
10 nucleotide sequence used, with the exception of GT1 flanking an allelic variation (Table 1). The mutation frequencies were found to be up to 37%, depending on the experimental setup. The frequency of multiple alleles mutated was found to be generally very high, and in a few experimental setups as high as 100% of detected mutated lines (see Table 1). To gain a
15 complete disruption of enzyme activities, all 4 alleles of the used tetraploid potato genotype were targeted for each gene. To reach mutations in all 4 alleles of a gene, additionally rounds of protoplast isolation and transfection are applied when needed.

Example 7 – In-vitro microtuber production

20 Shoots are grown on a microtuber induction medium consisting of 4.4 g/L MS- medium, 2.5 mg/L kinetin, 0.5 mg/L abscisic acid (ABA) , 8% sucrose, and 200 mg/L claforan in dark at 25°C. After 2-5 weeks microtubers have developed and are harvested. Microtubers are crushed and stained with Lugol's solution (6.7 g/L KI + 3.3 g/L I₂) mixed with glycerol (1:1). The starch
25 composition is visualized under light microscope where microtubers having > 92% amylopectin content are stained red-brown in color while starch containing > 9% amylose is stained blue. Starch is extracted by grinding microtubers in 2 ml 70% EtOH, followed by filtration through a nylon filter with a small mesh size. 8 ml 70% ethanol is added to the samples, followed by
30 centrifugation at 1000 x g for 10 min. The ethanol is removed and the starch is left to air-dry in room temperature overnight. The isolated starch is further used for analysis as described under Examples 8-10.

Example 8 – Greenhouse minituber production

Mutated lines are grown in soil in a greenhouse at 16 hours, 18/15°C day/night temperature, supplementary light intensity of approximately 200 $\mu\text{mol s}^{-1} \text{m}^2$ photons and 60% relative humidity. Each line is planted as in-vivo
5 cuttings in biological replicates in 7.5 L pots. Starch is isolated from developed minitubers by homogenization in a fruit juicer. Tris-HCl (pH 7.5, 50 mM), Na-dithionite (30 mM), and EDTA (10 mM) is added to the liquid fraction. Starch granules are allowed to sediment. The granules are washed four times with the same buffer and three times with acetone before drying overnight at
10 room temperature. The isolated starch is further used for analysis as described under Examples 9-11.

Example 9 - Starch stability evaluation

A 3 % w/w water suspension of starch is prepared by mixing 15 g DM of the purified gbssl-PS (potato starch), gbssl/ssIII-PS and gbssl/ssII-PS, and
15 gbssl/ssIII/ssII-PS starch, respectively, with 500 g water. The starch suspensions are heated in a water bath to 95°C and kept at 95°C for 30 minutes during continuous agitation. The starch solutions are put in a refrigerator for cooling down to 20 °C and consequently kept at room temperature. The viscosity of the solution is measured at room temperature with a Brookfield LV
20 directly after the solution has reached 20°C and methodically once per day for 7 days. As reference, similar procedures were performed with commercialized available amylopectin starches, i.e. waxy maize starch with less than 1% amylose (WMS), commercialized waxy potato starch with less than 2% amylose (WPS), commercialized available waxy rice starch with less than 4%
25 amylose (WRS) and commercially available waxy barley starch with less than 0.5% amylose (WBS).

The experiment demonstrates that the solutions of the starches obtained with the method according to the present invention are more stable than commercially available waxy potato starch. It is also clear that the starch
30 solution based on the gbssl/ssIII/ssII-PS is significantly more stable and thus robust against retrogradation compared with both the available waxy potato starch but also compared with the commercialized available waxy maize

starch. The result further proves that starches obtained with the method according to the present invention are not known before and that the robustness against retrogradation from the potato starches can be defined as $WPS < (gbssl-PS) < (gbssl/ssII-PS) < (gbssl/ssIII-PS) < (gbssl/ssIII/ssII-PS)$.

5 Example 10 – Starch retrogradation evaluation

A 5 % (w/w) water suspension of starch is prepared by mixing 22.5 g DM of the purified gbssl-PS, gbssl/ssII-PS, gbssl/ssIII-PS, and gbssl/ssIII/ssII-PS starch, respectively, with distilled water to a total weight of 450 g. The starch suspension is put into a Brabender Amyloviscograph model
10 E, using a 700 cmg torsion spring. In the Brabender Amyloviscograph the starch suspension is heated to 95 °C and is after the holding time of 15 min cooled to 25 °C. The viscosity is continuously measured and printed during the cooling phase. The starch pastes are stored at room temperature and are further measured with a Stable Micro System Texture Analyzer for 7 days. As
15 reference, similar procedures were performed with commercially available amylopectin starches, i.e. waxy maize starch with less than 1% amylose (WMS), commercially available waxy potato starch with less than 2% amylose (WPS), commercially available waxy rice starch with less than 4% amylose (WRS), and commercially available waxy barley starch with less than 0.5%
20 amylose (WBS).

This experiment shows that the setback viscosity during the Brabender run is not as large as the starch paste behavior during storage and in this aspect they are totally different compared to the waxy starches. It can be concluded that no waxy starches have any tendency to give strong viscosity
25 increases during cooling as it can be expected from starches with higher amylose contents which will lead to gel formation due to the retrogradation phenomenon correlated to the amylose content. From experiments using the texture analyzer it can be concluded that the gel formation is less for the novel presented amylopectin potato starches compared with commercially
30 available waxy potato starch which clearly demonstrates that the stability of the starch is improved. When the starches are divided according to their gel strength after 7 days it will give the following order; WPS / gbssl-PS /

gbssl/ssII-PS /WMS / gbssl/ssIII-PS/ WRS / gbssl/ssIII/ssII-PS/ WBS. Thus, the experiment shows that the starches obtained with the method according to the present invention are not known before and exhibit stability properties which are significantly different compared with commercially available potato starches.

Example 11 - Freeze and thaw evaluation

The starch solutions prepared in example 10 are, after cooling to room temperature, put into 50 ml centrifuge tubes and are further centrifuged at 1500 x g for 10 minutes. Thereafter, the water in the centrifuge tubes is siphoned off and weighed. The remaining concentrated starch in the tubes is frozen in a freezer at -18 °C for approximately 24 h. The starch paste is thawed and the solutions are further centrifuged at 1500 x g for 10 minutes. The procedure is repeated and the siphoned water, which is defined as syneresis, after each freeze/thaw cycle is calculated as the accumulated water loss. By dividing the amount of accumulated water loss after each freeze/thaw cycle with the starting weight of water in the solution, the percentage of syneresis can be defined for each starch product.

The results show that waxy maize starch exhibits 30% syneresis after one freeze/thaw cycle, waxy potato starch exhibit 55% syneresis after one freeze/thaw cycle, waxy rice starch exhibits 0% syneresis after one freeze/thaw cycle but 14 % after two freeze/thaw cycles, and waxy barley starch exhibits 0% after the three first freeze/thaw cycles and 7% after the fourth freeze/thaw cycle. The starches obtained with the method performs better than gbssl-PS, which performs better than WPS, but less than WRS and WMS, gbssl/ssIII-PS performs better than WRS, but less than WBS, and gbssl/ssII-PS performs better than WRS and comparable to WBS. It is clear that the freeze/thaw stability of the starches obtained with the method according to the present invention, is significantly improved compared to the commercially available waxy potato starch. It is also clear that the solution based on the gbssl/ssIII/ssII-PS is significantly more freeze/thaw stable compared to both the available waxy potato starch and also compared to the commercially available waxy maize starch and waxy rice starch and is

comparable to waxy barley starch. The result further proves that starches obtained with the method according to the present invention are novel and that the degree of freeze/thaw stability can be ranked as (gbssl-PS) < (gbssl/ssII-PS) < (gbssl/ssIII-PS) < (gbssl/ssIII/ssII-PS).

5 Example 12 – Starch composition in mutated lines

An analysis of a starch composition is performed essentially according to a modified method of Sargeant and Wycombe (1982) and Klucinec, J.D., D.B. Thompson (1998)) "*Method for determination of amylose content and amylopectin chain distribution*". The starch is dispersed in potassium
10 hydroxide, neutralised and precipitated with ethanol. The precipitate is dispersed and dissolved in DMSO at 100°C, mixed with sodium acetate buffer, and again heated. After cooling to 45°C, isoamylase is added. The sample is incubated overnight, whereafter the enzyme is inactivated at 100°C. The solution is filtered through 0,45 µm and injected in the HPSEC system.
15 The High Performance Size Exclusion Chromatography (HPSEC) system consists of the following parts: A high pressure pump, an autosampler with a 500 µl loop, a RI (refractive index) detector, a column oven heated to 70°C, a magnetic stirrer and a chromatography data system. Three PL-gel 10 µm Mixed-B 300 x 7.5 mm polystyrene divinyl benzene analytical columns
20 and one PL-gel 10 10 µm Mixed-B 100 x 7.5 mm guard column is used for the separation. The eluent is 50 mM lithium bromide in 100 % DMSO, and the flow rate is 0.5 ml/min.

