

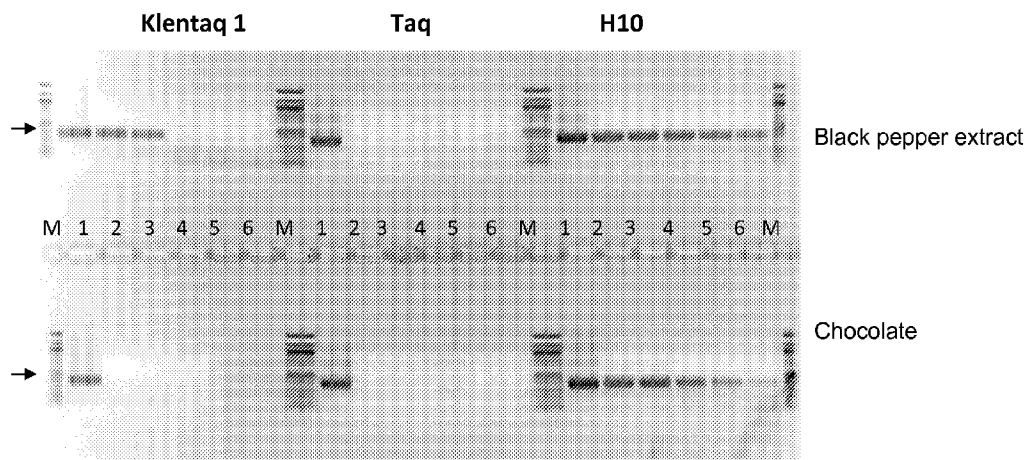


(86) Date de dépôt PCT/PCT Filing Date: 2013/10/16
(87) Date publication PCT/PCT Publication Date: 2014/04/24
(45) Date de délivrance/Issue Date: 2021/11/09
(85) Entrée phase nationale/National Entry: 2015/04/15
(86) N° demande PCT/PCT Application No.: US 2013/065313
(87) N° publication PCT/PCT Publication No.: 2014/062848
(30) Priorités/Priorities: 2012/10/16 (US61/714,671);
2013/04/12 (US61/811,611)

(51) Cl.Int./Int.Cl. *C12N 9/12* (2006.01),
C12N 15/54 (2006.01), *C12P 19/34* (2006.01),
C12Q 1/686 (2018.01)
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(54) Titre : POLYMERASES RESISTANTES A L'INHIBITION
(54) Title: INHIBITION-RESISTANT POLYMERASES

Performance of H10 Klentaq Mutant with Crude Samples Containing Chocolate or Black Pepper



(57) Abrégé/Abstract:

Provided herein are mutant polymerase enzymes resistant to inhibitors encountered in Polymerase Chain Reactions (PCR). Also provided are nucleic acids or constructs encoding isolated polypeptides having polymerase activity. Also provided are kits useful for PCR containing isolated polypeptides having polymerase activity or isolated nucleic acids encoding such. One aspect of the present disclosure includes an isolated mutant polypeptide having polymerase activity

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property
Organization
International Bureau



(10) International Publication Number
WO 2014/062848 A1

(43) International Publication Date
24 April 2014 (24.04.2014)

(51) International Patent Classification:
C12N 9/12 (2006.01)

(21) International Application Number:
PCT/US2013/065313

(22) International Filing Date:
16 October 2013 (16.10.2013)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/714,671 16 October 2012 (16.10.2012) US
61/811,611 12 April 2013 (12.04.2013) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: INHIBITION-RESISTANT POLYMERASES

Performance of H10 Klentaq Mutant with Crude Samples
Containing Chocolate or Black Pepper

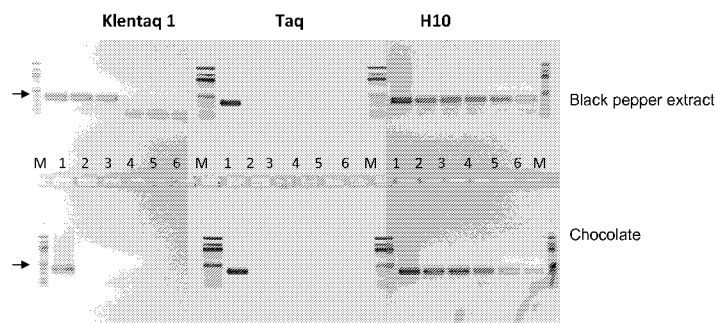


FIG. 1

(57) Abstract: Provided herein are mutant polymerase enzymes resistant to inhibitors encountered in Polymerase Chain Reactions (PCR). Also provided are nucleic acids or constructs encoding isolated polypeptides having polymerase activity. Also provided are kits useful for PCR containing isolated polypeptides having polymerase activity or isolated nucleic acids encoding such. One aspect of the present disclosure includes an isolated mutant polypeptide having polymerase activity

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INHIBITION-RESISTANT POLYMERASES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority from U.S. Provisional Application Serial No. 61/714,671, filed on 16 October 2012, and U.S. Provisional Application Serial
5 No. 61/811,611, filed on 12 April 2013.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

This invention was made with government support under grant number
10 IIP1127479 awarded by National Science Foundation. The government has certain rights in the invention.

BACKGROUND OF THE INVENTION

Known mutant polymerases include Omni Taq, i.e., FL-22 (SEQ ID NO: 3) (as
15 described in U.S. Patent Application Publication No. 2011/0027832) and Omni KlenTaq, i.e., KlenTaq-10 (SEQ ID NO: 4) (as described in U.S. Patent Application Publication No. 2006/0084074).

Known mutant polymerases and uses thereof are described in, for example, U.S. Patent No. 7,462,475, issued 09 December 2008; U.S. Patent Application
20 Publication No. 2009/0170060, published 02 July 2009; U.S. Patent Application Publication No. 2011/0027832, published 03 February 2011; U.S. Patent Application Publication No. 2012/0028259, published 02 February 2012; and international PCT application WO2012/088479, published 28 June 2012.

SUMMARY OF THE INVENTION

25 One aspect of the present disclosure includes an isolated mutant polypeptide having polymerase activity. In some embodiments, the isolated polypeptide

- includes an amino acid sequence at least 95% identical to SEQ ID NO: 1 and having at least one amino acid substitution selected from the group consisting E404G, G418E, V453L, A454S, R487G, I528ML533R, D551G, D578E, I599V, L657Q, D732N, K738R, L781I, and E818V, or a functional fragment thereof, wherein the functional fragment has
- 5 the selected substitution, wherein the isolated polypeptide has polymerase activity.
- In some embodiments, the functional fragment includes SEQ ID NO: 2 having at least one amino acid substitution selected from the group consisting of E404G, G418E, V453L, A454S, R487G, I528ML533R, D551G, D578E, I599V, L657Q, D732N, K738R, L781I, and E818V (per wild-type Taq numbering) and the
- 10 functional fragment retains polymerase activity.
- In some embodiments, the isolated polypeptide further includes at least one amino acid substitution selected from the group consisting of L609P, E626K, V649I, I707L, E708K, E708L, E708N, E708Q, E708I, E708W, E708R, E708V, or E708S (per wild-type Taq numbering).
- 15 In some embodiments, the isolated polypeptide has polymerase activity in the presence of an inhibitory substance in an amount sufficient to cause a wild type polymerase to fail to amplify a target nucleic acid in a polymerase chain reaction (PCR). In some embodiments, the isolated polypeptide has polymerase activity in the presence of an inhibitory substance in an amount sufficient to cause a wild
- 20 type Taq polymerase of SEQ ID NO: 1 to fail to amplify a target nucleic acid in a polymerase chain reaction (PCR). In some embodiments, the inhibitory substance is contained in a sample of one or more of chocolate, peanut butter, milk, seafood, meat, egg, plant material, blood, a blood fraction, urine, dye, soil, soil extract, humic acid, guanidinium thiocyanate (GITC), or ethanol.
- 25 In some embodiments, the isolated polypeptide is one of SEQ ID NO: 5 (mutant B-9), SEQ ID NO: 6 (mutant H-10), SEQ ID NO: 7 (mutant F-12), SEQ ID NO: 8 (mutant E-12), SEQ ID NO: 9 (mutant C-6), SEQ ID NO: 10 (mutant C-12), SEQ ID NO: 11 (mutant C-66), SEQ ID NO: 12 (mutant H-2), or SEQ ID NO: 13 (mutant A-111).
- 30 In some embodiments, the isolated polypeptide includes SEQ ID NO: 5 (mutant B-9) or a polypeptide sequence at least 95% identical to SEQ ID NO: 5 having 209G and polymerase activity.

In some embodiments, the isolated polypeptide includes SEQ ID NO: 6 (mutant H-10) or a polypeptide sequence at least 95% identical to SEQ ID NO: 6 having 140E and polymerase activity.

- 5 In some embodiments, the isolated polypeptide includes SEQ ID NO: 7 (mutant F-12) or a polypeptide sequence at least 95% identical to SEQ ID NO: 7 having 255R and polymerase activity.

In some embodiments, the isolated polypeptide includes SEQ ID NO: 8 (mutant E-12) or a polypeptide sequence at least 95% identical to SEQ ID NO: 8 having 503I and polymerase activity.

- 10 In some embodiments, the isolated polypeptide includes SEQ ID NO: 9 (mutant C-6) or a polypeptide sequence at least 95% identical to SEQ ID NO: 9 having 578E and polymerase activity.

- 15 In some embodiments, the isolated polypeptide includes SEQ ID NO: 10 (mutant C-12) or a polypeptide sequence at least 95% identical to SEQ ID NO: 10 having one or more of 551G, 599V, and 657Q and polymerase activity.

In some embodiments, the isolated polypeptide includes SEQ ID NO: 11 (mutant C-66) or a polypeptide sequence at least 95% identical to SEQ ID NO: 9 having 818V and polymerase activity.

- 20 In some embodiments, the isolated polypeptide includes SEQ ID NO: 12 (mutant H-2) or a polypeptide sequence at least 95% identical to SEQ ID NO: 12 having 404G and polymerase activity.

In some embodiments, the isolated polypeptide includes SEQ ID NO: 13 (mutant A-111) or a polypeptide sequence at least 95% identical to SEQ ID NO: 13 having 732N and polymerase activity.

- 25 In some embodiments, the isolated polypeptide includes SEQ ID NO: 14 (mutant A-111) or a polypeptide sequence at least 95% identical to SEQ ID NO: 14 having one or more of 175L, 176S, 250M, or 460R and polymerase activity.

- 30 Another aspect of the present disclosure provides a method of amplifying a target nucleic acid in a polymerase chain reaction (PCR). In some embodiments, the method includes forming an assay mixture of a sample containing a target nucleic acid, primers specific for the target nucleic acid, a

buffer, and an isolated polypeptide having polymerase activity described herein; and amplifying the target nucleic acid in the assay mixture in a PCR.

In some embodiments of the method, the sample includes an inhibitory substance in an amount sufficient to cause a wild type Taq polymerase (e.g., a
5 polymerase of SEQ ID NO: 1) to fail to amplify the target nucleic acid in the PCR.

In some embodiments of the method, the inhibitory substance is present in the sample comprising one or more of chocolate, peanut butter, milk, seafood, meat, egg, plant material, blood, a blood fraction, urine, dye, soil, soil extract, humic acid, guanidinium thiocyanate (GITC), or ethanol.

10 In some embodiments of the method, the assay mixture includes a dye up to about 100X, where X is a manufacturer unit for concentration for use in PCR. In some embodiments of the method, the assay mixture includes blood or a blood fraction up to about 40% of a total volume of the assay mixture. In some
15 embodiments of the method, the assay mixture includes soil or soil extract up to about 50% of a total volume of the assay mixture or an equivalent amount that provides up to about 5 ng of humic acid per μL of the assay mixture volume. In some embodiments of the method, the assay mixture includes a bile salt, or an equivalent amount of bile, up to about 2 μg per μL of the assay mixture or up to about 20% of a total volume of the assay mixture. In some embodiments of the
20 method, the assay mixture includes a plant material or a plant extract up to about 50% of a total volume of the assay mixture. In some embodiments of the method, the assay mixture includes urine up to about 90% of a total volume of the assay mixture. In some embodiments of the method, the assay mixture includes GITC up to about 200 mM in the assay mixture. In some embodiments
25 of the method, the assay mixture includes ethanol up to about 10% of a total volume of the assay mixture. In some embodiments of the method, the assay mixture includes tea polyphenols up to about 12 ng per μL of assay mixture. In some embodiments of the method, the assay mixture includes tannins up to about 0.5 μg per μL of assay mixture. In some embodiments of the method, the
30 assay mixture includes chocolate up to about 20 μg per μL of assay mixture. In some embodiments of the method, the assay mixture includes black pepper in an amount of up to 20 $\mu\text{g}/\mu\text{L}$ of assay mixture.

In some embodiments of the method, the PCR is a real-time PCR; the assay mixture further comprises at least one dye; and amplifying the target nucleic acid comprises amplifying the target nucleic acid in the assay mixture in a real-time PCR.

- 5 Another aspect of the present disclosure provides a nucleic acid encoding an isolated polypeptide having polymerase activity described herein. In some embodiments, a DNA construct contains operably linked components of a promoter functional in a host cell, a transcribable nucleic acid molecule encoding an isolated polypeptide having polymerase activity described herein, and a 3'
- 10 transcription termination sequence. In some embodiments is provided a host cell transformed with such a DNA construct, where the host cell expresses the encoded polymerase.

- Another aspect of the present disclosure provides kit that includes the isolated polypeptide having polymerase activity described herein, or a nucleic acid
- 15 encoding such, along with optional components useful or necessary for carrying out PCR or expressing a polymerase from a host cell.

Other objects and features will be in part apparent and in part pointed out hereinafter.

DESCRIPTION OF THE DRAWINGS

- 20 Those of skill in the art will understand that the drawings, described below, are for illustrative purposes only. The drawings are not intended to limit the scope of the present teachings in any way.

- FIG. 1 is an image of a series of gels showing performance of H-10 (SEQ ID NO: 6) Klentaq mutant with crude samples containing chocolate or black pepper. A 380 bp rRNA target was amplified from 1 ng bacterial DNA in 50 μ l reactions with 15 U Klentaq 1, w.t. Taq (New England Biolabs), and the Klentaq1 mutant H-10 (SEQ ID NO: 6) in the presence of 0, 3, 4, 5, 6 and 9 μ l of a crude black pepper extract (50 mg/ml, top panel), or 0, 2, 2.5, 3.0, 3.5 and 4.5 μ l 10% chocolate suspension (bottom panel), lanes 1-6. Lanes M, DNA ladder. The amplified
- 30 products were analyzed in ethidium bromide stained agarose gel. Further details regarding methodology are available in Example 1.

FIG. 2 is an image of a gel showing resistance of B-9 (SEQ ID NO: 5) and H-10 (SEQ ID NO: 6) KlenTaq mutants to black pepper inhibition. A 350 bp bacterial 16S rRNA target was amplified from 1 ng bacterial DNA with 0.8 μ l purified Omni KlenTaq (OKT) and KlenTaq mutants H-10 (SEQ ID NO: 6) and B-9 (SEQ ID NO: 5), in the presence of 0, 3, 4, 5, 6 and 7 μ l 10% black pepper extract (left to right, six reactions per enzyme) in 35 μ l reactions. Further details regarding methodology are available in Example 2.

FIG. 3 is an image of gel showing resistance of B-9 (SEQ ID NO: 5) and H-10 (SEQ ID NO: 6) KlenTaq mutants to chocolate inhibition. A 350 bp bacterial 16S rRNA target was amplified in 35 μ l reactions from 1 ng bacterial DNA with 0.8 μ l purified Omni KlenTaq (OKT) and KlenTaq mutants H-10 (SEQ ID NO: 6) and B-9 (SEQ ID NO: 5) in the presence of 0, 2, 2.5, 3, 3.5 and 4 μ l 10% chocolate (left to right, six reactions per enzyme). Further details regarding methodology are available in Example 3.