Since the starch is debranched the amylose fraction has the highest molecular weight and elutes fastest through the SEC columns, while the
25 amylopectin has been degraded into single chains and elutes after the amylose.

The chromatogram is split at the retention time corresponding to DP 200 ($M_w \sim 34\,000$ g/mol) which is the transition of amylose to amylopectin in debranched potato starch.

30 The determination of amylopectin and amylose in the starch is carried out on a High Performance Size Exclusion Chromatography system. Before the sample is injected into the separation system it is solublized in NaOH and

debranched with isoamylase. After the digestion of the amylopectin the amylose fraction has the biggest molecules and is eluted first through the separation system. The retention times for amylose and amylopectin are all based on the chromatogram (Fig. 6) of debranched native potato starch (full scale produced at Lyckeby Starch AB, Sweden). The material eluted in the first peak (1. in Fig. 6) is considered amylose, and the material eluted later in the chromatogram is then amylopectin (2+3. in Fig. 6). The amylopectin fraction is split between long chained amylopectin (2. in Fig. 6) and short chained amylopectin (3. in Fig. 6).

10 Starch was extracted from potato tubers from a number of individual mutated lines exemplified by lines 23178 (gbssl-PS), 18039 (gbssl/ssIII-PS), and 27031 (gbssl/ssIII-PS). In all cases, the bulked starch displayed more than 99% or 99.5% amylopectin. The result is shown in Table 3 and Fig. 7 for lines 27031 (gbssl/ssIII-PS) and 23178 (gbssl-PS) and in Fig. 8 for line 18039
15 (gbssl/ssIII-PS) together with traditional native potato starch. To investigate if any in between tuber variability could be found, starch isolated from five individual tubers of line 23178 (gbssl-PS) was assessed. The isolated starches of the five individual tubers all displayed more than 99.5% amylopectin. The results are shown in Table 3 and Fig. 9, where the results for line 23178#1
20 (gbssl-PS#1), 23178#2 (gbssl-PS#2), 23178#3 (gbssl-PS#3), 23178#4 (gbssl-PS#4), and 23178#5 (gbssl-PS#5) are shown together with the bulk (rest of all potatoes) 23178#Bulk (gbssl-PS#bulk). These results show that the present invention result in an amylopectin content as close to 100% as any method can determine. In addition, the results show that the present
25 invention results in a stable amylopectin content as close to 100% as any method can determine, across all individual tubers from the same line.

Table 3

Sample	1. Amylose (%)	% of amylopectin	
		2. Long Amylopectin chains (%)	3. Short Amylopectin chains (%)
Native potato starch (Lyckeby)	21	32	68
Commercial available waxy potato starch	<1	32	68
Waxy Maize starch	<1	22	79
BAP (Barley amylopectin starch)	<1	18	83
23178 #1 (gbssl-PS#1)	<1	38	62
23178 #2 (gbssl-PS#2)	<1	34	66
23178 #3 (gbssl-PS#3)	<1	33	67
23178 #4 (gbssl-PS#4)	<1	32	68
23178 #5 (gbssl-PS#5)	<1	35	65
23178#Bulk (gbssl-PS#bulk)	<1	35	65
18039 (gbssl+ssIII-PS)	<1	29	71
27031 (gbssl+ssIII-PS)	<1	27	74

Literature references

1. Zeeman, S.C., J. Kossmann, and A.M. Smith, Starch: Its Metabolism, Evolution, and Biotechnological Modification in Plants. Annual Review of Plant Biology, Vol 61, 2010. **61**: p. 209-234.
5
2. Kossmann, J. and J. Lloyd, Understanding and influencing starch biochemistry. Critical Reviews in Biochemistry and Molecular Biology, 2000. **35**(3): p. 141-196.
10
3. Jinek, M., et al., A Programmable Dual-RNA-Guided DNA Endonuclease in Adaptive Bacterial Immunity. Science, 2012. **337**(6096): p. 816-821.
- 15 4. Chen, C., L.A. Fenk, and M. de Bono, Efficient genome editing in Caenorhabditis elegans by CRISPR-targeted homologous recombination. Nucleic Acids Research, 2013. **41**(20).
5. Auer, T.O., et al., Highly efficient CRISPR/Cas9-mediated knock-in in zebrafish by homology-independent DNA repair. Genome Research, 2014. **24**(1): p. 142-153.
20
6. Li, J.-F., et al., Multiplex and homologous recombination-mediated genome editing in Arabidopsis and Nicotiana benthamiana using guide RNA and Cas9. Nature Biotechnology, 2013. **31**(8): p. 688-691.
25
7. Xie, K. and Y. Yang, RNA-Guided Genome Editing in Plants Using a CRISPR/Cas System. Molecular Plant, 2013. **6**(6): p. 1975-1983.
- 30 8. Belhaj, K., et al., Plant genome editing made easy: targeted mutagenesis in model and crop plants using the CRISPR/Cas system. Plant Methods, 2013. **9**.

9. Sun, X., et al., Targeted mutagenesis in soybean using the CRISPR-Cas9 system. *Scientific Reports*, 2015. **5**.
- 5 10. Pattanayak, V., et al., High-throughput profiling of off-target DNA cleavage reveals RNA-programmed Cas9 nuclease specificity. *Nature Biotechnology*, 2013. **31**(9): p. 839-+.
11. Hsu, P.D., et al., DNA targeting specificity of RNA-guided Cas9
10 nucleases. *Nature Biotechnology*, 2013. **31**(9): p. 827-+.
12. Nicolia, A., et al., Targeted gene mutation in tetraploid potato through transient TALEN expression in protoplasts. *Journal of Biotechnology*, (0).

Claims

1. Amylopectin potato starch with improved stability against retro-gradation and improved freeze and thaw stability, wherein it contains more
5 than 99 % amylopectin, preferably 100 % amylopectin.
2. The amylopectin potato starch according to claim 1, wherein it has been extracted from a potato (*Solanum tuberosum*) chosen from the group of potatoes in which
- 10 i) the expression and/or activity of the GBSSI enzyme has been completely eliminated,
- ii) the expression and/or activity of both the GBSSI enzyme and the SSIII enzyme has been completely eliminated,
- iii) the expression and/or activity of both the GBSSI enzyme and the SSII
15 enzyme has been completely eliminated, and
- iv) the expression and/or activity of the GBSSI enzyme, of the SSIII enzyme, and of the SSII enzyme has been completely eliminated, preferably from a potato belonging to group iv).
- 20 3. The amylopectin potato starch according to claim 1, wherein it when it has been extracted from a potato belonging to said groups ii) –iv) it also has a shorter amylopectin chain length compared to that of native amylopectin potato starch and a degree of branching which is higher compared to that of native amylopectin potato starch, wherein said degree of branching is more
25 than 4 %, preferably more than 5 %.
4. The amylopectin potato starch according to any one of the preceding claims, wherein it per definition according to a standardized freeze/thaw stability test shows less than 30 % syneresis after 2-4, preferably 2, repeated
30 freeze/thaw cycles.

5. The amylopectin starch according to any one of the preceding claims, wherein it has been purified after extraction from said potato by acid thinning, oxidation, acetylation, hydroxypropylation, cross-linking, sodium-octenyl succinylation, aluminum-octenyl succinylation, succinylation, pyrodextrinization, enzymatic modifications, alkaline roasting, or cationic modification.
6. The amylopectin potato starch according to any one of the preceding claims, wherein it has been gelatinized and further dried to a dry content of more than 80 % w/w DM, preferably more than 85 % w/w DM, and more preferably more than 90 % w/w DM.
7. The amylopectin potato starch according to any one of the preceding claims, wherein it has been degraded to a molecular weight of 100 000 – 1 000 000 Da, preferably 300 000– 800 000 Da, more preferably 500 000 – 700 000 Da, with enzymatic modification or acid treatment, pyrodextrinization, oxidation degradation, or combinations thereof, or wherein it has been inhibited by alkaline roasting or a bleaching reaction with oxidizing agents.
8. A method for the production of a potato (*Solanum tuberosum*) containing the amylopectin potato starch according to claims 1-4, wherein said method involves homology-directed mutagenesis using CRISPR/nuclease technology and comprises the following steps:
- a) provision of potato cells or potato tissue containing potato cells,
 - b) introduction into the nuclei of said potato cells of one or more CRISPR/nuclease complexes each comprising a specific targeting ribonucleotide sequence which is fully or essentially homologous to a target nucleotide sequence located in a DNA sequence immediately upstream of a PAM (5'-NGG-3' protospacer adjacent motif) in a gene coding for a GBSS enzyme and optionally also in a gene coding for an SSII enzyme and/or in a gene coding for an SSIII enzyme, wherein said mutagenesis takes place in one or more alleles of the potato genome, wherein when said targeting ribonucleotide sequence