FIG. 4 is an image of a gel showing resistance of C-12 (SEQ ID NO: 10) full-length Taq mutant to chocolate inhibition. A 346 bp 16S rRNA target was amplified in 35 μ l reactions from 350 pg of *E. coli* DNA with 0.8 μ l purified OmniTaq, mutant C-12 (SEQ ID NO: 10), or wild type Taq (NEB) with 0, 1, 2, 3, 4 or 5 μ l of a 10 % chocolate extract. Further details regarding methodology are available in Example 4.

FIG. 5 is an image of a gel showing resistance of C-12 (SEQ ID NO: 10) full-length Taq mutant to black pepper inhibition. A 346 bp 16S rRNA target was amplified in 35 μ l reactions from 350 pg of *E. coli* DNA with 0.8 μ l of purified OmniTaq, mutant C-12 (SEQ ID NO: 10), or wild-type Taq (NEB) with 0, 0.25, 0.5, 1, 2 or 4 μ l of black pepper extract at 500 mg/mL (Lanes 1-6). Further details regarding methodology are available in Example 5.

FIG. 6 is a series of amplification curves and melting curves showing resistance of H-10 (SEQ ID NO: 6) KlenTaq mutant to chocolate in qPCR (SYBR Green). *Salmonella* DNA was 10-fold serially diluted from 1,000 pg to 1pg and it was detected by qPCR with SYBR Green with primer HiLA-3. The reactions included 0.6 μ l of purified Omni KlenTaq (OKT) or mutant H-10 (SEQ ID NO: 6) with 2 μ l 10% chocolate extract per 35 μ l reaction. Further details regarding methodology

are available in Example 6.

FIG. 7 is a series of amplification curves and melting curves showing resistance of C-12 (SEQ ID NO: 10) full-length Taq mutant to chocolate in qPCR (SYBR Green). Salmonella DNA was 10-fold serially diluted from 100 pg to 1 pg and
 5 detected by qPCR with SYBR Green with primer HiLA-3. The reactions included 0.3 μ l of purified OmniTaq (OT) and 0.3 μ l of the C-12 (SEQ ID NO: 10) mutant with 2 μ l 10% chocolate extract per 35 μ l reaction. Further details regarding methodology are available in Example 7.

FIG. 8 is an image of a gel showing performance of the H-10 (SEQ ID NO: 6)
 10 Klentaq mutant in PCR with crude samples containing whole blood. A 1.1 kb target from the human CCR5 gene was amplified in 25 μ l reactions with 10 U Klentaq1, w.t. Taq (New England Biolabs), and the H-10 (SEQ ID NO: 6) Klentaq1 mutant from 40%, 20%, 10%, 5%, and 2.5% heparin treated blood, lanes 1-6, respectively. Lane 1 (positive controls) contained no blood, but 10 ng
 15 human DNA. Lane M, DNA ladder. The amplified products were analyzed in ethidium bromide stained agarose gel. Further details regarding methodology are available in Example 8.

FIG. 9 is an image of a gel showing performance of the H-10 (SEQ ID NO: 6) Klentaq mutant in PCR with crude samples containing humic acid. A 1.1 kb
 20 target from the human CCR5 gene was amplified from 10 ng human DNA in 25 μ l reactions with 5 U Klentaq1, w.t. Taq (New England Biolabs), and the H-10 (SEQ ID NO: 6) Klentaq1 mutant in the presence of 0, 12, 25, 50, 100 and 200 ng humic acid (approximate amounts), lanes 1-6, respectively. Lanes M, DNA ladder. Further details regarding methodology are available in Example 9.

FIG. 10 is a series of gel images showing resistance of Klentaq mutants to bile inhibition. A 350 bp bacterial 16S rRNA target was amplified from 1 ng bacterial
 25 DNA in 50 μ l reactions with 0.5 μ l purified Omni Klentaq (OKT) or the Klentaq mutants H-10 (SEQ ID NO: 6), E-12 (SEQ ID NO: 8), B-9 (SEQ ID NO: 5), F-12 (SEQ ID NO: 7), and C-6 (SEQ ID NO: 9), in the presence of 0, 0.4, 0.8, 1.2, 1.6
 30 and 2 μ l bile salts extract (left to right, six reactions per enzyme). Further details regarding methodology are available in Example 10.

FIG. 11 is an image of a gel showing performance of H-10 (SEQ ID NO: 6)

Klentaq mutant in PCR with crude samples containing plant tissue extract. A 320 bp target from the beta-actin gene was amplified from 10 ng human DNA in 50 µl reactions with 10 U Klentaq 1, w.t. Taq (New England Biolabs), and the H-10 (SEQ ID NO: 6) Klentaq1 mutant in the presence of 0, 0.5, 1.0, 1.5, 2.0 and 2.5 µl of a crude plant leaf extract (lanes 1-6). Lanes M, DNA ladder. Further details regarding methodology are available in Example 11.

FIG. 12 is an image of a gel showing resistance of full-length Taq mutant C-66 (SEQ ID NO: 11) to shrimp meat inhibition. A 250 bp 16S rRNA target was amplified in 25 ul reactions from 1ng *Listeria* DNA with 0.5 µl purified OmniTaq, C-66 (SEQ ID NO: 11) mutant, and wild type Taq (NEB) in the presence of 20%, 10%, 5%, 2.5 % or 0% shrimp meat homogenate (Lanes 1-5). Further details regarding methodology are available in Example 12.

FIG. 13 is a series of gel images showing resistance of full-length Taq mutant C-12 (SEQ ID NO: 10) to food inhibition. A 170 bp 16S rRNA target was amplified in 25 ul reactions from 1.4 ng of *Salmonella* DNA with 0.3 µl of purified OmniTaq, mutant C-12 (SEQ ID NO: 10) polymerase, or an equivalent amount of wild type Taq (NEB) activity with 0 (lane 1), 2.25 µl (lane 2), 4.5 µl (lanes 3,6,9,12), 9 µl (lanes 4,7,10,13 or 18 µl (5,8,11,14) of 10% (w/v) food extract. Further details regarding methodology are available in Example 13.

20 DETAILED DESCRIPTION OF THE INVENTION

The present disclosure is based at least in part on newly discovered Taq and Klentaq polymerase mutants that can tolerate high levels of major PCR inhibitors. In various embodiments, mutant DNA polymerase enzymes are resistant to PCR inhibitors including those present in, for example, food or food samples, such as chocolate, peanut butter, milk, seafood, meat, or egg, as well as blood, blood components, urine, humic acid, bile salts, plant tissue extracts, GITC (guanidinium) or ethanol. Such mutants and related compositions can replace key PCR components of enzyme, buffer and additives in commercially available kits, rendering them more robust and sensitive even in the presence of some PCR inhibitors, which usually can compromise detection. Also, mutant polymerases described herein can be used directly, without requiring a commercial kit. Provided herein are compositions and methods for end-point or

real-time PCR analyses of samples containing inhibitory substances, such as food-containing samples, utilizing mutant polymerase enzymes that are inhibition resistant.

The following U.S. patent applications may be referred to:

- 5 U.S. Patent No. 7,462,475, issued 09 December 2008; U.S. Patent Application Publication No. 2009/0170060, published 02 July 2009; U.S. Patent Application Publication No. 2011/0027832, published 03 February 2011; U.S. Patent Application Publication No. 2012/0028259, published 02 February 2012; and International PCT application WO2012/088479, published 28 June 2012.
- 10 Except as otherwise noted herein, therefore, the process of the present disclosure can be carried out in accordance with compositions or processes of these references.

MUTANT POLYMERASES

- 15 Some embodiments provide mutant polymerases that can be resistant to various PCR inhibitors.

- 20 According to conventional notation, amino acid mutations discussed herein may be represented, from left to right, by the one letter code for the wild type amino acid, the amino acid position number, and the one letter code for the mutant amino acid. For mutant polypeptide sequences, an amino acid different than corresponding wild type may be represented, from left to right, by the amino acid position number and the one letter code for the amino acid that is different than corresponding wild type.

- 25 A "variant" polypeptide described in the following paragraphs is as defined in the "variant" section further below. Exemplary sequence identity (e.g., at least about 95% sequence identity) is not meant to limit the full range of sequence identity as discussed in the "variant" section herein.

- 30 For the following discussion, wild type Taq numbering (corresponding to numbering of full-length Taq of SEQ ID NO: 1) is used in this descriptive text so as to make clear the relationship between the polypeptides. Wild type Taq (SEQ ID NO: 1) and truncated KlenTaq-1 (SEQ ID NO: 2) have complete sequence homology across positions 279-832 of SEQ ID NO: 1, except for positions 279

(Gly) and 280 (Ser) of SEQ ID NO: 1 (corresponding to positions 1 (Met) and 2 (Gly) of truncated SEQ ID NO: 2). The amino acid changes at 279-280 of wild type Taq (SEQ ID NO: 1) and positions 1-2 of truncated Klentaq-1 (SEQ ID NO: 2) are not necessarily associated with a difference in phenotype as described
5 herein.

With respect to wild-type Taq numbering, for truncated polymerase polypeptides (e.g., Klentaq-1 of SEQ ID NO: 2), position number 1 as notated in the Sequence Listing of SEQ ID NO: 2 corresponds to position number 279 as notated in the full-length Taq of SEQ ID NO: 1. Similarly, position number 2 of SEQ ID NO: 2
10 corresponds to position number 280 of SEQ ID NO: 1. Similarly, position number 554 of SEQ ID NO: 2 corresponds to position number 832 of SEQ ID NO: 1. In other words, one can determine the corresponding position in full-length SEQ ID NO: 1 by adding 278 to any position in SEQ ID NO: 2.

A mutant polymerase described herein can be produced according to methods
15 known in the art. For example, oligonucleotides providing the specific amino acid changes to a mutant polymerase described can be prepared by standard synthetic techniques (e.g., an automated DNA synthesizer) and used as PCR primers in site-directed mutagenesis. Standard procedures of expression of mutant polymerase polypeptides from encoding DNA sequences can then be
20 performed. Alternatively, the mutant DNA polymerase polypeptides can be directly synthesized according to methods known in the art.

A mutant polymerase having a mutation described herein can be a full length mutant polymerase or a truncated mutant polymerase, as compared to a wild-type Taq polymerase. For example, a truncated mutant polymerase can be
25 truncated at position 278 per wild-type Taq numbering (e.g., position 1 of the truncated mutant corresponds to position 279 of SEQ ID NO: 1). One of skill in the art will understand that a truncated mutant polymerase can be truncated at any position of a full length sequence so long as polymerase activity is retained.

A truncated mutant polymerase can be referred to as a "functional fragment" of a
30 longer polymerase, such as a full-length polymerase. For example, SEQ ID NO: 2 (Klentaq-1, KT-1) is a variant (having G279M and S280G per wild type Taq numbering) and functional fragment of SEQ ID NO: 1 (wild type Taq). As another

example SEQ ID NO: 4 (Omni Kt, KT-10) is a functional fragment of SEQ ID NO: 3 (Omni Taq, FL-12). A functional fragment is shorter than the length of a reference polymerase and retains polymerase activity.

- As disclosed herein, one or more amino acid mutations (e.g., addition, deletion, substitution) can be associated with a phenotype described herein. In some embodiments, a mutant polymerase (e.g., a full length mutant polymerase or a truncated mutant polymerase) can include one or more of the following substitutions: E404G, G418E, V453L, A454S, R487G, I528ML533R, D551G, D578E, I599V, L657Q, D732N, K738R, L781I, and E818V.
- 10 For example, a mutant polymerase can include SEQ ID NO: 1 having one or more substitutions selected from E404G, G418E, V453L, A454S, R487G, I528ML533R, D551G, D578E, I599V, L657Q, D732N, K738R, L781I, and E818V, or a variant (e.g., at least about 95% sequence identity) thereof having at least one of these substitutions and having polymerase activity.
- 15 As another example, a mutant polymerase can include SEQ ID NO: 2 having one or more substitutions selected from E404G, G418E, V453L, A454S, R487G, I528ML533R, D551G, D578E, I599V, L657Q, D732N, K738R, L781I, and E818V (per wild-type Taq numbering), or a variant (e.g., at least about 95% sequence identity) thereof having at least one of these substitutions and having
- 20 polymerase activity.
- In some embodiments, a mutant polymerase (e.g., a full length mutant polymerase or a truncated mutant polymerase) can include one or more of the following substitutions: L609P, E626K, V649I, I707L, E708K, E708L, E708N, E708Q, E708I, E708W, E708R, E708V, or E708S (per wild type numbering). A
- 25 substitution at one or more of these positions (e.g., 708) can occur in combination with one or more other substitutions described herein. For example, a mutant polymerase (e.g., a full length mutant polymerase or a truncated mutant polymerase) can have (a) at least one substitution selected from E404G, G418E, V453L, A454S, R487G, I528ML533R, D551G, D578E, I599V, L657Q,
- 30 D732N, K738R, L781I, and E818V and (b) at least one substitution selected from L609P, E626K, V649I, I707L, E708K, E708L, E708N, E708Q, E708I, E708W, E708R, E708V, and E708S (per wild type numbering). As another example, a

- mutant polymerase can include SEQ ID NO: 1 having (a) at least one substitution selected from E404G, G418E, V453L, A454S, R487G, I528ML533R, D551G, D578E, I599V, L657Q, D732N, K738R, L781I, and E818V and (b) at least one substitution selected from L609P, E626K, V649I, I707L, E708K, E708L, E708N, E708Q, E708I, E708W, E708R, E708V, and E708S (per wild type numbering). As another example, a mutant polymerase can include SEQ ID NO: 2 having (a) at least one substitution selected from E404G, G418E, V453L, A454S, R487G, I528ML533R, D551G, D578E, I599V, L657Q, D732N, K738R, L781I, and E818V (per wild-type Taq numbering) and (b) at least one substitution selected from L609P, E626K, V649I, I707L, E708K, E708L, E708N, E708Q, E708I, E708W, E708R, E708V, and E708S (per wild-type Taq numbering).

- In some embodiments, a mutant polymerase (e.g., a full length or truncated mutant polymerase) can include one or more of the following substitutions: E626K, I707L, E708K, R487G, V453L, A454S, I528M, L533M, and K738R (per wild type Taq numbering). As another example, a mutant polymerase (e.g., a full length or truncated mutant polymerase) can include one or more of the following substitutions: R487G, V453L, A454S, I528M, L533M, and K738R.

B-9.

- A mutant polymerase can include an amino acid sequence of SEQ ID NO: 5 (mutant B-9), or a variant (e.g., at least about 95% sequence identity) thereof having 209G and retaining polymerase activity. Note that 209G in SEQ ID NO: 5 corresponds to R487G according to wild type Taq numbering.

- A mutant polymerase can include an amino acid sequence of SEQ ID NO: 2 having mutation R209G, or a variant (e.g., at least about 95% sequence identity) thereof with R209G and retaining polymerase activity. Note that R209G in SEQ ID NO: 2 corresponds to R487G according to wild type Taq numbering.

- A mutant polymerase can include an amino acid sequence of positions 279-832 of SEQ ID NO: 1 having mutation R487G (according to wild-type Taq numbering), or a variant (e.g., at least about 95% sequence identity) thereof with R487G and retaining polymerase activity.

H-10.

- A mutant polymerase can include an amino acid sequence of SEQ ID NO: 6 (mutant H-10), or a variant (e.g., at least about 95% sequence identity) thereof having 140E and retaining polymerase activity. Note that 140E in SEQ ID NO: 6 corresponds to G418E according to wild type Taq numbering. For example, a mutant polymerase can be a variant (e.g., at least about 95% sequence identity) of an amino acid sequence of SEQ ID NO: 6 having one or more of 140E, 348K, 429L, or 430S and retaining polymerase activity. Note that 348K, 429L, and 430S in SEQ ID NO: 6 correspond to E626K, I707L, and E708S according to wild type Taq numbering.
- 10 A mutant polymerase can include an amino acid sequence of SEQ ID NO: 2 having mutation G140E, or a variant (e.g., at least about 95% sequence identity) thereof with G140E and retaining polymerase activity. Note that G140E in SEQ ID NO: 2 corresponds to G418E according to wild type Taq numbering. For example, a mutant polymerase can be a variant (e.g., at least about 95% sequence identity) of an amino acid sequence of SEQ ID NO: 2 having one or more of G140E, E348K, I429L, or E430S and retaining polymerase activity.