- identifies the complementary strand of the target nucleotide sequence, said one or more CRISPR/nuclease complexes cut(s) said DNA sequence, leading to a subsequent complete lack of the ability of the potato to produce a functional GBSSI enzyme, optionally also a functional SSII and/or SSIII enzyme,
- 5 c) wherein step b) optionally is repeated until the potato lacks the ability to produce said functional GBSSI enzyme, optionally also a functional SSII and/or SSIII enzyme, in all of the alleles.
- 10 9. The method according to claim 8, wherein the homology-directed mutagenesis leads to a complete lack of the ability of the potato genome to produce a functional GBSSI enzyme, SSII enzyme, and SSIII enzyme.
10. The method according to any one of claims 8 and 9, wherein the
- 15 CRISPR/nuclease technique is a CRISPR/Cas technique, preferably a CRISPR/Cas9 technique or CRISPR/Cpf1 technique, and wherein the target nucleotide sequence of the CRISPR/Cas9 complex consists of 20 bp.
11. The method according to any one of claims 8-10, wherein said
- 20 targeting ribonucleotide sequence is fully or essentially homologous to one or more from the following group of target nucleotide sequences:
- | | |
|------------------------------------|------------------|
| GT1: 5'-GATATTAGAATCACATAGGG-3' | SEQ. ID. NO. 1 |
| GT2: 5'-TGTTGACAAGGGTGTGGAAT-3' | SEQ. ID. NO. 2 |
| 25 GT3: 5'-GCTACCATTGTTTGTGGAAA-3' | SEQ. ID. NO. 3 |
| GT4: 5'-GACAAGAAGATCCCTTTGAT-3' | SEQ. ID. NO. 4 |
| S2T1: 5'-GTGCTAAAAGGGGTAAGTTG-3' | SEQ. ID. NO. 5 |
| S2T2: 5'-GGGGTGCCCTTTCATCGGCC-3' | SEQ. ID. NO. 6 |
| S2T3: 5'-GCTCCAGTAGAGAGCAAATG-3' | SEQ. ID. NO. 7 |
| 30 S3T1: 5'-GAACATCTGAACCAAATTC-3' | SEQ. ID. NO. 8 |
| S3T2: 5'-GAGGTGGCAATGGACCCAGG-3' | SEQ. ID. NO. 9 |
| S3T3: 5'-GGAACTAATGCCAGTAGCA-3' | SEQ. ID. NO. 10, |

wherein in the case said targeting ribonucleotide sequence is essentially homologous to a target nucleotide sequences, it may differ from the fully homologous one as to sequence length and base identity, but only in such a way that the desired mutation still is obtained.

5

12. The method according to any one of claims 8-11, wherein said potato is a tuber, a leaf, a shoot, a stem, a flower, a cell or a protoplast.

13. The method according to any one of claims 8-12, wherein it is performed in 4 alleles of the potato genome.

14. The method according to any one of claims 8-11, wherein a successful mutation and elimination of said enzyme activities are confirmed by PCR methodology.

15

15. Potato chosen from the group of potatoes in which

- i) the expression and/or activity of the GBSSI enzyme has been completely eliminated,
 - ii) the expression and/or activity of both the GBSSI enzyme and the SSIII enzyme has been completely eliminated,
 - iii) the expression and/or activity of both the GBSSI enzyme and the SSII enzyme has been completely eliminated, and
 - iv) the expression and/or activity of the GBSSI enzyme, of the SSIII enzyme, and of the SSII enzyme has been completely eliminated,
- preferably from a potato belonging to group iv), wherein said potato preferably has been obtained with the method according to any one of claims 7-13.

25

16. A method for the production of an amylopectin potato starch according to claim 1, wherein it is extracted from the potato according to claim 14, wherein said potato has been produced according to any one of the method claims 7- 13.

30

17. Use of a purified starch according to any one of claims 1-7 in food applications

- 5 - as a texturizer in liquid formulations, wherein the starch concentration is 0.05-15 % w/w, preferably 0.5-10 % w/w, more preferably 1.5-6 % w/w,
- as a texturizer in formulations wherein the food product is additionally frozen,
- 10 - preferably in coating applications in which a vegetable or animal derived food product is coated with the starch and/or starch in a formulation with other ingredients, and followed by additional deep frying.
- as a stabilizer of water-in-oil (W/O) emulsions in liquid products and spreads, or
- 15 - as an emulsion stabilizer for oil-in-water (O/W) emulsions in a liquid state and in applications where the oil-in-water emulsion is additionally spray dried to a powder, wherein said amylopectin potato starch first has been modified with sodium octenyl succinate or aluminium octenyl succinate.

20

18. Use of a purified starch according to any one of claims 1-7 in paper applications, preferably for surface sizing and coating of paper, or as a wet-end starch in paper production.