- A mutant polymerase can include an amino acid sequence of positions 279-832 of SEQ ID NO: 1 having mutation G418E (according to wild-type Taq numbering), or a variant (e.g., at least about 95% sequence identity) thereof with G418E and retaining polymerase activity. For example, a mutant polymerase can be a variant (e.g., at least about 95% sequence identity) of an amino acid sequence of SEQ ID NO: 1 having one or more of G418E, E626K, I707L, and E708S and retaining polymerase activity.

F-12.

- 25 A mutant polymerase can include an amino acid sequence of SEQ ID NO: 7 (mutant F-12), or a variant (e.g., at least about 95% sequence identity) thereof having 255R and retaining polymerase activity. Note that 255R in SEQ ID NO: 7 corresponds to L533R according to wild type Taq numbering.

- A mutant polymerase can include an amino acid sequence of SEQ ID NO: 2 having mutation L255R, or a variant (e.g., at least about 95% sequence identity) thereof with L255R and retaining polymerase activity. Note that L255R in SEQ ID NO: 2 corresponds to L533R according to wild type Taq numbering.

A mutant polymerase can include an amino acid sequence of positions 279-832 of SEQ ID NO: 1 having mutation L533R (according to wild-type Taq numbering), or a variant (e.g., at least about 95% sequence identity) thereof with L533R and retaining polymerase activity.

5 E-12.

A mutant polymerase can include an amino acid sequence of SEQ ID NO: 8 (mutant E-12), or a variant (e.g., at least about 95% sequence identity) thereof having 503I and retaining polymerase activity. Note that 503I in SEQ ID NO: 8 corresponds to L781I according to wild type Taq numbering.

- 10 A mutant polymerase can include an amino acid sequence of SEQ ID NO: 2 having mutation L503I, or a variant (e.g., at least about 95% sequence identity) thereof with L503I and retaining polymerase activity. Note that L503I in SEQ ID NO: 2 corresponds to L781I according to wild type Taq numbering.

- 15 A mutant polymerase can include an amino acid sequence of positions 279-832 of SEQ ID NO: 1 having mutation L781I (according to wild-type Taq numbering), or a variant (e.g., at least about 95% sequence identity) thereof with L781I and retaining polymerase activity.

H-101.

- 20 A mutant polymerase can include an amino acid sequence of SEQ ID NO: 14 (mutant H-101), or a variant (e.g., at least about 95% sequence identity) thereof having at least one of 175L, 176S, 250M, or 460R and retaining polymerase activity. Note that 175L, 176S, 250M, and 460R in SEQ ID NO: 14 corresponds to V453L, A454S, I528M, and K738R, respectively, according to wild type Taq numbering.

- 25 A mutant polymerase can include an amino acid sequence of SEQ ID NO: 2 having mutations V175L, A176S, I250M, and K460R, or a variant (e.g., at least about 95% sequence identity) thereof with at least one of V175L, A176S, I250M, or K460R and retaining polymerase activity. Note that V175L, A176S, I250M, and K460R in SEQ ID NO: 2 corresponds to V453L, A454S, I528M, and K738R, respectively, according to wild type Taq numbering.
- 30

A mutant polymerase can include an amino acid sequence of positions 279-832

of SEQ ID NO: 1 having mutation V453L, A454S, I528M, and K738R (according to wild-type Taq numbering), or a variant (e.g., at least about 95% sequence identity) thereof with at least one of V453L, A454S, I528M, and K738R and retaining polymerase activity.

5 C-6.

A mutant polymerase can include an amino acid sequence of SEQ ID NO: 9 (mutant C-6), or a variant (e.g., at least about 95% sequence identity) thereof having 578E and retaining polymerase activity. Note that 578E in SEQ ID NO: 9 corresponds to D578E according to wild type Taq numbering.

- 10 A mutant polymerase can include an amino acid sequence of SEQ ID NO: 1 having mutation D578E (according to wild-type Taq numbering), or a variant (e.g., at least about 95% sequence identity) thereof with D578E and retaining polymerase activity.

C-12.

- 15 A mutant polymerase can include an amino acid sequence of SEQ ID NO: 10 (mutant C-12), or a variant (e.g., at least about 95% sequence identity) thereof having 551G, 599V, and 657Q and retaining polymerase activity. Note that 551G, 599V, and 657Q in SEQ ID NO: 10 correspond to D551G, I599V, and L657Q, respectively, according to wild type Taq numbering.

- 20 A mutant polymerase can include an amino acid sequence of SEQ ID NO: 1 having one or more mutations of D551G, I599V, and L657Q (according to wild-type Taq numbering), or a variant (e.g., at least about 95% sequence identity) thereof with one or more mutations of D551G, I599V, and L657Q and retaining polymerase activity.

25 C-66.

A mutant polymerase can include an amino acid sequence of SEQ ID NO: 11 (mutant C-66), or a variant (e.g., at least about 95% sequence identity) thereof having 818V and retaining polymerase activity. Note that 818V in SEQ ID NO: 11 corresponds to E818V according to wild type Taq numbering.

- 30 A mutant polymerase can include an amino acid sequence of SEQ ID NO: 1 having mutation E818V (according to wild-type Taq numbering), or a variant

(e.g., at least about 95% sequence identity) thereof with E818V and retaining polymerase activity.

H-2.

5 A mutant polymerase can include an amino acid sequence of SEQ ID NO: 12 (mutant H-2), or a variant (e.g., at least about 95% sequence identity) thereof having 404G and retaining polymerase activity. Note that 404G in SEQ ID NO: 12 corresponds to E404G according to wild type Taq numbering.

10 A mutant polymerase can include an amino acid sequence of SEQ ID NO: 1 having mutation E404G (according to wild-type Taq numbering), or a variant (e.g., at least about 95% sequence identity) thereof with E404G and retaining polymerase activity.

A-111.

15 A mutant polymerase can include an amino acid sequence of SEQ ID NO: 13 (mutant A-111), or a variant (e.g., at least about 95% sequence identity) thereof having 732N and retaining polymerase activity. Note that 732N in SEQ ID NO: 13 corresponds to D732N according to wild type Taq numbering.

20 A mutant polymerase can include an amino acid sequence of SEQ ID NO: 1 having mutation D732N (according to wild-type Taq numbering), or a variant (e.g., at least about 95% sequence identity) thereof with D732N and retaining polymerase activity.

25 A mutant polymerase described herein can be used in conjunction with compositions or processes described in US Patent No. 6,403,341; US Patent No. 7,393,635; US Patent No. 7,462,475; WO 2012/088479 (and corresponding US App Ser No. 13/997,194); US Pat App Pub No. 2010/0013291; US Pat App Pub No. 2012/0028259.

30 Another aspect of the present disclosure provides a polynucleotide encoding a mutant polymerase described herein. Also provided is a nucleic acid construct (e.g., an expression vector) including polynucleotide encoding a mutant polymerase described herein. A construct (e.g., a DNA construct) can include the following operably associated components: a promoter functional in a host cell, a nucleotide sequence (e.g., a heterologous DNA sequence, an exogenous

DNA segment, or a heterologous nucleic acid) encoding a mutant polymerase described herein, a transcriptional termination sequence. Generation of an encoding polynucleotide, a nucleic acid construct (e.g., an expression vector), transformation of a host cell with such construct, and expression of a mutant polymerase from a transformed host cell is within the state of the art.

VARIANTS

The term "variant" polypeptides (or encoding polynucleotides) is discussed below. The description of "variant" below is included in each recitation of "variant" in the description of mutant polymerases herein. For example, the full range of sequence identity discussed below applies equally to "variant" polypeptides discussed elsewhere herein.

Included in the scope of the present disclosure are variant polypeptides (or encoding polynucleotides) with at least 80% sequence identity to sequences described herein, so long as such variants retain a polymerase activity (e.g., a resistant polymerase activity).

For example, a variant polypeptide (or an encoding polynucleotide) with polymerase activity can have at least about 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 99.9% sequence identity to sequences disclosed herein (including disclosed sequences having substitutions described herein). It is understood that in some embodiments, "about" modifies each of these recited sequence identity values. A variant polypeptide (or encoding polynucleotides) with polymerase activity can have at least 95% sequence identity to a sequence disclosed herein. A variant polypeptide (or an encoding polynucleotide) with polymerase activity can have at least 99% sequence identity to a sequence disclosed herein. The species are representative of the genus of variant polypeptides of each of these respective sequences because all variants must possess the specified catalytic activity (e.g., resistant polymerase activity) and must have the percent identity required above to the reference sequence.

Design, generation, and testing of the variant polypeptides having the above required percent identities to the sequences of the mutant DNA polymerases and

retaining a required resistant phenotype is within the skill of the art. For example, directed evolution and rapid isolation of mutants can be according to methods described in references including, but not limited to, Link et al. (2007) Nature Reviews 5(9), 680-688; Sanger et al. (1991) Gene 97(1), 119-123; Ghadessy et al. (2001) Proc Natl Acad Sci USA 98(8) 4552-4557. Thus, one skilled in the art could generate a large number of polypeptide variants having, for example, at least 95-99% identity to the sequences of mutant DNA polymerases described herein and screen such for phenotypes including, dye-resistance, blood-resistance, or soil-resistance according to methods routine in the art. Generally, conservative substitutions can be made at any position so long as the required activity is retained.

Amino acid sequence identity percent (%) is understood as the percentage of amino acid residues that are identical with amino acid residues in a candidate sequence in comparison to a reference sequence when the two sequences are aligned. To determine percent amino acid identity, sequences are aligned and if necessary, gaps are introduced to achieve the maximum percent sequence identity; conservative substitutions are not considered as part of the sequence identity. Amino acid sequence alignment procedures to determine percent identity are well known to those of skill in the art. Often publicly available computer software, such as BLAST, BLAST2, ALIGN2 or Megalign (DNASTAR) software, is used to align peptide sequences. Those skilled in the art can determine appropriate parameters for measuring alignment, including any algorithms needed to achieve maximal alignment over the full-length of the sequences being compared. When amino acid sequences are aligned, the percent amino acid sequence identity of a given amino acid sequence A to, with, or against a given amino acid sequence B (which can alternatively be phrased as a given amino acid sequence A that has or comprises a certain percent amino acid sequence identity to, with, or against a given amino acid sequence B) can be calculated as: percent amino acid sequence identity = $X/Y \times 100$, where X is the number of amino acid residues scored as identical matches by the sequence alignment program's or algorithm's alignment of A and B, and Y is the total number of amino acid residues in B. If the length of amino acid sequence A is not equal to the length of amino acid sequence B, the percent amino acid

sequence identity of A to B will not equal the percent amino acid sequence identity of B to A.

PHENOTYPE

- As described herein, a mutant polymerase described herein can have
- 5 polymerase activity and a resistance to one or more substances that can inhibit PCR. A mutant polymerase described herein can have a phenotype including polymerase activity and an ability to fully or partially complete a PCR in a reaction mixture including an inhibitory substance at a concentration that a wild type Taq polymerase (e.g., SEQ ID NO: 1) would fail to amplify a target nucleic
- 10 acid. Resistant polymerase activity can be retention of all or most polymerase activity, or sufficient polymerase to complete a PCR, in the presence of a sample containing one or more of chocolate, pepper, milk, seafood, meat, egg, blood, urine, humic acid, bile, or plant material in sufficient quantity to inhibit or substantially inhibit a corresponding wild type polymerase.
- 15 A polymerase enzyme is understood to add a free nucleotide to an -OH group on the 3' end of a newly forming nucleic acid strand, resulting in elongation of the strand in a 5'-3' direction. Directionality of the newly forming strand (the daughter strand) is understood to be opposite to the direction in which a polymerase moves along a template strand. Thus, a polymerase moves along the template
- 20 strand in a 3'-5' direction, and the daughter strand is formed in a 5'-3' direction. In some embodiments, polymerase activity includes the ability of a polymerase to fully or partially complete a PCR. PCR is described further below.

- A phenotype of a mutant polymerase described herein can have polymerase activity and resistance to one or more substances that can inhibit PCR. A mutant
- 25 polymerase described herein can have a phenotype including polymerase activity and an ability to fully or partially complete a PCR in a reaction mixture including an inhibitory substance at a concentration that a wild type Taq polymerase would fail to amplify a target nucleic acid. An inhibitory substance can be present in food or food samples, such as chocolate, peanut butter, milk, seafood, meat, or egg, or other foods or food samples. GITC (guanidinium) or
- 30 ethanol are exemplary inhibitory substance that can be present in an assay

mixture. An inhibitory substance can be present in chocolate, pepper, blood, urine, humic acid, bile, tannins, melanin, indigo dyes, or plant material. For example, an inhibitory substance can be a polyphenol, such as a polyphenol present in a sample described above. Thus, a mutant polymerase described
 5 herein can be used to amplify a target polynucleotide in a PCR in the presence of one or more inhibitory substances.

Generally, a mutant polymerase described herein can tolerate at least an order of magnitude greater concentration of an inhibitory substance described herein as compared to a conventional polymerase (e.g., wild-type Taq). A mutant
 10 polymerase described herein can provide for amplification of a target nucleic acid in a sample containing an inhibitory substance at a level inhibitory to a wild type Taq, Klentaq, Omni Taq, or Omni Klentaq.

Phenotypes of exemplary mutant polymerases are described in TABLE 1. Each amino acid change recited in Table 1 can occur independently or in combination
 15 with one or more other amino acid changes in a mutant polymerase of the present disclosure.

TABLE 1: Mutant Enzymes. Substitutions are according to wild-type Taq numbering. Phenotype features: the performance of the enzymes in the presence of various PCR inhibitors is given in scale (+ to +++), relative to the Omni Klentaq (Klentaq-10) or OmniTaq (FL-22) mutants performance. In the case of blood, +, ++, and +++ roughly correspond to functionality in 10%, 20%, and 40% blood, respectively. * GITC stands for Guanidinium isothiocyanate. # Tobacco Leaf Extract used as challenging PCR inhibitor in the last column.

Mutant	Length	AA Changes (w.t.#)	Choc. Resist.	Black Pepper Resist.	GITC*	EtOH	Blood Resist.	Humic Resist.	Bile Resist.	Plant [#] Resist.
Omni KT (SEQ ID NO: 4)	KT	E626K I707L E708K	+	+	Not tested	Not tested	+	++	+	+

B-9 (SEQ ID NO: 5)	KT	R487G	+++	+++	Not tested	Not tested	++	+++	+++	++
H-10 (SEQ ID NO: 6)	KT	G418E E626K I707L E708S	+++	+++	Not tested	Not tested	++(+)	+++	+++	++
F-12 (SEQ ID NO: 7)	KT	L533R	++	++	Not tested	Not tested	+++	++	++	Not tested
E-12 (SEQ ID NO: 8)	KT	L781I	++	+++	Not tested	Not tested	++	++	+++	Not tested
H-101 (SEQ ID NO: 14)	KT	V453L A454S I528M K738R	++	+++	Not tested	Not tested	+++	+++	++	Not tested
Omni Taq (SEQ ID NO: 3)	Taq	E626K I707L E708N	+	+	Not tested	Not tested	+	+	+	+
C-6 (SEQ ID NO: 9)	Taq	D578E	+++	++	+++	+++	Not tested	++	+++	++
C-12 (SEQ ID NO: 10)	Taq	D551G, I599V, L657Q	+++	+++	Not tested	Not tested	Not tested	++	+++	++
C-66 (SEQ ID	Taq	E818V	+++	+++	Not tested	Not tested	+++	++	+++	+++

NO: 11)										
H-2 (SEQ ID NO: 12)	Taq	E404G	+++	+++	+++	+++	+++	+++	+++	+++
A-111 (SEQ ID NO: 13)	Taq	D732N	++	++	Not tested	Not tested	+++	+	+++	++

Dyes.

Various embodiments of the mutant polymerase enzymes described herein can tolerate increased concentrations of dyes, such as those used in real-time PCR (qPCR). A mutant polymerase can be used to amplify a DNA target in a real-time PCR of a DNA target in the presence of an inhibitory dye. A mutant polymerase can be used in combination with an enzyme having reverse transcriptase activity to amplify an RNA target in a real-time reverse transcriptase (RT) PCR of an RNA target in the presence of an inhibitory dye. Such increased concentrations include, but are not limited to, up to about 0.5X, 1X, 1.5X, 2X, 2.5X, 3X, 3.5X, 4X, 4.5X, 5X, 5.5X, 6X, 6.5X, 7X, 7.5X, 8X, 8.5X, 9X, 9.5X, 10X, 15X, 20X, 25X, 30X, 35X, 40X, 45X, 50X, 55X, 60X, 65X, 70X, 80X, 90X, or 100X, or even higher over the dye concentration conventionally used in the assay. As an example, X can be the standard manufacturers unit for dye concentration provided in a commercial product (e.g., SYBR Green, Molecular Probes, Eugene, Oregon). For example, for SYBR Green, X corresponds to a concentration of about 10 μ M.

Dye-resistance can be readily determined by assays known in the art and described in US Pat App Pub No. 2011/0027832.

Dyes for use in the methods described herein include, but are not limited to, SYBR Green (Molecular Probes, Eugene, Oregon), LC Green (Idaho Technology, Salt Lake City, Utah), PicoGreen (Molecular Probes, Eugene, Oregon), TOTO (Molecular Probes, Eugene, Oregon), YOYO (Molecular Probes,

Eugene, Oregon) and SYTO9 (Molecular Probes, Eugene, Oregon).

A dye can be a nucleic acid intercalating dye. A nucleic acid intercalating dye is understood to be a molecule that bind to nucleic acids in a reversible, non-covalent fashion, by insertion between the base pairs of the double helix, thereby
 5 indicating the presence and amount of nucleic acids. Generally, nucleic acid intercalating dyes are planar, aromatic, ring-shaped chromophore molecules. In some embodiments, intercalating dyes include fluorescent dyes. Numerous intercalating dyes are known in the art. Some non-limiting examples include PICO GREEN (P-7581, Molecular Probes), EB (E-8751, Sigma), propidium
 10 iodide (P-4170, Sigma), Acridine orange (A-6014, Sigma), 7-aminoactinomycin D (A-1310, Molecular Probes), cyanine dyes (e.g., TOTO, YOYO, BOBO, and POPO), SYTO, SYBR Green I, SYBR Green II, SYBR DX, OliGreen, CyQuant GR, SYTOX Green, SYTO9, SYTO10, SYTO 17, SYBRI 4, FUN-1, DEAD Red, Hexidium Iodide, Dihydroethidium, Ethidium Homodimer, 9-Amino-6-Chloro-2-
 15 Methoxyacridine, DAPI, DAPI, Indole dye, Imidazole dye, Actinomycin D, Hydroxystilbamidine, and LDS 751 (U.S. Pat. No. 6,210,885), BOXTO, LC Green, Evagreen, Bebo.

With their tolerance to high dye concentrations, the mutant polymerases described herein can outperform other conventional polymerase enzymes,
 20 including top commercial PCR enzymes, with commercially available dyes used in qPCR including, but not limited to, SYBR Green, LC Green (Idaho Technology, Salt Lake City, Utah), PICO, TOTO (Molecular Probes, Eugene, Oregon), YOYO (Molecular Probes, Eugene, Oregon), SYTO (Molecular Probes, Eugene, Oregon), and ethidium bromide. Some of these dyes are even more
 25 inhibitory than SYBR Green to a conventional Taq enzyme in PCR.

Blood.

In some embodiments, a mutant polymerase described herein can amplify a target nucleic acid in the presence of blood or blood components. A mutant polymerase can be used to amplify a DNA target in a real-time PCR of a DNA
 30 target in the presence of blood or blood components. A mutant polymerase can be used in combination with an enzyme having reverse transcriptase activity to amplify an RNA target in a real-time reverse transcriptase (RT) PCR of an RNA

target in the presence of blood or blood components.

Blood-resistance can be readily determined by assays described in US Pat App Pub No. 2006/0084074 or US Pat App Pub No. 2011/0027832.

Whole blood generally comprises plasma, serum, and blood cells. Blood
5 components include, but are not limited to, red blood cells, white blood cells
(e.g., leukocytes or platelets, i.e., thrombocytes), plasma, serum, hemoglobin,
water, proteins, glucose, amino acids, fatty acids, mineral ions, hormones,
carbon dioxide, urea, and lactic acid. A mutant polymerase described herein can
be used in PCR to amplify a nucleic acid target in the presence of one or more
10 such blood components.

Blood plasma is generally understood as a liquid suspension in which blood cells
are circulated. Thus, blood plasma can include one or more of water, proteins,
glucose, amino acids, fatty acids, mineral ions, hormones, carbon dioxide, urea,
lactic acid, platelets (i.e., thrombocytes), and blood cells. In a human subject,
15 blood plasma represents about 55% of whole blood, or about 2.7 to 3 liters in an
average human subject. Blood plasma contains about 92% water, 8% blood
plasma proteins, and trace amounts of other materials. Blood plasma can
contain serum albumin, blood-clotting factors, immunoglobulins, lipoproteins,
other proteins, and electrolytes (e.g., sodium and chloride). A crude sample
20 comprising blood plasma can also contain blood cells. A mutant polymerase
described herein can be used in PCR to amplify a nucleic acid target in the
presence of blood plasma.

Blood serum is generally understood as plasma from which clotting proteins
have been removed, leaving mostly albumin and immunoglobulins. A mutant
25 polymerase described herein can be used in PCR to amplify a nucleic acid target
in the presence of blood serum.

In some embodiments, a mutant polymerase can display amplification activity in
PCR assays (e.g., end point or real-time PCR) containing from about 1% to
about 40% whole blood in the reaction mixture (vol/vol). For example, whole
30 blood can comprise at least about 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9%, 10%,
11%, 12%, 13%, 14%, 15%, 16%, 17%, 18%, 19%, 20%, 21%, 22%, 23%, 24%,
25%, 26%, 27%, 28%, 29%, 30%, 31%, 32%, 33%, 34%, 35%, 36%, 37%, 38%,

39%, or 40% of a total volume of a PCR assay mixture comprising a mutant polymerase described herein. In contrast, the full-length wild-type Taq enzyme (SEQ ID NO: 1) is usually completely inhibited in a blood concentration range of about 0.004% to about 0.2% whole blood in the reaction mixture (vol/vol).

- 5 In some embodiments, a mutant polymerase can display amplification activity in PCR assays (e.g., end point or real-time PCR) containing from about 1% to about 25% blood plasma in the reaction mixture (vol/vol). For example, blood plasma can comprise at least about 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9%, 10%, 11%, 12%, 13%, 14%, 15%, 16%, 17%, 18%, 19%, 20%, 21%, 22%, 23%,
10 24%, or 25% of a total volume of a PCR assay mixture comprising a mutant polymerase described herein.

- In some embodiments, a mutant polymerase can display amplification activity in PCR assays (e.g., end point or real-time PCR) containing from about 1% to about 25% blood serum in the reaction mixture (vol/vol). For example, blood
15 serum can comprise at least about 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9%, 10%, 11%, 12%, 13%, 14%, 15%, 16%, 17%, 18%, 19%, 20%, 21%, 22%, 23%, 24%, or 25% of a total volume of a PCR assay mixture comprising a mutant polymerase described herein.

Soil.

- 20 In some embodiments, a mutant polymerase described herein can amplify a target nucleic acid in the presence of an inhibitor found in soil or soil extract. A mutant polymerase can be used to amplify a DNA target in a real-time PCR of a DNA target in the presence of an inhibitor found in soil or soil extract. A mutant polymerase can be used in combination with an enzyme having reverse
25 transcriptase activity to amplify an RNA target in a real-time reverse transcriptase (RT) PCR of an RNA target in the presence of an inhibitor found in soil or soil extract.

- Soil inhibitors and soil extract inhibitors include, but are not limited to, humic acid, fulvic acid, polysaccharides, and metal ions. A mutant polymerase can
30 display amplification activity in PCR assays containing from about 1% to about 50% soil or soil extract in the reaction mixture (vol/vol). For example, soil extract can comprise up to about 50%, 45%, 40%, 35%, 30%, 25%, 20%, 15%, 10%,

5%, or 1% of a total volume of a PCR assay mixture comprising a mutant polymerase described herein. The amount of soil or soil extract in the assay mixture can depend upon the levels of inhibitory substances in the soil or soil extract. Generally, a mutant polymerase described herein can tolerate at least an

5 order of magnitude greater concentration of these inhibitory substances, as compared to a conventional polymerase (e.g., wild-type Taq). Assays to determine the level of inhibitory substances in a sample are known in the art. Soil-resistance can be readily determined by assays described in US Pat App Pub No. 2011/0027832.

10 Direct extraction of total DNA from soil samples can result in a co-extraction of humic acid, known as the most potent soil inhibitor to PCR analysis. Humic substances represent a mixture of partially characterized polyphenols that are produced during the decomposition of organic matter. Conventional DNA

15 polymerase enzymes are inhibited at about 1 ng of humic acid per 50 uL reaction volume. Various embodiments of the mutant polymerases described herein are resistant to soil or soil extract that contains, for example, various levels of humic acid. Preferably, the volume of soil or soil extract used in the PCR assay mixture is the soil or soil extract equivalent that provides up to about 200 ng of humic

20 acid per 50 uL reaction volume. For example, the volume of soil or soil extract used in the PCR assay mixture can be the soil or soil extract equivalent that provides from about 1 ng up to about 200 ng of humic acid per 50 uL reaction volume. As another example, the volume of soil or soil extract used in the PCR

25 assay mixture can be the soil or soil extract equivalent that provides from about 5 ng up to about 200 ng of humic acid per 50 uL reaction volume. As another example, the volume of soil or soil extract used in the PCR assay mixture can be the soil or soil extract equivalent that provides about 1 ng, about 5 ng, about 10

ng, about 20 ng, about 30 ng, about 40 ng, about 50 ng, about 60 ng, about 70 ng, about 75 ng, about 80 ng, about 85 ng, about 90 ng, about 95 ng, about 100

30 ng, about 110 ng, about 120 ng, about 130 ng, about 140 ng, about 140 ng, about 150 ng, about 160 ng, about 170 ng, about 180 ng, about 190 ng, or about 200 ng of humic acid per 50 uL reaction volume. Assays to determine the amount of humic acid in a sample are known in the art.

Bile.

In some embodiments, a mutant polymerase described herein can amplify a target nucleic acid in the presence of bile or bile salts, a known PCR inhibitor. A mutant polymerase can be used to amplify a DNA target in a real-time PCR of a DNA target in the presence of bile. A mutant polymerase can be used in
 5 combination with an enzyme having reverse transcriptase activity to amplify an RNA target in a real-time reverse transcriptase (RT) PCR of an RNA target in the presence of bile.

A mutant polymerase described herein can provide for amplification of a target nucleic acid in a sample containing bile or bile salts at a level inhibitory to a wild
 10 type Taq, Klentaq, Omni Taq, or Omni Klentaq. Bile is understood to contain about 10% bile salts. Values recited below for bile salt extract can be extrapolated to bile.

For example, bile salts (or an equivalent amount of bile) can comprise up to about 100 µg per 50 µL reaction volume comprising a mutant polymerase
 15 described herein. As another example, bile salt extract (or an equivalent amount of bile) can comprise about 1 µg, 10 µg, 20 µg, 30 µg, 40 µg, 50 µg, 60 µg, 70 µg, 80 µg, 90 µg, or 100 µg per 50 µL reaction volume comprising a mutant polymerase described herein.

For example, bile salt extract (or an equivalent amount of bile) can comprise
 20 from about 0.1% up to about 20% of a total volume of a PCR assay mixture comprising a mutant polymerase described herein. As another example, bile salt extract (or an equivalent amount of bile) can comprise about 1.6% up to about 4% of a total volume of a PCR assay mixture comprising a mutant polymerase described herein. As another example, bile salt extract (or an equivalent amount
 25 of bile) can comprise about 0.1%, 0.5%, 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9%, 10%, 11%, 12%, 13%, 14%, 15%, 16%, 17%, 18%, 19%, or 20% or more of a total volume of a PCR assay mixture comprising a mutant polymerase described herein. As another example, bile salt extract (or an equivalent amount thereof)
 30 can comprise about 0.8%, 1.6%, 2.4%, 3.2%, or 4.0% (see e.g., Example 10, FIG. 10).

Bile can contain one or more of the following: cholic acid, chenodeoxycholic acid, glycocholic acid, taurocholic acid, deoxycholic acid, or lithocholic acid. A mutant polymerase described herein can provide for amplification of a target nucleic

acid in a sample containing one or more of cholic acid, chenodeoxycholic acid, glycocholic acid, taurocholic acid, deoxycholic acid, or lithocholic acid at a level inhibitory to a wild type Taq, Klentaq, Omni Taq, or Omni Klentaq.

Generally, a mutant polymerase described herein can tolerate at least an order
5 of magnitude greater concentration of these inhibitory substances, as compared to a conventional polymerase (e.g., wild-type Taq). A mutant polymerase described herein can provide for amplification of a target nucleic acid in a sample containing bile or bile salt extract at a level inhibitory to a wild type Taq, Klentaq, Omni Taq, or Omni Klentaq.

10 Plant.

In some embodiments, a mutant polymerase described herein can amplify a target nucleic acid in the presence of an inhibitor found in plant material or a plant extract. A mutant polymerase can be used to amplify a DNA target in a real-time PCR of a DNA target in the presence of an inhibitor found in plant
15 material or a plant extract. A mutant polymerase can be used in combination with an enzyme having reverse transcriptase activity to amplify an RNA target in a real-time reverse transcriptase (RT) PCR of an RNA target in the presence of an inhibitor found in plant material or a plant extract.

Plant material or plant extract inhibitors include, but are not limited to,
20 polyphenols or condensed tanins. A sample containing plant or plant extract can contain condensed tannins at up to about 50% of dry weight. Such a sample or fraction thereof can be included in an assay mixture. For example, plant material or plant extract can comprise at least about 1% up to about 50%; at least about 1% up to about 50%; at least about 1% up to about 40%; at least about 1% up to about 30%; at least about 1% up to about 20%; or at least about 1% up to about
25 10% of a total volume of a PCR assay mixture comprising a mutant polymerase described herein. For example, plant material or a plant extract can comprise up to about 50%, 45%, 40%, 35%, 30%, 25%, 20%, 15%, 10%, 5%, or 1% of a total volume of a PCR assay mixture comprising a mutant polymerase described
30 herein. The amount of plant material or a plant extract in the assay mixture can depend upon the levels of inhibitory substances in the plant material or a plant extract. Generally, a mutant polymerase described herein can tolerate at least an

order of magnitude greater concentration of these inhibitory substances, as compared to a conventional polymerase (e.g., wild-type Taq). Assays to determine the level of inhibitory substances in a sample are known in the art.

Exemplary plant material, or extract thereof, includes, but is not limited to,
5 soybean, tomato, tobacco, or tea.

A mutant polymerase described herein can provide for amplification of a target nucleic acid in a sample containing up to about 300 ng of tea polyphenols per 25 μ l reaction volume. For example, a mutant polymerase described herein can provide for amplification of a target nucleic acid in a sample containing up to
10 about 50 ng, up to about 75 ng, up to about 100 ng, up to about 125 ng, up to about 150 ng, up to about 175 ng, up to about 200 ng, up to about 225 ng, up to about 250 ng, up to about 275 ng, or up to about 300 ng of tea polyphenols per 25 μ l reaction volume.