25

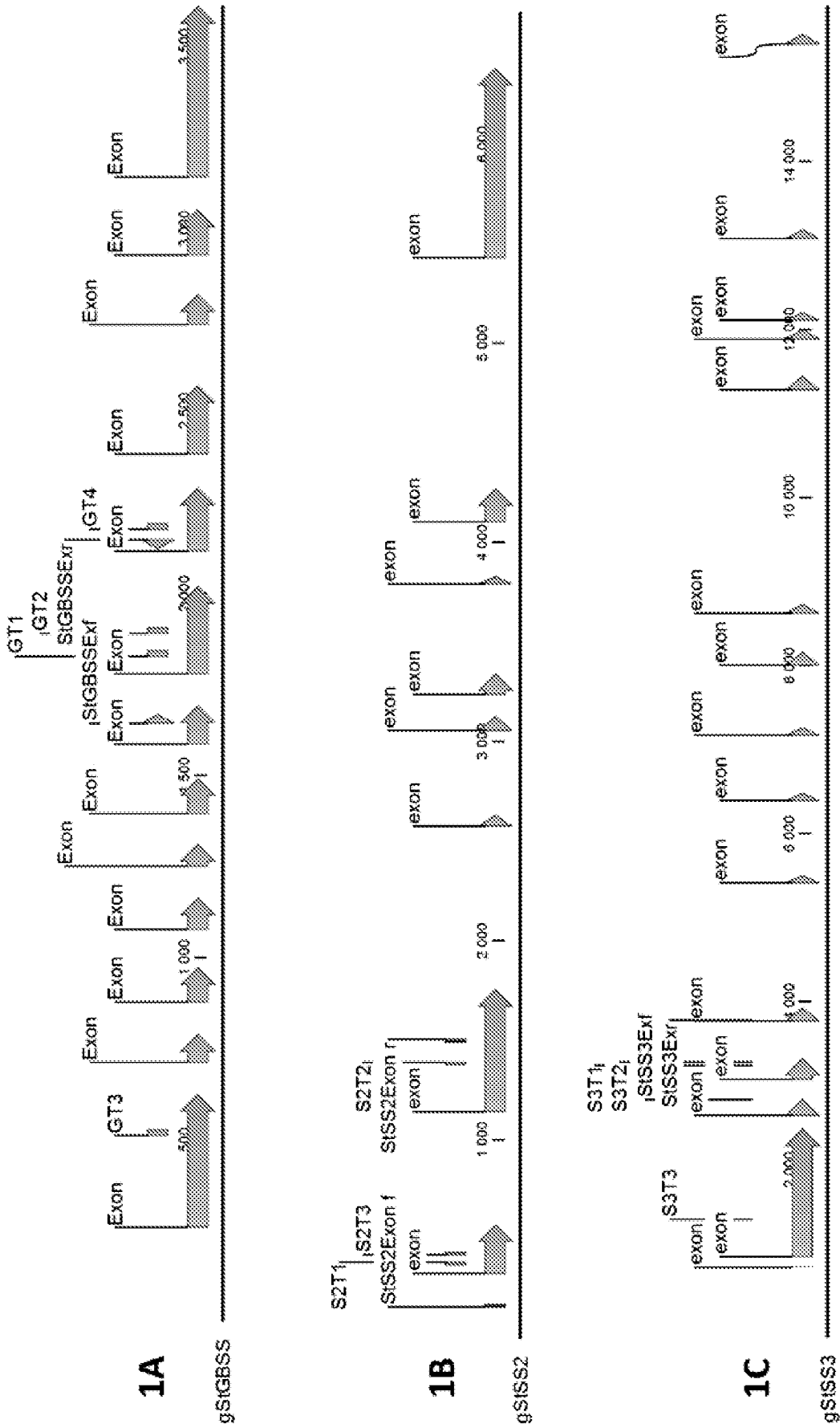


Fig. 1A-C

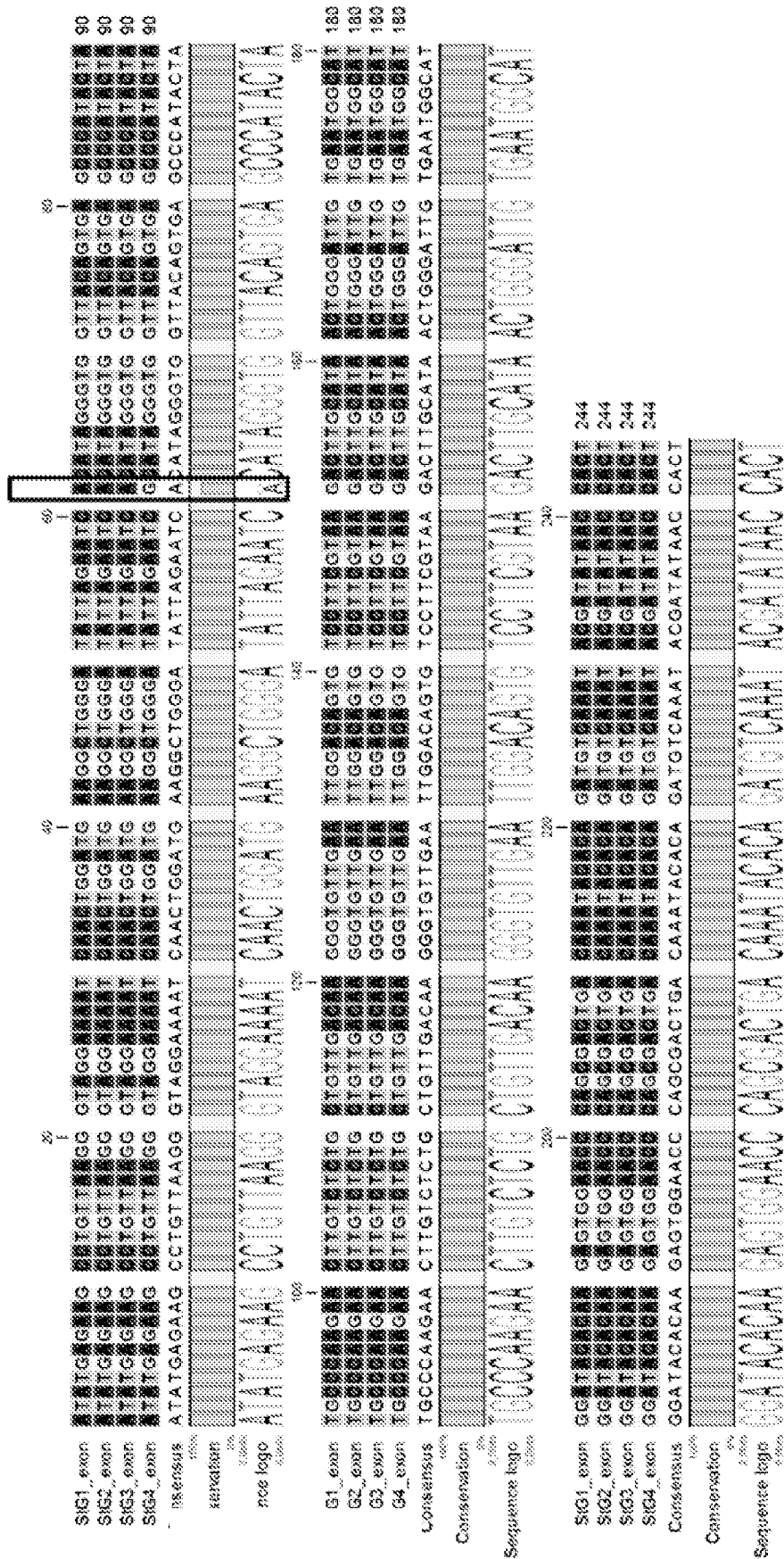


Fig. 2A

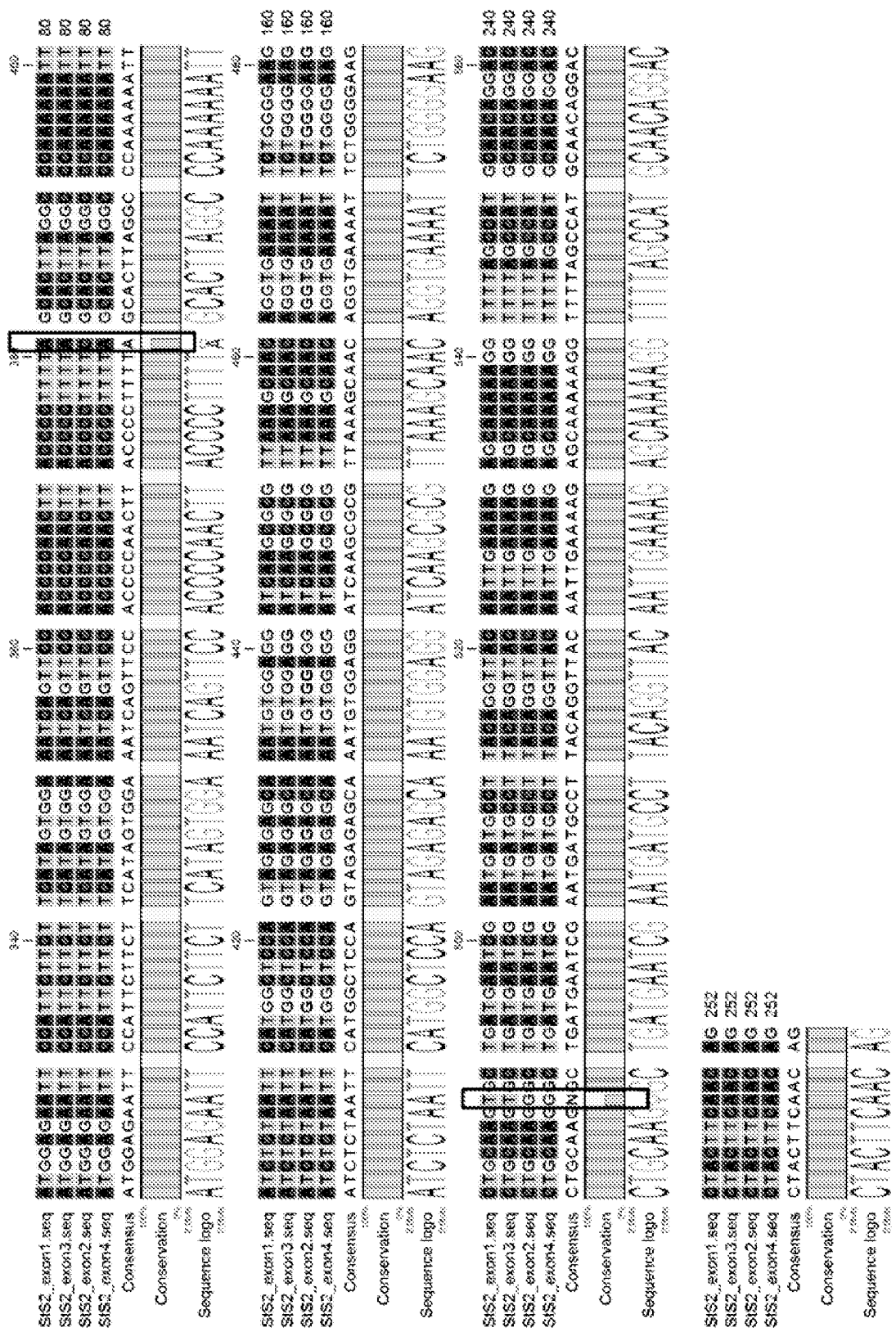


Fig. 2B

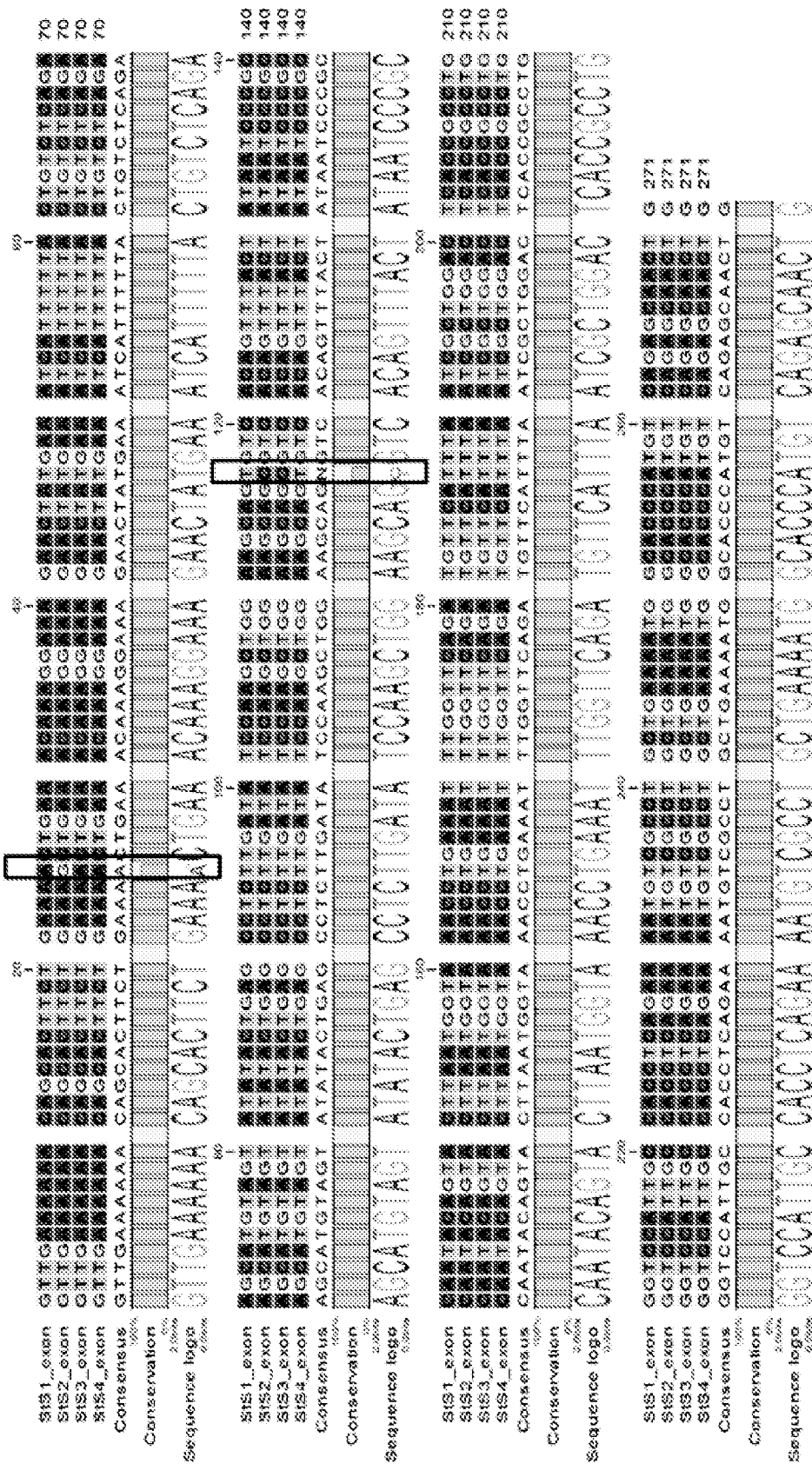


Fig. 2C

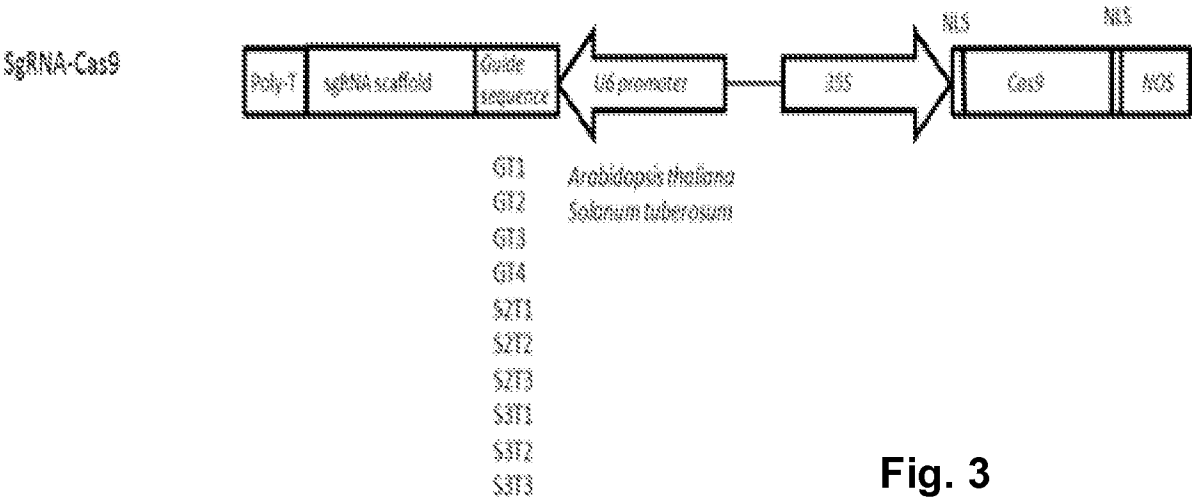


Fig. 3

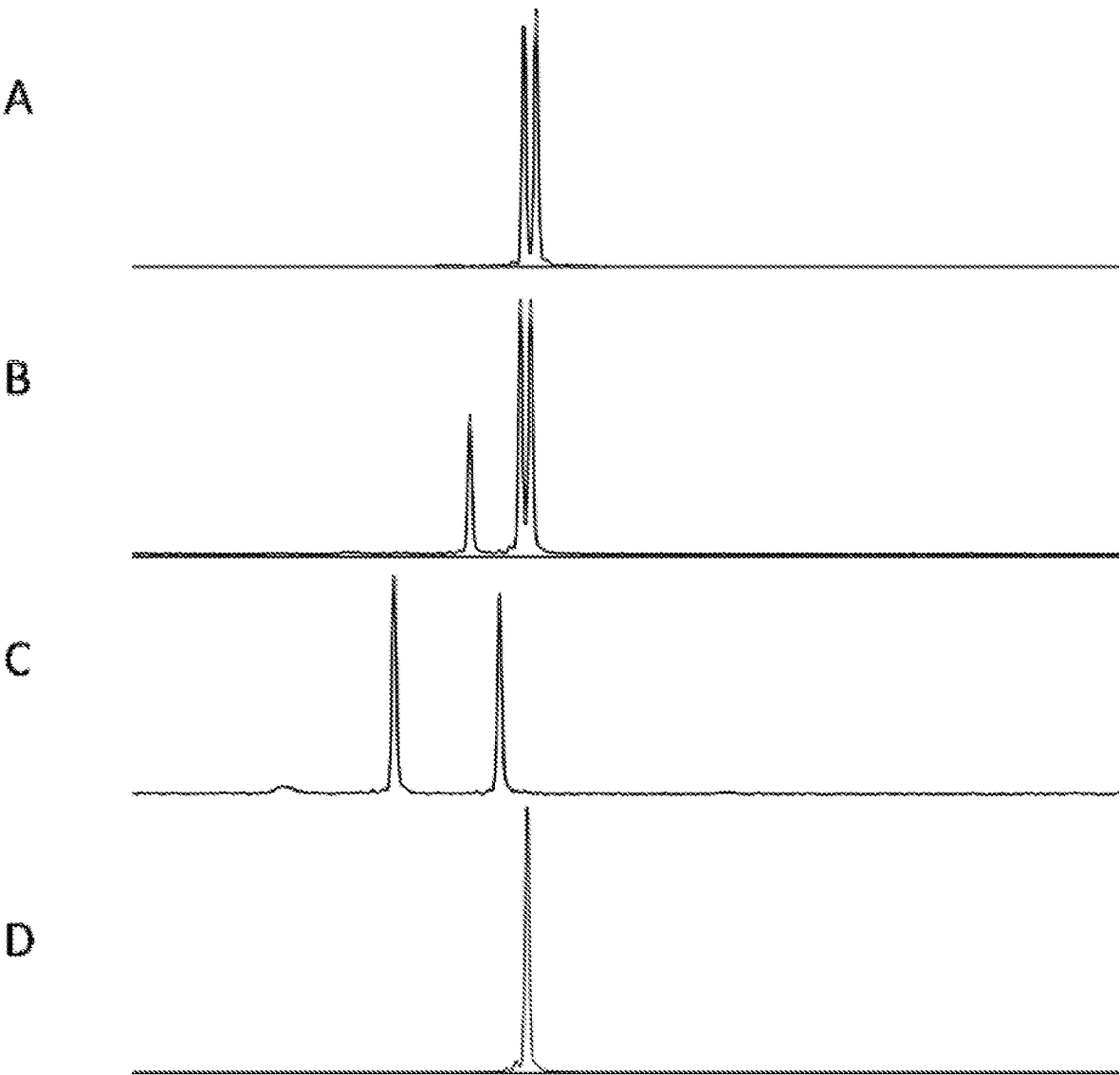


Fig. 4

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GT1

		<u>Indels</u>
P1003	GGGATATTAGAATCACAT—GGGTGGTTACAGTGAGCCC	-1
P1004	GGGATATTAGAAT-----GGGTGGTTACAGTGAGCCC	-6
P1004	GGGATATTAGAATCACAT—GGGTGGTTACAGTGAGCCC	-1
P1030	GGGATATTAGAA-----GGGTGGTTACAGTGAGCCC	-7
P1043	GGGATATTAGAATCA----GGGTGGTTACAGTGAGCCC	-4
P1046	GGGATATTAGAATC-----GGGTGGTTACAGTGAGCCC	-5
P1071	GGGATATTAGAATCACAT—GGGTGGTTACAGTGAGCCC	-1
P1071	GGGATATTAGAATCACA—GGGTGGTTACAGTGAGCCC	-2
P2046	GGGATATTA-----GGGTGGTTACAGTGAGCCC	-10
P2058	GGGATATTAGAATCA---AGGGTGGTTACAGTGAGCCC	-3
P2096	GGGATATTAGAATCACAT—GGGTGGTTACAGTGAGCCC	-1
P5023	GGGATATTAGAATCACAT—GGGTGGTTACAGTGAGCCC	-1
P5046	GGGATATTAGAATCACAT—GGGTGGTTACAGTGAGCCC	-1
P5055	GGGATATTAGAATCACAT—GGGTGGTTACAGTGAGCCC	-1
P5059	GGGATATTAGAATCACAT—GGGTGGTTACAGTGAGCCC	-1
WT	GGGATATTAGAATCACATAGGGTGGTTACAGTGAGCCC	SEQ. ID. NO. 31