As another example, an assay mixture containing a mutant polymerase
15 described herein can contain plant or plant extract at an equivalent amount that provides up to about 25 μ g of tannins per 50 μ L reaction volume; up to about 20 μ g of tannins per 50 μ L reaction volume; or up to about 10 μ g of tannins per 50 μ L reaction volume. Concentrations of polyphenols discussed above can be extrapolated to other polyphenol-containing samples.

20 Assays to determine the level of inhibitory substances in a sample and resistance of a polymerase are known in the art. For example, polyphenolic content can be assessed according to volumetric titration (e.g., oxidizing agent such as permanganate), colorimetric assay (e.g., Porter's Assay, Folin-Ciocalteu reaction), antioxidant capacity of a fraction (e.g., TEAC assay, DPPH assay,
25 ORAC assay, FRAP assay, lipoprotein oxidation inhibition assay), biosensor, or diode array detector-coupled HPLC.

Urine.

In some embodiments, a mutant polymerase described herein can amplify a target nucleic acid in the presence of urine, a known PCR inhibitor. A mutant
30 polymerase can be used to amplify a DNA target in a real-time PCR of a DNA target in the presence of urine. A mutant polymerase can be used in combination with an enzyme having reverse transcriptase activity to amplify an RNA target in

a real-time reverse transcriptase (RT) PCR of an RNA target in the presence of urine.

A mutant polymerase described herein can provide for amplification of a target nucleic acid in a sample containing urine at a level inhibitory to a wild type Taq, Klentaq, Omni Taq, or Omni Klentaq.

In some embodiments, a mutant polymerase can display amplification activity in PCR assays (e.g., end point or real-time PCR) containing up to about 90% urine. For example, urine can be present in an assay mixture comprising a mutant polymerase described herein at about 1%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, or 90%.

GITC.

In some embodiments, a mutant polymerase described herein can amplify a target nucleic acid in the presence of guanidinium thiocyanate (GITC) (also known as guanidine thiocyanate), a known PCR inhibitor. GITC is a chaotropic agent commonly used in the extraction of DNA or RNA. GITC can be present in a sample after using a GITC-phenol-chloroform extraction method.

A mutant polymerase can be used to amplify a DNA target in a real-time PCR of a DNA target in the presence of GITC. A mutant polymerase can be used in combination with an enzyme having reverse transcriptase activity to amplify an RNA target in a real-time reverse transcriptase (RT) PCR of an RNA target in the presence of GITC.

A mutant polymerase described herein can provide for amplification of a target nucleic acid in a sample containing GITC at a level inhibitory to a wild type Taq, Klentaq, Omni Taq, or Omni Klentaq.

In some embodiments, a mutant polymerase can display amplification activity in PCR assays (e.g., end point or real-time PCR) containing up to about 200 mM GITC. For example, GITC can be present in an assay mixture comprising a mutant polymerase described herein at about 1 mM, 10 mM, 20 mM, 30 mM, 40 mM, 50 mM, 60 mM, 70 mM, 80 mM, 90 mM, 100 mM, 110 mM, 120 mM, 130 mM, 140 mM, 150 mM, 160 mM, 170 mM, 180 mM, 190 mM, or 200 mM.

Ethanol.

In some embodiments, a mutant polymerase described herein can amplify a target nucleic acid in the presence of ethanol, a known PCR inhibitor. A mutant polymerase can be used to amplify a DNA target in a real-time PCR of a DNA target in the presence of ethanol. A mutant polymerase can be used in
5 combination with an enzyme having reverse transcriptase activity to amplify an RNA target in a real-time reverse transcriptase (RT) PCR of an RNA target in the presence of ethanol.

A mutant polymerase described herein can provide for amplification of a target nucleic acid in a sample containing ethanol at a level inhibitory to a wild type
10 Taq, Klentaq, Omni Taq, or Omni Klentaq.

In some embodiments, a mutant polymerase can display amplification activity in PCR assays (e.g., end point or real-time PCR) containing up to about 10% ethanol. For example, ethanol can be present in an assay mixture comprising a mutant polymerase described herein at about 1%, 2%, 3%, 4%, 5%, 6%, 7%,
15 8%, 9% or 10%.

Food.

In some embodiments, a mutant polymerase described herein can amplify a target nucleic acid in the presence of food samples containing an inhibitory substance. A mutant polymerase can be used to amplify a DNA target in a real-
20 time PCR of a DNA target in the presence of ethanol. A mutant polymerase can be used in combination with an enzyme having reverse transcriptase activity to amplify an RNA target in a real-time reverse transcriptase (RT) PCR of an RNA target in the presence of ethanol.

Food samples known to contain inhibitory substances (e.g., polyphenols)
25 include, but are not limited to, chocolate, peanut butter, milk, seafood, meat, egg, potato skins, tea, berries, beer, wine, olive oil, walnuts, peanuts, or other plant material including fruits, vegetables, or tubers.

For example, a wild type Taq polymerase (SEQ ID NO: 1) is completely inhibited at a chocolate concentration of more than about 0.04 µg/µl chocolate in a
30 sample while other polymerases, such as Omni Taq (SEQ ID NO: 3) or Omni Klentaq (SEQ ID NO: 4) can tolerate about 5 µg/µl chocolate. In contrast, a mutant polymerase described herein can maintain polymerase activity even

- where a chocolate concentration exceeds more than about 5 µg/µl chocolate (more than about 5, 10, or 15 µg/µl chocolate) in a sample. As another example, an assay mixture containing a mutant polymerase described herein can contain a concentration of chocolate up to about 20 µg/µl. As another example, an assay
- 5 mixture containing a mutant polymerase described herein can contain a concentration of chocolate at least about 0.05 µg/µl up to about 20 µg/µl.

PCR

- A mutant polymerase (including all variants thereof) described herein can be used in a variety of polymerase reactions known to the art (see e.g., Dorak
- 10 (2006) Real-Time PCR, Taylor & Francis, ISBN 041537734X; Bustin, ed. (2004) A-Z of Quantitative PCR, International University Line, ISBN 0963681788; King and O'Connel (2002) RT-PCR Protocols, 1st Ed., Human Press, ISBN-10 0896038750). For example, a mutant polymerase can be employed in PCR reactions, primer extension reactions, etc.
- 15 For example, a mutant polymerases described herein can be used in nucleic acid amplification processes (either alone or in combination with one or more other enzymes), such as Allele-specific PCR; Assembly PCR or Polymerase Cycling Assembly; Asymmetric PCR; Linear-After-The-Exponential-PCR; Helicase-dependent amplification; Hot-start PCR; Intersequence-specific PCR;
- 20 Inverse PCR; Ligation-mediated PCR; Methylation-specific PCR; Miniprimer PCR; Multiplex Ligation-dependent Probe Amplification; Multiplex-PCR; Nested PCR; Overlap-extension PCR; Quantitative PCR; Quantitative End-Point PCR; Quantitative Real-Time PCR; RT-PCR (Reverse Transcription PCR); Solid Phase PCR; Thermal asymmetric interlaced PCR; Touchdown PCR; PAN-AC;
- 25 Universal Fast Walking; Long PCR; Rapid Amplified Polymorphic DNA Analysis; Rapid Amplification of cDNA Ends (RACE); Differential Display PCR; In situ PCR; High-Fidelity PCR; PCR or DNA Sequencing (cycle sequencing).

- A target nucleic acid of a sample can be any target nucleic acid of interest. For example, a target nucleic acid can be a deoxyribonucleic acid (DNA), a
- 30 ribonucleic acid (RNA), or an artificial nucleic acid analog (e.g., a peptide nucleic acid, morpholino- and locked nucleic acid, glycol nucleic acid, or threose nucleic

acid).

- A primer is understood to refer to an oligonucleotide, whether occurring naturally or produced synthetically, which is capable of acting as a point of initiation of nucleic acid synthesis when placed under conditions in which
- 5 synthesis of a primer extension product which is complementary to a nucleic acid strand is induced, e.g. , in the presence of four different nucleotide triphosphates and thermostable enzyme in an appropriate buffer ("buffer" includes pH, ionic strength, cofactors, etc.) and at a suitable temperature. The primer is preferably single-stranded for maximum efficiency in amplification, but may alternatively be
- 10 double-stranded. If double-stranded, the primer is first treated to separate its strands before being used to prepare extension products. Preferably, the primer is an oligodeoxyribonucleotide. The primer must be sufficiently long to prime the synthesis of extension products in the presence of the thermostable enzyme. The exact lengths of the primers will depend on many factors, including
- 15 temperature, source of primer and use of the method. For example, depending on the complexity of the target sequence, the oligonucleotide primer typically contains 15-25 nucleotides, although it may contain more or few nucleotides. Short primer molecules generally require colder temperatures to form sufficiently stable hybrid complexes with template.
- 20 A target nucleic acid, e.g., a template DNA molecule, is understood to be a strand of a nucleic acid from which a complementary nucleic acid strand can be synthesized by a DNA polymerase, for example, in a primer extension reaction.
- In some embodiments, the use of a mutant polymerase enzyme described herein does not require any, or substantial, changes in the typical protocol, but
- 25 can allow, for example, for the presence of higher concentrations of inhibitory substances. A mutant polymerase described herein, and methods for use thereof, can allow for elimination or substantial elimination of an enrichment step for sample preparation. Eliminating an enrichment step can significantly reduce the time to detection or quantification.
- 30 A mutant polymerase described herein can be used in an end-point PCR. For example, end-point PCR is commonly carried out in a reaction volume of about 10-200 μ l in small reaction tubes (about 0.2-0.5 ml volumes) in a thermal cycler.

A mutant polymerase described herein can be used with a variety of commercially available end-point PCR kits. The use of a mutant polymerase enzyme described herein generally does not require any, or substantial, changes in the typical end-point PCR protocol, but can allow, for example, a sample
5 having a higher amount of an inhibitory substance.

A mutant polymerase described herein can be used in real-time PCR (also known as a quantitative polymerase chain reaction (qPCR)). For example, a mutant polymerase described herein can be used in a real-time PCR assay featuring a non-specific fluorescent dye (e.g., a fluorochrome) that can
10 intercalate with any double-stranded DNA. With a non-specific fluorescent dye, an increase in DNA product during PCR can lead to an increase in fluorescence intensity and is measured at each cycle, thus allowing DNA concentrations to be quantified.

As another example, a mutant polymerase described herein can be used in a
15 real-time PCR assay featuring a hybridization probe. As another example, a mutant polymerase described herein can be used in a real-time PCR multiplex assay featuring a hybridization probe. A hybridization probe can be a sequence-specific DNA probe including a fluorescent reporter at one end and a quencher of fluorescence at the opposite end of the probe, where break down of the probe
20 by a 5' to 3' exonuclease activity of a polymerase can break the reporter-quencher proximity and thus allow unquenched emission of fluorescence, which can be detected after excitation with a laser (e.g., a TaqMan® assay). With a hybridization probe, an increase in the product targeted by the reporter probe at each PCR cycle can cause a proportional increase in fluorescence due to the
25 breakdown of the probe and release of the reporter. A mutant polymerase described herein can be used with a variety of commercially available real-time PCR kits.

Thus, methods described herein can be applied to improve the nucleic acid detection in an end-point PCR or a real-time PCR.

30 In some embodiments, a mutant polymerase described herein can be used in combination with an enzyme having reverse transcriptase activity in a real-time reverse transcriptase (RT) PCR amplification of an RNA target. It is noted that

reverse transcriptase (RT) PCR is not to be confused with real-time polymerase chain reaction (Q-PCR), which is sometimes (incorrectly) abbreviated as RT-PCR in the art. In RT-PCR, an RNA strand is first reverse transcribed into its DNA complement (complementary DNA, or cDNA) using the enzyme reverse transcriptase, and the resulting cDNA is amplified using traditional PCR. Like
5 with end-point PCR, conventional RT-PCR protocols require extensive purification steps prior to amplification to purify RNA from inhibitors and ribonucleases, which can destroy the RNA template. Both the inhibition and degradation of RNA are major concerns in important clinical and diagnostics
10 tests, which may lead to false-negative results.

The buffer for use in the various PCR assay mixtures described herein is generally a physiologically compatible buffer that is compatible with the function of enzyme activities and enables cells or biological macromolecules to retain their normal physiological and biochemical functions. Typically, a physiologically
15 compatible buffer will include a buffering agent (e.g., TRIS, MES, PO₄, HEPES, etc.), a chelating agent (e.g., EDTA, EGTA, or the like), a salt (e.g., ammonium sulfate, NaCl, KCl, MgCl₂, CaCl₂, NaOAc, KOAc, Mg(OAc)₂, etc.) and optionally a stabilizing agent (e.g., sucrose, glycerine, Tween20, etc.).

Various PCR additives and enhancers can be employed with the methods
20 described herein. For example, betaine (e.g., MasterAmp™ 10X PCR, Epicentre Biotechnologies) can be added to the PCR assay, to further aid in overcoming the inhibition by inhibitory substances described herein. Betaine can be included at final concentration about 1 M to about 2M. Generally, betaine alone is insufficient to overcome the inhibition of various inhibitory substances described
25 herein when used with conventional DNA polymerases.

As another example, a mutant polymerase described herein can be used in conjunction with a PCR enhancer described in US Pat Pub No. 2012/0028259 or WO 2012/088479. For example, a mutant polymerase
30 can be used in conjunction with a PCR enhancer including trehalose (e.g., about 0.1 to about 1.0 M D-(+)-trehalose per amplification reaction mixture volume), carnitine (about 0.1 to about 1.5 M L-carnitine per amplification reaction mixture volume), or a non-ionic detergent (e.g., Brij-58,

NP-40, Nonidet P-40, Igepal CA-630, Brij-58, Tween-20, NP-40, or Triton X-100 at about 0.01% to about 8% non-ionic detergent per amplification reaction mixture volume) or optionally one or more of heparin (e.g., an amount of heparin equivalent to about 2 units to about 50 units heparin per mL of whole blood, plasma, or serum in an amplification reaction mixture), casein (at least about 0.05% up to about 2.5% per amplification reaction mixture volume), or polyvinylpyrrolidone (PVP) or a modified polymer of PVP (PVPP) (e.g., about 0.1% up to about 25%). As another example, a mutant polymerase can be used in conjunction with a PCR enhancer including about 0.6 M trehalose per amplification reaction mixture volume; about 0.5 M carnitine per amplification reaction mixture volume; or a non-ionic detergent (e.g., a polyoxyethylene cetyl ether at about 0.04% to about 0.2% or a nonyl phenoxy polyethoxy ethanol at about 0.4% to about 0.8% per amplification reaction mixture volume); or optional heparin at about 10 units per mL of whole blood, blood fraction, plasma, or serum.

As another example, a mutant polymerase described herein can be used in conjunction with commercially available PCR amplification reaction enhancers, such as MasterAmp™ 10X PCR Enhancer, Epicentre Biotechnologies; TaqMaster PCR Enhancer, MasterTaq Kit, PCR Extender System, 5 PRIME GmbH; Hi-Spec Additive, Bioline; PCRboost™, Biomatrix®; PCRX Enhancer System, Invitrogen; Taq Extender™ PCR Additive, Perfect Match® PCR Enhancer, Stratagene; Polymer-Aide PCR Enhancer, Sigma-Aldrich.

KITS

Also provided are kits. Such kits can include an agent or composition described herein and, in certain embodiments, instructions for administration. Such kits can facilitate performance of the methods described herein. When supplied as a kit, the different components of the composition can be packaged in separate containers and admixed immediately before use. Components include, but are not limited to a mutant polymerase described herein or a nucleic acid encoding such mutant polymerase or, optionally, a primer, a buffer, or other composition or component (e.g., a magnesium salt) necessary or helpful for PCR. Such packaging of the components separately can, if desired, be presented in a pack

or dispenser device which may contain one or more assay unit forms containing a composition. The pack may, for example, comprise metal or plastic foil such as a blister pack. Such packaging of the components separately can also, in certain instances, permit long-term storage without losing activity of the components.

Kits may also include reagents in separate containers such as, for example, sterile water or saline to be added to a lyophilized active component packaged separately. For example, sealed glass ampules may contain a lyophilized component and in a separate ampule, sterile water, sterile saline or sterile each of which has been packaged under a neutral non-reacting gas, such as nitrogen. Ampules may consist of any suitable material, such as glass, organic polymers, such as polycarbonate, polystyrene, ceramic, metal or any other material typically employed to hold reagents. Other examples of suitable containers include bottles that may be fabricated from similar substances as ampules, and envelopes that may consist of foil-lined interiors, such as aluminum or an alloy. Other containers include test tubes, vials, flasks, bottles, syringes, and the like. Containers may have a sterile access port, such as a bottle having a stopper that can be pierced by a hypodermic injection needle. Other containers may have two compartments that are separated by a readily removable membrane that upon removal permits the components to mix. Removable membranes may be glass, plastic, rubber, and the like.

In certain embodiments, kits can be supplied with instructional materials. Instructions may be printed on paper or other substrate, or may be supplied as an electronic-readable medium, such as a floppy disc, mini-CD-ROM, CD-ROM, DVD-ROM, Zip disc, videotape, audio tape, and the like. Detailed instructions may not be physically associated with the kit; instead, a user may be directed to an Internet web site specified by the manufacturer or distributor of the kit.

MOLECULAR ENGINEERING

The following definitions and methods are provided to better define the present invention and to guide those of ordinary skill in the art in the practice of the present invention. Unless otherwise noted, terms are to be understood according

to conventional usage by those of ordinary skill in the relevant art.

Compositions and methods described herein utilizing molecular biology protocols can be according to a variety of standard techniques known to the art (see, e.g., Sambrook and Russell (2006) Condensed Protocols from Molecular Cloning: A

- 5 Laboratory Manual, Cold Spring Harbor Laboratory Press, ISBN-10: 0879697717; Ausubel et al. (2002) Short Protocols in Molecular Biology, 5th ed., Current Protocols, ISBN-10: 0471250929; Sambrook and Russell (2001) Molecular Cloning: A Laboratory Manual, 3d ed., Cold Spring Harbor Laboratory Press, ISBN-10: 0879695773; Elhai, J. and Wolk, C. P. 1988. Methods in
- 10 Enzymology 167, 747-754; Studier (2005) Protein Expr Purif. 41(1), 207-234; Gellissen, ed. (2005) Production of Recombinant Proteins: Novel Microbial and Eukaryotic Expression Systems, Wiley-VCH, ISBN-10: 3527310363; Baneyx (2004) Protein Expression Technologies, Taylor & Francis, ISBN-10: 0954523253).
- 15 A mutation refers to a change introduced into a parental sequence, including, but not limited to, substitutions, insertions, or deletions (including truncations). The consequences of a mutation include, but are not limited to, the creation of a new character, property, function, phenotype or trait not found in the protein encoded by the parental sequence.
- 20 Enzyme activity refers to the specificity and efficiency of a DNA polymerase. Enzyme activity of a DNA polymerase can also be referred to as polymerase activity, which typically refers to the activity of a DNA polymerase in catalyzing the template-directed synthesis of a polynucleotide. Enzyme activity of a polymerase can be measured using various techniques and methods known in
- 25 the art. For example, serial dilutions of polymerase can be prepared in dilution buffer. The reaction mixtures can be incubated at, e.g., 74C and stopped by cooling to, e.g., 40C and adding ice-cold EDTA. An aliquot can be removed from each reaction mixture. Unincorporated radioactively labeled dCTP can be removed from each aliquot by gel filtration (e.g., Centri-Sep, Princeton
- 30 Separations, Adelphia, N. J.). The column eluate can be mixed with scintillation fluid. Radioactivity in the column eluate can be quantified with a scintillation counter to determine the amount of product synthesized by the polymerase. One

unit of polymerase activity can be defined as the amount of polymerase necessary to synthesize 10 nmole of product in 30 minutes (see e.g., Lawyer et al. 1989 J. Biol. Chem. 264, 6427-647). Other methods of measuring polymerase activity are known in the art (see e.g. Sambrook and Russell (2001) Molecular Cloning: A Laboratory Manual, 3d ed., Cold Spring Harbor Laboratory Press, ISBN-10: 0879695773).

The terms "heterologous DNA sequence", "exogenous DNA segment" or "heterologous nucleic acid," as used herein, each refer to a sequence that originates from a source foreign to the particular host cell or, if from the same source, is modified from its original form. Thus, a heterologous gene in a host cell includes a gene that is endogenous to the particular host cell but has been modified through, for example, the use of DNA shuffling. The terms also include non-naturally occurring multiple copies of a naturally occurring DNA sequence. Thus, the terms refer to a DNA segment that is foreign or heterologous to the cell, or homologous to the cell but in a position within the host cell nucleic acid in which the element is not ordinarily found. Exogenous DNA segments are expressed to yield exogenous polypeptides. A "homologous" DNA sequence is a DNA sequence that is naturally associated with a host cell into which it is introduced.

Expression vector, expression construct, plasmid, or recombinant DNA construct is generally understood to refer to a nucleic acid that has been generated via human intervention, including by recombinant means or direct chemical synthesis, with a series of specified nucleic acid elements that permit transcription or translation of a particular nucleic acid in, for example, a host cell.

The expression vector can be part of a plasmid, virus, or nucleic acid fragment. Typically, the expression vector can include a nucleic acid to be transcribed operably linked to a promoter.

A "promoter" is generally understood as a nucleic acid control sequence that directs transcription of a nucleic acid. An inducible promoter is generally understood as a promoter that mediates transcription of an operably linked gene in response to a particular stimulus. A promoter can include necessary nucleic acid sequences near the start site of transcription, such as, in the case of a

polymerase II type promoter, a TATA element. A promoter can optionally include distal enhancer or repressor elements, which can be located as much as several thousand base pairs from the start site of transcription.

5 A "transcribable nucleic acid molecule" as used herein refers to any nucleic acid molecule capable of being transcribed into a RNA molecule. Methods are known for introducing constructs into a cell in such a manner that the transcribable nucleic acid molecule is transcribed into a functional mRNA molecule that is translated and therefore expressed as a protein product. For the practice of the present disclosure, conventional compositions and methods for preparing and
10 using constructs and host cells are well known to one skilled in the art (see e.g., Sambrook and Russel (2006) Condensed Protocols from Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory Press, ISBN-10: 0879697717; Ausubel et al. (2002) Short Protocols in Molecular Biology, 5th ed., Current Protocols, ISBN-10: 0471250929; Sambrook and Russel (2001)
15 Molecular Cloning: A Laboratory Manual, 3d ed., Cold Spring Harbor Laboratory Press, ISBN-10: 0879695773; Elhai, J. and Wolk, C. P. 1988. Methods in Enzymology 167, 747-754).

The "transcription start site" or "initiation site" is the position surrounding the first nucleotide that is part of the transcribed sequence, which is also defined as
20 position +1. With respect to this site all other sequences of the gene and its controlling regions can be numbered. Downstream sequences (i.e., further protein encoding sequences in the 3' direction) can be denominated positive, while upstream sequences (mostly of the controlling regions in the 5' direction) are denominated negative.

25 "Operably-linked" or "functionally linked" refers preferably to the association of nucleic acid sequences on a single nucleic acid fragment so that the function of one is affected by the other. For example, a regulatory DNA sequence is said to be "operably linked to" or "associated with" a DNA sequence that codes for an RNA or a polypeptide if the two sequences are situated such that the regulatory
30 DNA sequence affects expression of the coding DNA sequence (i.e., that the coding sequence or functional RNA is under the transcriptional control of the promoter). Coding sequences can be operably-linked to regulatory sequences in

sense or antisense orientation. The two nucleic acid molecules may be part of a single contiguous nucleic acid molecule and may be adjacent. For example, a promoter is operably linked to a gene of interest if the promoter regulates or mediates transcription of the gene of interest in a cell.

- 5 A "construct" is generally understood as any recombinant nucleic acid molecule such as a plasmid, cosmid, virus, autonomously replicating nucleic acid molecule, phage, or linear or circular single-stranded or double-stranded DNA or RNA nucleic acid molecule, derived from any source, capable of genomic integration or autonomous replication, comprising a nucleic acid molecule where
10 one or more nucleic acid molecule has been operably linked.

- A constructs of the present disclosure can contain a promoter operably linked to a transcribable nucleic acid molecule operably linked to a 3' transcription termination nucleic acid molecule. In addition, constructs can include but are not limited to additional regulatory nucleic acid molecules from, e.g., the 3'-
15 untranslated region (3' UTR). Constructs can include but are not limited to the 5' untranslated regions (5' UTR) of an mRNA nucleic acid molecule which can play an important role in translation initiation and can also be a genetic component in an expression construct. These additional upstream and downstream regulatory nucleic acid molecules may be derived from a source that is native or
20 heterologous with respect to the other elements present on the promoter construct.

- The term "transformation" refers to the transfer of a nucleic acid fragment into the genome of a host cell, resulting in genetically stable inheritance. Host cells containing the transformed nucleic acid fragments are referred to as "transgenic"
25 cells, and organisms comprising transgenic cells are referred to as "transgenic organisms".

- "Transformed," "transgenic," and "recombinant" refer to a host cell or organism such as a bacterium, cyanobacterium, animal or a plant into which a heterologous nucleic acid molecule has been introduced. The nucleic acid
30 molecule can be stably integrated into the genome as generally known in the art and disclosed (Sambrook 1989; Innis 1995; Gelfand 1995; Innis & Gelfand 1999). Known methods of PCR include, but are not limited to, methods using

paired primers, nested primers, single specific primers, degenerate primers, gene-specific primers, vector-specific primers, partially mismatched primers, and the like. The term "untransformed" refers to normal cells that have not been through the transformation process.

- 5 Design, generation, and testing of the variant polynucleotides, and their encoded polypeptides, having the above required percent identities and retaining a required activity of the expressed protein is within the skill of the art. For example, directed evolution and rapid isolation of mutants can be according to methods described in references including, but not limited to, Link et al. (2007)
- 10 Nature Reviews 5(9), 680-688; Sanger et al. (1991) Gene 97(1), 119-123; Ghadessy et al. (2001) Proc Natl Acad Sci USA 98(8) 4552-4557. Thus, one skilled in the art could generate a large number of nucleotide or polypeptide variants having, for example, at least 95-99% identity to the reference sequence described herein and screen such for desired phenotypes according to methods
- 15 routine in the art.

Nucleotide amino acid sequence identity percent (%) is understood as the percentage of nucleotide or amino acid residues that are identical with nucleotide or amino acid residues in a candidate sequence in comparison to a reference sequence when the two sequences are aligned. To determine percent identity,

20 sequences are aligned and if necessary, gaps are introduced to achieve the maximum percent sequence identity. Sequence alignment procedures to determine percent identity are well known to those of skill in the art. Often publicly available computer software such as BLAST, BLAST2, ALIGN2 or Megalign (DNASTAR) software is used to align sequences. Those skilled in the

25 art can determine appropriate parameters for measuring alignment, including any algorithms needed to achieve maximal alignment over the full-length of the sequences being compared. When sequences are aligned, the percent sequence identity of a given sequence A to, with, or against a given sequence B (which can alternatively be phrased as a given sequence A that has or

30 comprises a certain percent sequence identity to, with, or against a given sequence B) can be calculated as: percent sequence identity = $X/Y100$, where X is the number of residues scored as identical matches by the sequence alignment program's or algorithm's alignment of A and B and Y is the total

number of residues in B. If the length of sequence A is not equal to the length of sequence B, the percent sequence identity of A to B will not equal the percent sequence identity of B to A.

Generally, conservative substitutions can be made at any position so long as the required activity is retained. So-called conservative exchanges can be carried out in which the amino acid which is replaced has a similar property as the original amino acid, for example the exchange of Glu by Asp, Gln by Asn, Val by Ile, Leu by Ile, and Ser by Thr. Deletion is the replacement of an amino acid by a direct bond. Positions for deletions include the termini of a polypeptide and linkages between individual protein domains. Insertions are introductions of amino acids into the polypeptide chain, a direct bond formally being replaced by one or more amino acids. Amino acid sequence can be modulated with the help of art-known computer simulation programs that can produce a polypeptide with, for example, improved activity or altered regulation. On the basis of this artificially generated polypeptide sequences, a corresponding nucleic acid molecule coding for such a modulated polypeptide can be synthesized in-vitro using the specific codon-usage of the desired host cell.

Definitions and methods described herein are provided to better define the present disclosure and to guide those of ordinary skill in the art in the practice of the present disclosure. Unless otherwise noted, terms are to be understood according to conventional usage by those of ordinary skill in the relevant art.

In some embodiments, numbers expressing quantities of ingredients, properties such as molecular weight, reaction conditions, and so forth, used to describe and claim certain embodiments of the present disclosure are to be understood as being modified in some instances by the term "about." In some embodiments, the term "about" is used to indicate that a value includes the standard deviation of the mean for the device or method being employed to determine the value. In some embodiments, the numerical parameters set forth in the written description and attached claims are approximations that can vary depending upon the desired properties sought to be obtained by a particular embodiment. In some embodiments, the numerical parameters should be construed in light of the number of reported significant digits and by applying ordinary rounding

techniques. Notwithstanding that the numerical ranges and parameters setting forth the broad scope of some embodiments of the present disclosure are approximations, the numerical values set forth in the specific examples are reported as precisely as practicable. The numerical values presented in some
5 embodiments of the present disclosure may contain certain errors necessarily resulting from the standard deviation found in their respective testing measurements. The recitation of ranges of values herein is merely intended to serve as a shorthand method of referring individually to each separate value falling within the range. Unless otherwise indicated herein, each individual value
10 is incorporated into the specification as if it were individually recited herein. Conversely, recitation of discrete values is understood to include a range between each of the recited discrete values.

In some embodiments, the terms “a” and “an” and “the” and similar references used in the context of describing a particular embodiment (especially in the
15 context of certain of the following claims) can be construed to cover both the singular and the plural, unless specifically noted otherwise. In some embodiments, the term “or” as used herein, including the claims, is used to mean “and/or” unless explicitly indicated to refer to alternatives only or the alternatives are mutually exclusive.

20 The terms “comprise,” “have” and “include” are open-ended linking verbs. Any forms or tenses of one or more of these verbs, such as “comprises,” “comprising,” “has,” “having,” “includes” and “including,” are also open-ended. For example, any method that “comprises,” “has” or “includes” one or more steps is not limited to possessing only those one or more steps and can also cover
25 other unlisted steps. Similarly, any composition or device that “comprises,” “has” or “includes” one or more features is not limited to possessing only those one or more features and can cover other unlisted features.

All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use
30 of any and all examples, or exemplary language (e.g., “such as”) provided with respect to certain embodiments herein is intended merely to better illuminate the present disclosure and does not pose a limitation on the scope of the present

disclosure otherwise claimed. No language in the specification should be construed as indicating any non-claimed element essential to the practice of the present disclosure.

5 Groupings of alternative elements or embodiments of the present disclosure disclosed herein are not to be construed as limitations. Each group member can be referred to and claimed individually or in any combination with other members of the group or other elements found herein. One or more members of a group can be included in, or deleted from, a group for reasons of convenience or patentability. When any such inclusion or deletion occurs, the specification is
10 herein deemed to contain the group as modified thus fulfilling the written description of all Markush groups used in the appended claims.

Citation of a reference herein shall not be construed as an admission that such is prior art to the present disclosure.

15 Having described the present disclosure in detail, it will be apparent that modifications, variations, and equivalent embodiments are possible without departing the scope of the present disclosure defined in the appended claims. Furthermore, it should be appreciated that all examples in the present disclosure are provided as non-limiting examples.