GT2

		<u>Indels</u>
P7021	TTGTCTCTGCTGTTGACAAGGGT-----AATTGGACAGTGTCC	-4
P7021	TTGTCTCTGCTGTTGACAAGGGTGTGAAATTGGACAGTGTCC	+1
P7021	TTGTCTCTGCTGTTGACAAGGGTG---ATTGGACAGTGTCC	-3
P7033	TTGTCTCTGCTGTTGACAAGGGTGTGTT-AATTGGACAGTGTCC	-1
P7061	TTGTCTCTGCTGTTGACAAGGGTGTGTT-AATTGGACAGTGTCC	-1
P8006	TTGTCTCTGCTGTTGACAAGGGTGTGTT—TTGGACAGTGTCC	-2
P8018	TTGTCTCTGCTGTTGACAA-----AATTGGACAGTGTCC	-8
WT	TTGTCTCTGCTGTTGACAAGGGTGTGAAATTGGACAGTGTCC	SEQ. ID. NO. 32

GT3

		<u>Indels</u>
P9064	CTGGATGCTCAGCTACCATTTGTTT--AAAGGGAATGAACTTGAT	-2
WT	CTGGATGCTCAGCTACCATTTGTTTGTAAAGGGAATGAACTTGAT	SEQ. ID. NO. 33

Fig. 5

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GT4

		<u>Indels</u>
P10019	CCTGTTGACAAGAAGATCCCT—GATTGGCTTCATCGG	-2
P10023	CCTGTTGACAAGAAGATCCCTTT A GATTGGCTTCATCGG	+1
P10025	CCTGTTGACAAGAAG—GATTGGCTTCATCGG	-8
P10025	CCTGTTGACAAGAAGATCC—GATTGGCTTCATCGG	-4
P10031	CCTGTTGACAAGAAGATCCCTTT T GATTGGCTTCATCGG	+1
P10031	CCTGTTGACAAGAA—GATTGGCTTCATCGG	-9
P10084	CCTGTTGACAAGAAGATCCCT—GATTGGCTTCATCGG	-2
P10084	CCTGTTGACAAGAAGATCC-----CTTCATCGG	-8
P10087	CCTGTTGACAAGAAGATCCCT—GATTGGCTTCATCGG	-2
P11088	CCTGTT-----GATTGGCTTCATCGG	-17
P11088	CCTGTTGACAAGAAGATCCCT—ATTGGCTTCATCGG	-3