20 EXAMPLES

The following non-limiting examples are provided to further illustrate the present disclosure. It should be appreciated by those of skill in the art that the techniques disclosed in the examples that follow represent approaches the inventors have found function well in the practice of the present disclosure, and thus can be
25 considered to constitute examples of modes for its practice. However, those of skill in the art should, in light of the present disclosure, appreciate that many changes can be made in the specific embodiments that are disclosed and still obtain a like or similar result without departing from the spirit and scope of the present disclosure.

EXAMPLE 1

The following example shows performance of the H-10 (SEQ ID NO: 6) Klentaq mutant with crude samples containing chocolate or black pepper

- A 380 bp rRNA target was amplified from 1 ng bacterial DNA in 50 µl reactions with 15 U Klentaq 1, w.t. Taq (New England Biolabs), and the Klentaq1 mutant H-10 (SEQ ID NO: 6) in the presence of 0, 3, 4, 5, 6 and 9 µl of a crude black pepper extract (see e.g., FIG. 1, 50 mg/ml, top panel), or 0, 2, 2.5, 3.0, 3.5 and 4.5 µl 10% chocolate suspension (see e.g., FIG. 1, bottom panel), lanes 1-6. The amplified products were analyzed in ethidium bromide stained agarose gel.
- Results showed that the H-10 (SEQ ID NO: 6) mutant DNA polymerase outperformed both wild type Taq and truncated Klentaq1 while remaining functional in all concentrations of the food related PCR inhibitors tested (see e.g., FIG. 1).

EXAMPLE 2

- The following example shows resistance of B-9 (SEQ ID NO: 5) and H-10 (SEQ ID NO: 6) Klentaq mutants to black pepper inhibition.

- A 350 bp bacterial 16S rRNA target was amplified from 1 ng bacterial DNA with 0.8 µl purified Omni Klentaq (OKT) and Klentaq mutants H-10 (SEQ ID NO: 6) and B-9 (SEQ ID NO: 5), in the presence of 0, 3, 4, 5, 6 and 7 µl 10% black pepper extract (see e.g., FIG. 2, left to right, six reactions per enzyme) in 35 ul reactions. No PCR enhancer was used in the reactions.

Results showed the B-9 (SEQ ID NO: 5) and H-10 (SEQ ID NO: 6) mutants had higher resistance than Omni Klentaq to black pepper inhibition (see e.g., FIG. 2).

EXAMPLE 3

- The following example shows resistance of B-9 (SEQ ID NO: 5) and H-10 (SEQ ID NO: 6) Klentaq mutants to chocolate inhibition.

A 350 bp bacterial 16S rRNA target was amplified in 35 ul reactions from 1 ng bacterial DNA with 0.8 µl purified Omni Klentaq (OKT) and Klentaq mutants H-10 (SEQ ID NO: 6) and B-9 (SEQ ID NO: 5) in the presence of 0, 2, 2.5, 3, 3.5 and

4 µl 10% chocolate (see e.g., FIG. 3, left to right, six reactions per enzyme). No PCR enhancer was used in the reactions.

Results showed that the B-9 (SEQ ID NO: 5) and H-10 (SEQ ID NO: 6) mutants had higher resistance than Omni Klentaq to chocolate inhibition (see e.g., FIG. 3).

EXAMPLE 4

The following example shows resistance of C-12 (SEQ ID NO: 10) full-length Taq mutant to chocolate inhibition.

A 346 bp 16S rRNA target was amplified in 35 µl reactions from 350 pg of *E. coli* DNA with 0.8 µl purified OmniTaq, mutant C-12 (SEQ ID NO: 10), or wild type Taq (NEB) with 0, 1, 2, 3, 4 or 5 µL of a 10 % chocolate extract (see e.g., FIG. 4).

Results showed that C-12 (SEQ ID NO: 10) had activity at 5 µl of chocolate extract, while OmniTaq was partially inhibited at 2 µl and completely inhibited at 4µl chocolate. Taq was inactivated at only 1 µl of chocolate.

EXAMPLE 5

The following example shows resistance of C-12 (SEQ ID NO: 10) full-length Taq mutant to black pepper inhibition.

A 346 bp 16S rRNA target was amplified in 35 µl reactions from 350 pg of *E. coli* DNA with 0.8 µl of purified OmniTaq, mutant C-12 (SEQ ID NO: 10), or wild-type Taq (NEB) with 0, 0.25, 0.5, 1, 2 or 4 µl of black pepper extract at 500 mg/mL (see e.g., FIG. 5, Lanes 1-6).

Results showed that the C-12 (SEQ ID NO: 10) mutant showed activity at 1 µl of pepper extract while Omni Taq was completely inhibited at that concentration. Taq was inactivated at only 0.25 µl black pepper

EXAMPLE 6

The following example shows resistance of H-10 (SEQ ID NO: 6) Klentaq mutant to chocolate in qPCR (SYBR Green).

Salmonella DNA was 10-fold serially diluted from 1,000 pg to 1pg and it was detected by qPCR with SYBR Green with primer HiLA-3. The reactions included 0.6 µl of purified Omni KlenTaq (OKT) or mutant H-10 (SEQ ID NO: 6) with 2 µl 10% chocolate extract per 35 µl reaction.

- 5 Results showed that the H-10 (SEQ ID NO: 6) mutant had resistance to chocolate while OKT was strongly inhibited.

EXAMPLE 7

The following example shows resistance of C-12 (SEQ ID NO: 10) full-length Taq mutant to chocolate in qPCR (SYBR Green).

- 10 Salmonella DNA was 10-fold serially diluted from 100 pg to 1pg and detected by qPCR with SYBR Green with primer HiLA-3. The reactions included 0.3 µl of purified OmniTaq (OT) and 0.3 µl of the C-12 (SEQ ID NO: 10) mutant with 2 µL 10% chocolate extract per 35 µl reaction (see e.g., FIG. 7).

- Results showed that the C-12 (SEQ ID NO: 10) mutant had a higher resistance to chocolate while OT was strongly inhibited.
- 15

EXAMPLE 8

The following example shows performance of the H-10 (SEQ ID NO: 6) KlenTaq mutant in PCR with crude samples containing whole blood.

- A 1.1 kb target from the human CCR5 gene was amplified in 25 µl reactions with 10 U KlenTaq1, w.t. Taq (New England Biolabs), and the H-10 (SEQ ID NO: 6) KlenTaq1 mutant from 40%, 20%, 10%, 5%, and 2.5% heparin treated blood, lanes 1-6, respectively. Lane 1 (positive controls) contained no blood, but 10 ng human DNA (see e.g., FIG. 8). The amplified products were analyzed in ethidium bromide stained agarose gel.
- 20

- 25 Results showed that the H-10 (SEQ ID NO: 6) mutant polymerase outperformed both the wild type Taq and its truncated version, KlenTaq1, where the H-10 (SEQ ID NO: 6) mutant showed higher resistance to the blood inhibition.

EXAMPLE 9

The following example shows performance of the H-10 (SEQ ID NO: 6) Klentaq mutant in PCR with crude samples containing humic acid.

- 5 A 1.1 kb target from the human CCR5 gene was amplified from 10 ng human DNA in 25 μ l reactions with 5 U Klentaq1, w.t. Taq (New England Biolabs), and the H-10 (SEQ ID NO: 6) Klentaq1 mutant in the presence of 0, 12, 25, 50, 100 and 200 ng humic acid (approximate amounts) (see e.g., FIG. 9, lanes 1-6, respectively). The amplified products were analyzed in ethidium bromide stained agarose gel.
- 10 Results showed that the H-10 (SEQ ID NO: 6) mutant polymerase outperformed both the wild type Taq and its truncated version, Klentaq1, where H-10 (SEQ ID NO: 6) showed higher resistance to the PCR inhibitor humic acid.

EXAMPLE 10

The following example shows resistance of Klentaq mutants to bile inhibition.

- 15 A 350 bp bacterial 16S rRNA target was amplified from 1 ng bacterial DNA in 50 μ l reactions with 0.5 μ l purified Omni Klentaq (OKT) or the Klentaq mutants H-10 (SEQ ID NO: 6), E-12 (SEQ ID NO: 8), B-9 (SEQ ID NO: 5), F-12 (SEQ ID NO: 7), and C-6 (SEQ ID NO: 9), in the presence of 0, 0.4, 0.8, 1.2, 1.6 and 2 μ l bile salts extract (see e.g., FIG. 10, left to right, six reactions per enzyme). No PCR enhancer was used in the reactions.
- 20

Results showed that all tested mutant polymerases showed higher than Omni Klentaq resistance to bile inhibition.

EXAMPLE 11

- 25 The following example shows performance of H-10 (SEQ ID NO: 6) Klentaq mutant in PCR with crude samples containing plant tissue extract.

A 320 bp target from the beta-actin gene was amplified from 10 ng human DNA in 50 μ l reactions with 10 U Klentaq 1, w.t. Taq (New England Biolabs), and the H-10 (SEQ ID NO: 6) Klentaq1 mutant in the presence of 0, 0.5, 1.0, 1.5, 2.0 and 2.5 μ l of a crude plant leaf extract (see e.g., FIG. 11, lanes 1-6). The amplified

products were analyzed in ethidium bromide stained agarose gel.

Results showed that the H-10 (SEQ ID NO: 6) mutant DNA polymerase outperformed both the wild type Taq and its truncated version, Klentaq1, where H-10 (SEQ ID NO: 6) showed higher resistance to the PCR inhibitors in the plant
5 tissue.

EXAMPLE 12

The following example shows resistance of full-length Taq mutant C-66 (SEQ ID NO: 11) to shrimp meat inhibition.

A 250 bp 16S rRNA target was amplified in 25 ul reactions from 1ng *Listeria*
10 DNA with 0.5 µl purified OmniTaq, C-66 (SEQ ID NO: 11) mutant, and plain Taq (NEB) in the presence of 20%, 10%, 5%, 2.5 % or 0% shrimp meat homogenate (see e.g., FIG. 12, lanes 1-5).

Results showed that the C-66 (SEQ ID NO: 11) mutant polymerase had some activity at all tested concentrations while OmniTaq was clearly inhibited at 10%
15 or above. Taq began showing inhibition at 2.5%.

EXAMPLE 13

The following example shows resistance of full-length Taq mutant C-12 (SEQ ID NO: 10) to food inhibition.

A 170 bp 16S rRNA target was amplified in 25 ul reactions from 1.4 ng of
20 *Salmonella* DNA with 0.3 µl of purified OmniTaq, mutant C-12 (SEQ ID NO: 10) polymerase, or an equivalent amount of wild type Taq (NEB) activity with 0, 2.25 µl, 4.5 µl, 9 µl, or 18 µl of 10% (w/v) food extract (see e.g., FIG. 13).

Results showed that the Taq mutant C-12 (SEQ ID NO: 10) polymerase showed greater resistance to tested food samples than wild type Taq or OmniTaq.

SEQUENCES

SEQ ID NO: 1

Full length Taq polymerase (GenBank Accession No. J04639)

5 Met Arg Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu Leu
 1 5 10 15
 Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys Gly
 20 25 30
 10 Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe Ala
 35 40 45
 Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile Val
 50 55 60
 Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly Gly
 65 70 75 80
 20 Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln Leu
 85 90 95
 Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu Glu
 100 105 110
 25 Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys Lys
 115 120 125
 Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Lys Asp
 130 135 140
 Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro Glu Gly
 145 150 155 160
 35 Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg Pro
 165 170 175
 Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp Asn
 180 185 190
 40 Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu Leu
 195 200 205
 Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp Arg Leu
 210 215 220
 Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp Leu Lys
 225 230 235 240
 50 Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu Glu Val
 245 250 255
 Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg Ala Phe
 260 265 270
 55 Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu Leu
 275 280 285
 Glu Ser Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu Gly
 290 295 300
 60 Ala Phe Val Gly Phe Val Leu Ser Arg Lys Glu Pro Met Trp Ala Asp
 305 310 315 320

Leu Leu Ala Leu Ala Ala Ala Arg Gly Gly Arg Val His Arg Ala Pro
 325 330 335
 5 Glu Pro Tyr Lys Ala Leu Arg Asp Leu Lys Glu Ala Arg Gly Leu Leu
 340 345 350
 Ala Lys Asp Leu Ser Val Leu Ala Leu Arg Glu Gly Leu Gly Leu Pro
 355 360 365
 10 Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser Asn
 370 375 380
 Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr Glu
 385 390 395 400
 15 Glu Ala Gly Glu Arg Ala Ala Leu Ser Glu Arg Leu Phe Ala Asn Leu
 405 410 415
 20 Trp Gly Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Arg Glu
 420 425 430
 Val Glu Arg Pro Leu Ser Ala Val Leu Ala His Met Glu Ala Thr Gly
 435 440 445
 25 Val Arg Leu Asp Val Ala Tyr Leu Arg Ala Leu Ser Leu Glu Val Ala
 450 455 460
 Glu Glu Ile Ala Arg Leu Glu Ala Glu Val Phe Arg Leu Ala Gly His
 465 470 475 480
 30 Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe Asp
 485 490 495
 35 Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg
 500 505 510
 Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro Ile
 515 520 525
 40 Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser Thr
 530 535 540
 Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg Leu
 545 550 555 560
 45 His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser
 565 570 575
 50 Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly Gln
 580 585 590
 Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val Ala
 595 600 605
 55 Leu Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser Gly
 610 615 620
 Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His Thr
 625 630 635 640
 60 Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp Pro
 645 650 655
 65 Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly
 660 665 670
 Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu Glu
 675 680 685

Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val Arg
690 695 700

5 Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val
705 710 715 720

Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Glu Ala Arg
725 730 735

10 Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met Pro
740 745 750

Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys Leu
755 760 765

15 Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val His
770 775 780

20 Asp Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val Ala
785 790 795 800

Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val Pro
805 810 815

25 Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys Glu
820 825 830

SEQ ID NO: 2

30 Klentaq-1

Met Gly Leu Leu His Glu Phe Gly Leu Leu Glu Ser Pro Lys Ala Leu
1 5 10 15

35 Glu Glu Ala Pro Trp Pro Pro Pro Glu Gly Ala Phe Val Gly Phe Val
20 25 30

Leu Ser Arg Lys Glu Pro Met Trp Ala Asp Leu Leu Ala Leu Ala Ala
35 40 45

40 Ala Arg Gly Gly Arg Val His Arg Ala Pro Glu Pro Tyr Lys Ala Leu
50 55 60

Arg Asp Leu Lys Glu Ala Arg Gly Leu Leu Ala Lys Asp Leu Ser Val
45 65 70 75 80

Leu Ala Leu Arg Glu Gly Leu Gly Leu Pro Pro Gly Asp Asp Pro Met
85 90 95

50 Leu Leu Ala Tyr Leu Leu Asp Pro Ser Asn Thr Thr Pro Glu Gly Val
100 105 110

Ala Arg Arg Tyr Gly Gly Glu Trp Thr Glu Glu Ala Gly Glu Arg Ala

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	115	120	125
	Ala Leu Ser Glu Arg Leu Phe Ala Asn Leu Trp Gly Arg Leu Glu Gly		
	130	135	140
5	Glu Glu Arg Leu Leu Trp Leu Tyr Arg Glu Val Glu Arg Pro Leu Ser		
	145	150	155 160
	Ala Val Leu Ala His Met Glu Ala Thr Gly Val Arg Leu Asp Val Ala		
10	165	170	175
	Tyr Leu Arg Ala Leu Ser Leu Glu Val Ala Glu Glu Ile Ala Arg Leu		
	180	185	190
15	Glu Ala Glu Val Phe Arg Leu Ala Gly His Pro Phe Asn Leu Asn Ser		
	195	200	205
	Arg Asp Gln Leu Glu Arg Val Leu Phe Asp Glu Leu Gly Leu Pro Ala		
20	210	215	220
	Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg Ser Thr Ser Ala Ala Val		
	225	230	235 240
	Leu Glu Ala Leu Arg Glu Ala His Pro Ile Val Glu Lys Ile Leu Gln		
25	245	250	255
	Tyr Arg Glu Leu Thr Lys Leu Lys Ser Thr Tyr Ile Asp Pro Leu Pro		
	260	265	270
30	Asp Leu Ile His Pro Arg Thr Gly Arg Leu His Thr Arg Phe Asn Gln		
	275	280	285
	Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser Ser Asp Pro Asn Leu Gln		
35	290	295	300
	Asn Ile Pro Val Arg Thr Pro Leu Gly Gln Arg Ile Arg Arg Ala Phe		
	305	310	315 320
	Ile Ala Glu Glu Gly Trp Leu Leu Val Ala Leu Asp Tyr Ser Gln Ile		
40	325	330	335
	Glu Leu Arg Val Leu Ala His Leu Ser Gly Asp Glu Asn Leu Ile Arg		
	340	345	350
45	Val Phe Gln Glu Gly Arg Asp Ile His Thr Glu Thr Ala Ser Trp Met		
	355	360	365