P11088	CCTGTTGACAAGAAGATCCCTTT T GATTGGCTTCATCGG	+1
WT	CCTGTTGACAAGAAGATCCCTTTGATTGGCTTCATCGG	SEQ. ID. NO. 34

S2T1

		<u>Indels</u>
P19022	TTTTGGGCCTAAGTGCTAAAAGGGGTA—TTGGGGTGG	-2
P19022	TTTTGGGCCTAAGTGCTAAAAGGGGTAA-TTGGGGTGG	-1
P19022	TTTTGGGCCTAAGTGCTAAAAGGGGTAAG T TTGGGGTGG	+1
P19026	TTTTGGGCCTAAGTGCTAAAAGGGGT—TTGGGGTGG	-3
WT	TTTTGGGCCTAAGTGCTAAAAGGGGTAAGTTGGGGTGG	SEQ. ID. NO. 35

S2T2

		<u>Indels</u>
P21011	GGGGGTGCCCTTTCATCG T GCCAGGTCCCTTTT	+1
WT	GGGGGTGCCCTTTCATCGGCCAGGTCCCTTTT	SEQ. ID. NO. 36

S3T1

		<u>Indels</u>
P12019	CAGCGATTAAATGAACATCTGAACCAA—TTCAGGTTT	-2
WT	CAGCGATTAAATGAACATCTGAACCAAATTCAGGTTT	SEQ. ID. NO. 37

Fig. 5 (cont.)

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S3T2

		<u>Indels</u>
P19022	GGCGACATTTTCTGAGGTGGCAATGGAC-- AGGCGGTG	-2
P21004	GGCGACATTTTCTGAGGTGGCAATG-----AGGCGGTG	-5
P21006	GGCGACATTTTCTGAGGTGGCAATGGAC-- AGGCGGTG	-2
P21009	GGCGACATTTTCTGAGGTGGCAATGG-----AGGCGGTG	-4
P21011	GGCGACATTTTCTGAGGTGG----- AGGCGGTG	-10
WT	GGCAACATTTTCTGAGGTGGCAATGGACCCAGGCGGTG	SEQ. ID. NO. 38

Fig. 5 (cont.)

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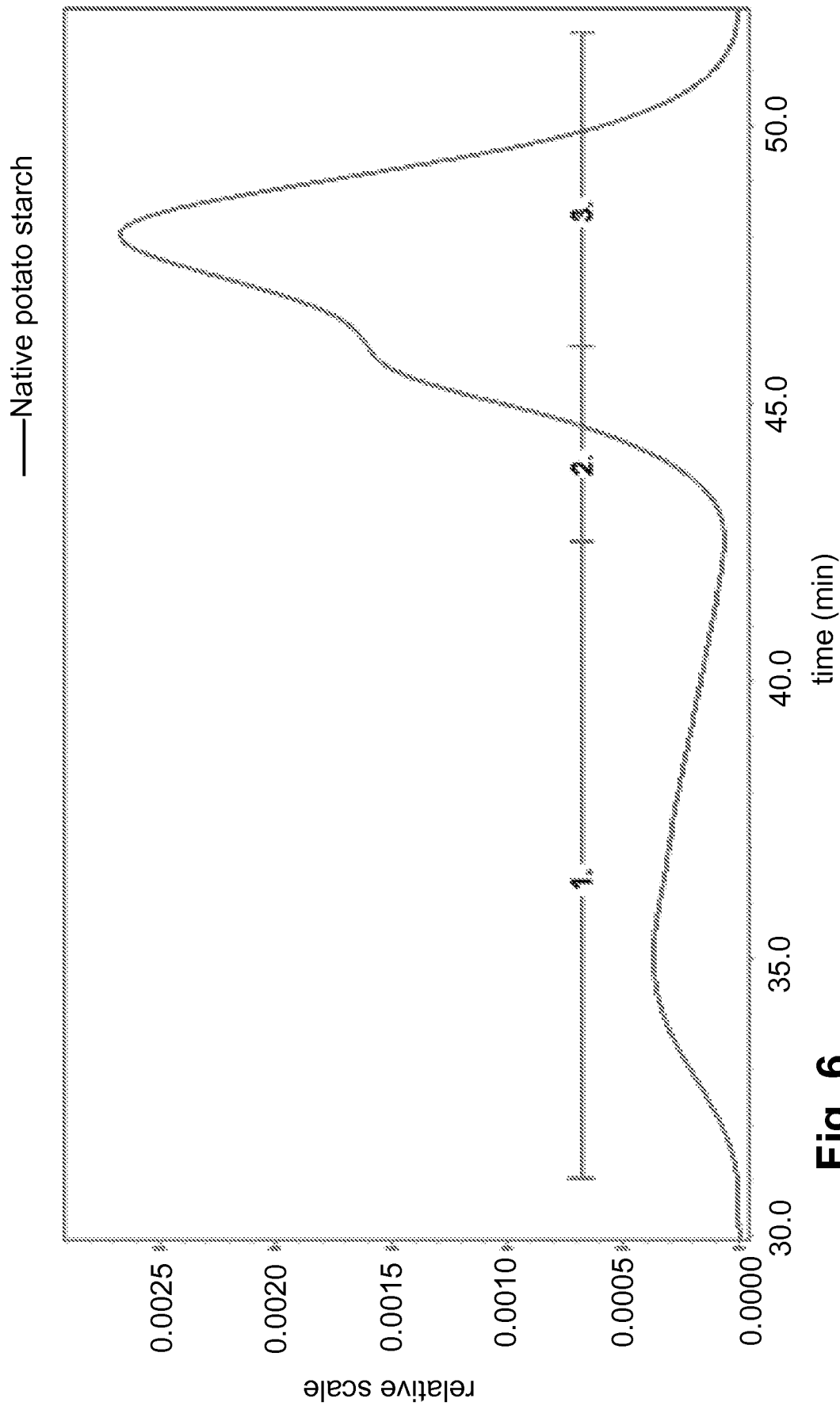


Fig. 6

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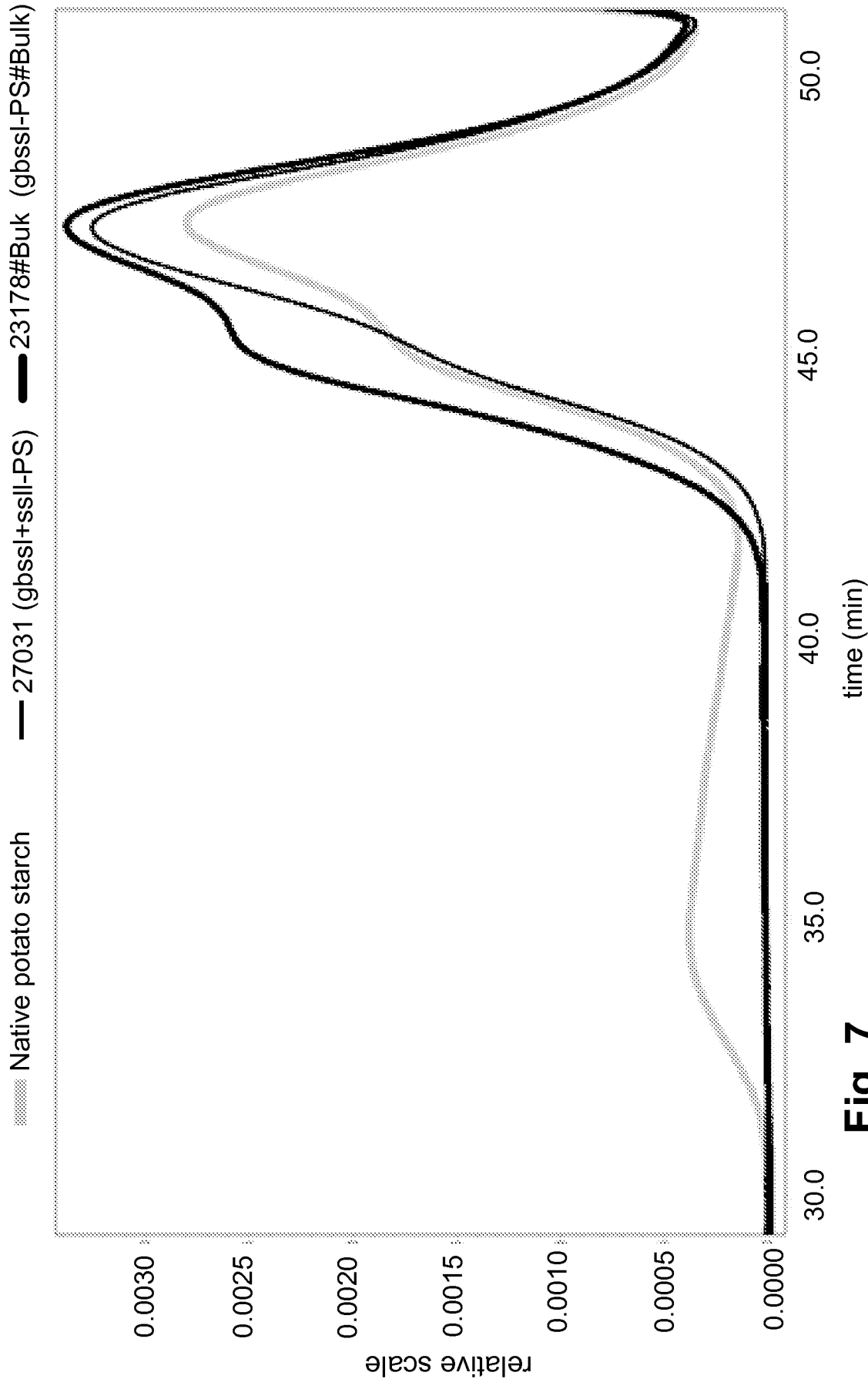


Fig. 7

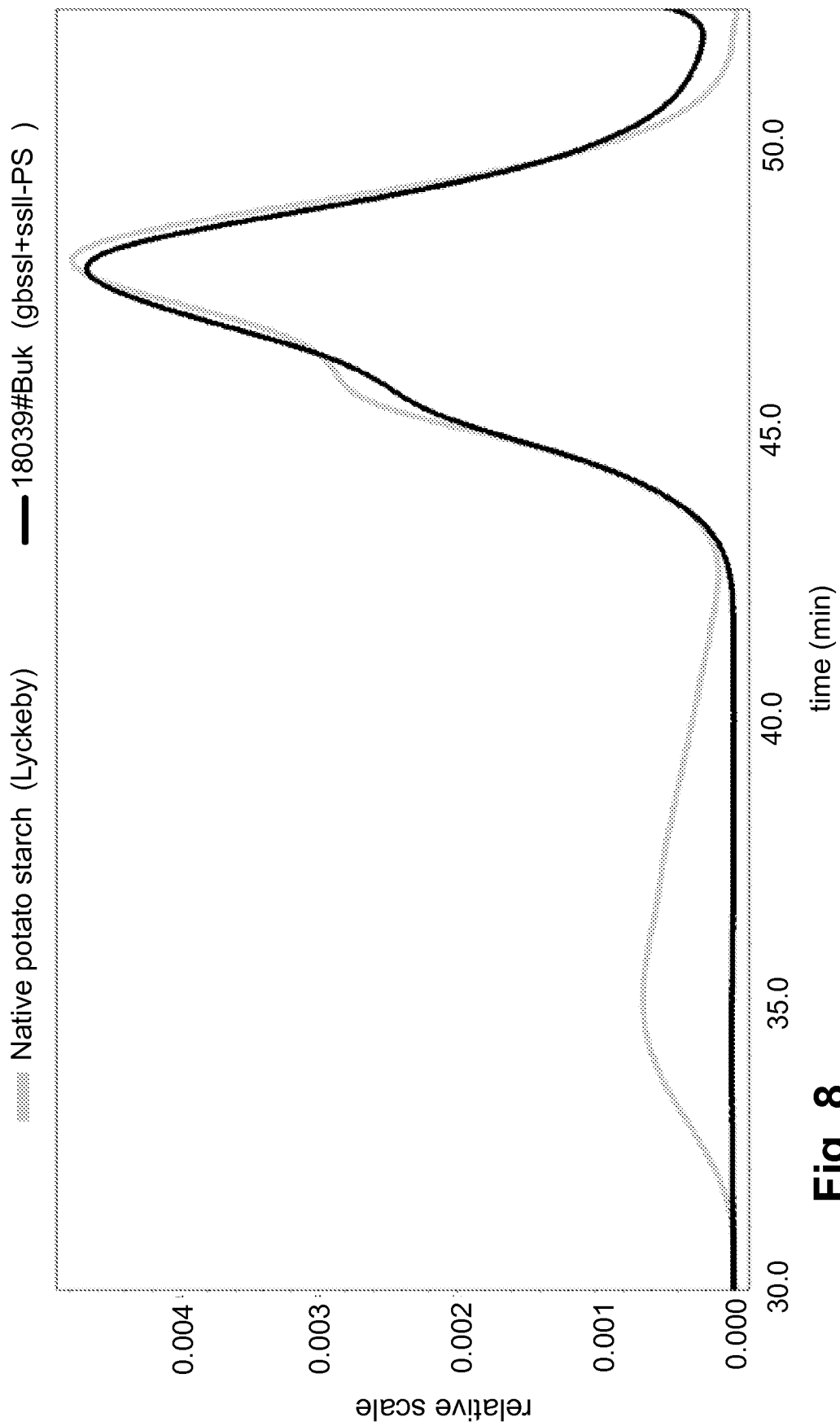


Fig. 8

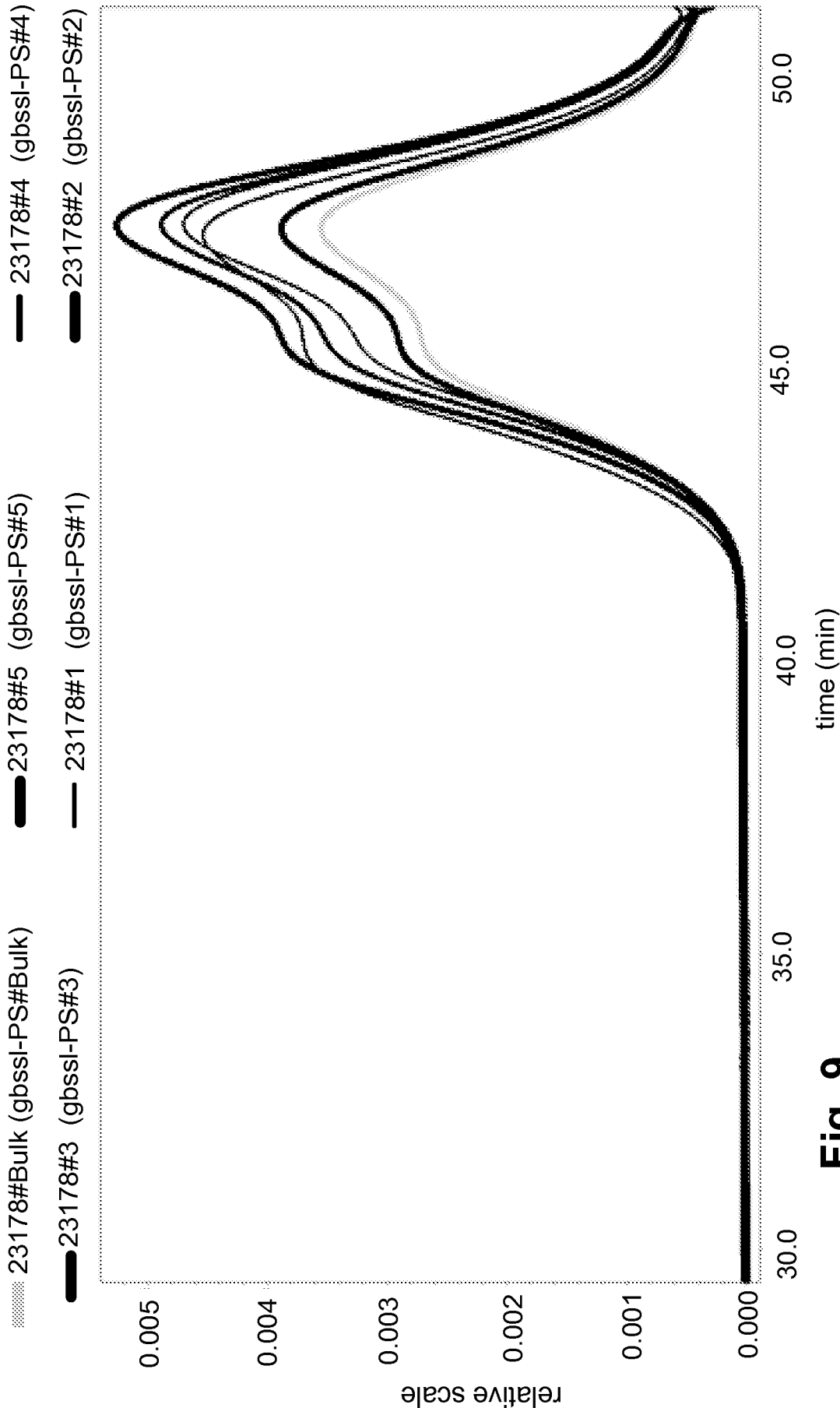


Fig. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2017/050429

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: A01H, C08B, C12N

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

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data, BIOSIS, COMPENDEX, EMBASE, MEDLINE, REGISTRY, DGENE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2015193858 A1 (CELLECTIS), 23 December 2015 (2015-12-23); See page 1, line 32-page 2, line 4; page 2, lines 19-21; page 15, lines 17-32; claims 34, 37-38 and 40	1-2, 4-8, 10-18
Y	--	3, 9
Y	WO 0119975 A2 (NATIONAL STARCH AND CHEMICAL INVESTMENT HOLDING CORPORATION), 22 March 2001 (2001-03-22); See page 10, last paragraph and claims 61-63	3, 9
A	Belhaj K et al. "Editing plant genomes with CRISPR/Cas9", Current Opinion in Biotechnology, 2015, vol. 32, pages 76-84; See "Conclusions"	1-18



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

05-07-2017

Date of mailing of the international search report

05-07-2017

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INTERNATIONAL SEARCH REPORT

 International application No.
 PCT/SE2017/050429

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2008090008 A1 (BAYER CROPSCIENCE AG), 31 July 2008 (2008-07-31); See page 1, lines 16-25 --	1-18
X	Kossmann J et al., "Understanding and influencing starch biochemistry", Critical Reviews in Plant Sciences, 2000, Vol. 19, no. 3, pages 171-226; See page 183, left column, first paragraph --	1
X	US 6600093 B1 (COOPERATIVE VERKOOP-EN PRODUCTIEVERENIGING VAN AARDAPPELMEEL EN DERIVATEN AVEBE B.A.), 29 July 2003 (2003-07-29); See example 2 and table 5 --	1-2, 4, 15
X	Hong Yan et al., "Study on physicochemical characteristics of waxy potato starch in comparison with other waxy starches", Starch, 2011, vol. 63, pages 754-759; See page 754, left column "Introduction", lines 7-8 --	1
X	Yao-Yu Xie et al., "Effect of repeated retrogradation on structural characteristics and in vitro digestibility of waxy potato starch", Food Chemistry, 2014, vol. 163, pages 219-225; See page 220, left column, second paragraph --	1
A	WO 2005123927 A1 (BAYER CROPSCIENCE GMBH), 29 December 2005 (2005-12-29); See the whole document --	1-18
P, X	Andersson M et al., "Efficient targeted multiallelic mutagenesis in tetraploid potato (<i>Solanum tuberosum</i>) by transient CRISPR-Cas9 expression in protoplasts", Plant Cell Rep., Jan 2017, vol. 36, pages 117-128; See the whole document --	1-18
P, X	Khlestkin V.K. et al., "Target genes for development of potato (<i>Solanum tuberosum</i> L.) cultivars with desired starch properties (review)", Agricultural Biology, Jan-Feb 2017, vol. 52, no. 1, pages 25-36; See the English abstract -- -----	1-18

Continuation of: second sheet

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SE2017/050429

WO	2015193858 A1	23/12/2015	CA	2952906 A1	23/12/2015
			EP	3158072 A1	26/04/2017
			US	20150368659 A1	24/12/2015
WO	0119975 A2	22/03/2001	AT	391184 T	15/04/2008
			AU	7031000 A	17/04/2001
			CA	2388364 A1	22/03/2001
			DE	60038496 T2	24/12/2008
			DK	1212440 T3	28/07/2008
			JP	2003509047 A	11/03/2003
WO	2008090008 A1	31/07/2008	AU	2008208999 B2	03/10/2013
			CA	2675553 A1	31/07/2008
			CN	101589149 B	21/05/2014
			EP	2121932 A1	25/11/2009
			EP	1950303 A1	30/07/2008
			JP	2010516263 A	20/05/2010
			JP	5591541 B2	17/09/2014
			US	20130060016 A1	07/03/2013
			US	20090317535 A1	24/12/2009
US	6600093 B1	29/07/2003	US	8252975 B2	28/08/2012
			NONE		
WO	2005123927 A1	29/12/2005	CA	2569889 A1	29/12/2005
			DE	102004029763 A1	05/01/2006
			EP	1761633 A1	14/03/2007
			US	8067670 B2	29/11/2011
			US	20080251225 A1	16/10/2008