Phe Gly Val Pro Arg Glu Ala Val Asp Pro Leu Met Arg Arg Ala Ala
 370 375 380

5 Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly Met Ser Ala His Arg Leu
 385 390 395 400

Ser Gln Glu Leu Ala Ile Pro Tyr Glu Glu Ala Gln Ala Phe Ile Glu
 405 410 415

10 Arg Tyr Phe Gln Ser Phe Pro Lys Val Arg Ala Trp Ile Glu Lys Thr
 420 425 430

Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val Glu Thr Leu Phe Gly Arg
 15 435 440 445

Arg Arg Tyr Val Pro Asp Leu Glu Ala Arg Val Lys Ser Val Arg Glu
 450 455 460

20 Ala Ala Glu Arg Met Ala Phe Asn Met Pro Val Gln Gly Thr Ala Ala
 465 470 475 480

Asp Leu Met Lys Leu Ala Met Val Lys Leu Phe Pro Arg Leu Glu Glu
 485 490 495

25 Met Gly Ala Arg Met Leu Leu Gln Val His Asp Glu Leu Val Leu Glu
 500 505 510

Ala Pro Lys Glu Arg Ala Glu Ala Val Ala Arg Leu Ala Lys Glu Val
 30 515 520 525

Met Glu Gly Val Tyr Pro Leu Ala Val Pro Leu Glu Val Glu Val Gly
 530 535 540

35 Ile Gly Glu Asp Trp Leu Ser Ala Lys Glu
 545 550

SEQ ID NO: 3

Omni Taq (FL-22)

40 Met Arg Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu Leu
 1 5 10 15

45 Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys Gly
 20 25 30

Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe Ala
 35 40 45
 5 Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile Val
 50 55 60
 Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly Gly
 65 70 75 80
 10 Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln Leu
 85 90 95
 Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu Glu
 100 105 110
 Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys Lys
 115 120 125
 20 Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Lys Asp
 130 135 140
 Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro Glu Gly
 145 150 155 160
 25 Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg Pro
 165 170 175
 Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp Asn
 180 185 190
 Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu Leu
 195 200 205
 35 Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp Arg Leu
 210 215 220
 Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp Leu Lys
 225 230 235 240
 40 Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu Glu Val
 245 250 255
 Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg Ala Phe
 260 265 270
 Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu Leu
 275 280 285
 50 Glu Ser Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu Gly
 290 295 300
 Ala Phe Val Gly Phe Val Leu Ser Arg Lys Glu Pro Met Trp Ala Asp
 305 310 315 320
 55 Leu Leu Ala Leu Ala Ala Ala Arg Gly Gly Arg Val His Arg Ala Pro
 325 330 335
 Glu Pro Tyr Lys Ala Leu Arg Asp Leu Lys Glu Ala Arg Gly Leu Leu
 340 345 350
 Ala Lys Asp Leu Ser Val Leu Ala Leu Arg Glu Gly Leu Gly Leu Pro
 355 360 365
 65 Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser Asn
 370 375 380
 Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr Glu
 385 390 395 400

Glu Ala Gly Glu Arg Ala Ala Leu Ser Glu Arg Leu Phe Ala Asn Leu
 405 410 415
 5 Trp Gly Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Arg Glu
 420 425 430
 Val Glu Arg Pro Leu Ser Ala Val Leu Ala His Met Glu Ala Thr Gly
 435 440 445
 10 Val Arg Leu Asp Val Ala Tyr Leu Arg Ala Leu Ser Leu Glu Val Ala
 450 455 460
 Glu Glu Ile Ala Arg Leu Glu Ala Glu Val Phe Arg Leu Ala Gly His
 465 470 475 480
 15 Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe Asp
 485 490 495
 20 Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg
 500 505 510
 Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro Ile
 515 520 525
 25 Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser Thr
 530 535 540
 Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg Leu
 545 550 555 560
 30 His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser
 565 570 575
 35 Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly Gln
 580 585 590
 Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val Ala
 595 600 605
 40 Leu Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser Gly
 610 615 620
 Asp Lys Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His Thr
 625 630 635 640
 45 Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp Pro
 645 650 655
 50 Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly
 660 665 670
 Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu Glu
 675 680 685
 55 Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val Arg
 690 695 700
 Ala Trp Leu Asn Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val
 705 710 715 720
 60 Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Glu Ala Arg
 725 730 735
 65 Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met Pro
 740 745 750
 Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys Leu
 755 760 765

Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val His
 770 775 780
 5 Asp Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val Ala
 785 790 795 800
 Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val Pro
 805 810 815
 10 Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys Glu
 820 825 830

SEQ ID NO: 4

15 Omniklentaq (i.e., OmnikT or Klentaq-10)
 Met Gly Leu Leu His Glu Phe Gly Leu Leu Glu Ser Pro Lys Ala Leu
 1 5 10 15
 Glu Glu Ala Pro Trp Pro Pro Glu Gly Ala Phe Val Gly Phe Val
 20 20 25 30
 Leu Ser Arg Lys Glu Pro Met Trp Ala Asp Leu Leu Ala Leu Ala Ala
 35 40 45
 25 Ala Arg Gly Gly Arg Val His Arg Ala Pro Glu Pro Tyr Lys Ala Leu
 50 55 60
 Arg Asp Leu Lys Glu Ala Arg Gly Leu Leu Ala Lys Asp Leu Ser Val
 65 70 75 80
 30 Leu Ala Leu Arg Glu Gly Leu Gly Leu Pro Pro Gly Asp Asp Pro Met
 85 90 95
 Leu Leu Ala Tyr Leu Leu Asp Pro Ser Asn Thr Thr Pro Glu Gly Val
 35 100 105 110
 Ala Arg Arg Tyr Gly Gly Glu Trp Thr Glu Glu Ala Gly Glu Arg Ala
 115 120 125
 40 Ala Leu Ser Glu Arg Leu Phe Ala Asn Leu Trp Gly Arg Leu Glu Gly
 130 135 140
 Glu Glu Arg Leu Leu Trp Leu Tyr Arg Glu Val Glu Arg Pro Leu Ser
 145 150 155 160
 45 Ala Val Leu Ala His Met Glu Ala Thr Gly Val Arg Leu Asp Val Ala
 165 170 175

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Tyr Leu Arg Ala Leu Ser Leu Glu Val Ala Glu Glu Ile Ala Arg Leu
 180 185 190

5 Glu Ala Glu Val Phe Arg Leu Ala Gly His Pro Phe Asn Leu Asn Ser
 195 200 205

Arg Asp Gln Leu Glu Arg Val Leu Phe Asp Glu Leu Gly Leu Pro Ala
 210 215 220

10 Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg Ser Thr Ser Ala Ala Val
 225 230 235 240

Leu Glu Ala Leu Arg Glu Ala His Pro Ile Val Glu Lys Ile Leu Gln
 245 250 255

15 Tyr Arg Glu Leu Thr Lys Leu Lys Ser Thr Tyr Ile Asp Pro Leu Pro
 260 265 270

Asp Leu Ile His Pro Arg Thr Gly Arg Leu His Thr Arg Phe Asn Gln
 275 280 285

Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser Ser Asp Pro Asn Leu Gln
 290 295 300

25 Asn Ile Pro Val Arg Thr Pro Leu Gly Gln Arg Ile Arg Arg Ala Phe
 305 310 315 320

Ile Ala Glu Glu Gly Trp Leu Leu Val Ala Leu Asp Tyr Ser Gln Ile
 325 330 335

30 Glu Leu Arg Val Leu Ala His Leu Ser Gly Asp Lys Asn Leu Ile Arg
 340 345 350

Val Phe Gln Glu Gly Arg Asp Ile His Thr Glu Thr Ala Ser Trp Met
 355 360 365

Phe Gly Val Pro Arg Glu Ala Val Asp Pro Leu Met Arg Arg Ala Ala
 370 375 380

40 Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly Met Ser Ala His Arg Leu
 385 390 395 400

Ser Gln Glu Leu Ala Ile Pro Tyr Glu Glu Ala Gln Ala Phe Ile Glu
 405 410 415

45 Arg Tyr Phe Gln Ser Phe Pro Lys Val Arg Ala Trp Leu Lys Lys Thr

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420 425 430
 Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val Glu Thr Leu Phe Gly Arg
 435 440 445
 5
 Arg Arg Tyr Val Pro Asp Leu Glu Ala Arg Val Lys Ser Val Arg Glu
 450 455 460
 Ala Ala Glu Arg Met Ala Phe Asn Met Pro Val Gln Gly Thr Ala Ala
 10 465 470 475 480
 Asp Leu Met Lys Leu Ala Met Val Lys Leu Phe Pro Arg Leu Glu Glu
 485 490 495
 15 Met Gly Ala Arg Met Leu Leu Gln Val His Asp Glu Leu Val Leu Glu
 500 505 510
 Ala Pro Lys Glu Arg Ala Glu Ala Val Ala Arg Leu Ala Lys Glu Val
 515 520 525
 20 Met Glu Gly Val Tyr Pro Leu Ala Val Pro Leu Glu Val Glu Val Gly
 530 535 540
 Ile Gly Glu Asp Trp Leu Ser Ala Lys Glu
 25 545 550

SEQ ID NO: 5

B-9

Met Gly Leu Leu His Glu Phe Gly Leu Leu Glu Ser Pro Lys Ala Leu
 30 1 5 10 15
 Glu Glu Ala Pro Trp Pro Pro Pro Glu Gly Ala Phe Val Gly Phe Val
 20 25 30
 35 Leu Ser Arg Lys Glu Pro Met Trp Ala Asp Leu Leu Ala Leu Ala Ala
 35 40 45
 Ala Arg Gly Gly Arg Val His Arg Ala Pro Glu Pro Tyr Lys Ala Leu
 50 55 60
 40 Arg Asp Leu Lys Glu Ala Arg Gly Leu Leu Ala Lys Asp Leu Ser Val
 65 70 75 80
 Leu Ala Leu Arg Glu Gly Leu Gly Leu Pro Pro Gly Asp Asp Pro Met
 60

	85	90	95
	Leu Leu Ala Tyr Leu Leu Asp Pro Ser Asn Thr Thr Pro Glu Gly Val		
	100	105	110
5	Ala Arg Arg Tyr Gly Gly Glu Trp Thr Glu Glu Ala Gly Glu Arg Ala		
	115	120	125
	Ala Leu Ser Glu Arg Leu Phe Ala Asn Leu Trp Gly Arg Leu Glu Gly		
10	130	135	140
	Glu Glu Arg Leu Leu Trp Leu Tyr Arg Glu Val Glu Arg Pro Leu Ser		
	145	150	155
	Ala Val Leu Ala His Met Glu Ala Thr Gly Val Arg Leu Asp Val Ala		
15	165	170	175
	Tyr Leu Arg Ala Leu Ser Leu Glu Val Ala Glu Glu Ile Ala Arg Leu		
	180	185	190
20	Glu Ala Glu Val Phe Arg Leu Ala Gly His Pro Phe Asn Leu Asn Ser		
	195	200	205
	<u>Gly</u> Asp Gln Leu Glu Arg Val Leu Phe Asp Glu Leu Gly Leu Pro Ala		
25	210	215	220
	Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg Ser Thr Ser Ala Ala Val		
	225	230	235
	Leu Glu Ala Leu Arg Glu Ala His Pro Ile Val Glu Lys Ile Leu Gln		
30	245	250	255
	Tyr Arg Glu Leu Thr Lys Leu Lys Ser Thr Tyr Ile Asp Pro Leu Pro		
	260	265	270
35	Asp Leu Ile His Pro Arg Thr Gly Arg Leu His Thr Arg Phe Asn Gln		
	275	280	285
	Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser Ser Asp Pro Asn Leu Gln		
40	290	295	300
	Asn Ile Pro Val Arg Thr Pro Leu Gly Gln Arg Ile Arg Arg Ala Phe		
	305	310	315
	Ile Ala Glu Glu Gly Trp Leu Leu Val Ala Leu Asp Tyr Ser Gln Ile		
45	325	330	335

Glu Leu Arg Val Leu Ala His Leu Ser Gly Asp Glu Asn Leu Ile Arg
 340 345 350

5 Val Phe Gln Glu Gly Arg Asp Ile His Thr Glu Thr Ala Ser Trp Met
 355 360 365

Phe Gly Val Pro Arg Glu Ala Val Asp Pro Leu Met Arg Arg Ala Ala
 370 375 380

10 Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly Met Ser Ala His Arg Leu
 385 390 395 400

Ser Gln Glu Leu Ala Ile Pro Tyr Glu Glu Ala Gln Ala Phe Ile Glu
 15 405 410 415

Arg Tyr Phe Gln Ser Phe Pro Lys Val Arg Ala Trp Ile Glu Lys Thr
 420 425 430

20 Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val Glu Thr Leu Phe Gly Arg
 435 440 445

Arg Arg Tyr Val Pro Asp Leu Glu Ala Arg Val Lys Ser Val Arg Glu
 450 455 460

25 Ala Ala Glu Arg Met Ala Phe Asn Met Pro Val Gln Gly Thr Ala Ala
 465 470 475 480

Asp Leu Met Lys Leu Ala Met Val Lys Leu Phe Pro Arg Leu Glu Glu
 30 485 490 495

Met Gly Ala Arg Met Leu Leu Gln Val His Asp Glu Leu Val Leu Glu
 500 505 510

35 Ala Pro Lys Glu Arg Ala Glu Ala Val Ala Arg Leu Ala Lys Glu Val
 515 520 525

Met Glu Gly Val Tyr Pro Leu Ala Val Pro Leu Glu Val Glu Val Gly
 530 535 540

40 Ile Gly Glu Asp Trp Leu Ser Ala Lys Glu
 545 550

SEQ ID NO: 6

Met Gly Leu Leu His Glu Phe Gly Leu Leu Glu Ser Pro Lys Ala Leu
 1 5 10 15
 5 Glu Glu Ala Pro Trp Pro Pro Pro Glu Gly Ala Phe Val Gly Phe Val
 20 25 30
 Leu Ser Arg Lys Glu Pro Met Trp Ala Asp Leu Leu Ala Leu Ala Ala
 35 40 45
 10 Ala Arg Gly Gly Arg Val His Arg Ala Pro Glu Pro Tyr Lys Ala Leu
 50 55 60
 Arg Asp Leu Lys Glu Ala Arg Gly Leu Leu Ala Lys Asp Leu Ser Val
 15 65 70 75 80
 Leu Ala Leu Arg Glu Gly Leu Gly Leu Pro Pro Gly Asp Asp Pro Met
 85 90 95
 20 Leu Leu Ala Tyr Leu Leu Asp Pro Ser Asn Thr Thr Pro Glu Gly Val
 100 105 110
 Ala Arg Arg Tyr Gly Gly Glu Trp Thr Glu Glu Ala Gly Glu Arg Ala
 115 120 125
 25 Ala Leu Ser Glu Arg Leu Phe Ala Asn Leu Trp Glu Arg Leu Glu Gly
 130 135 140
 Glu Glu Arg Leu Leu Trp Leu Tyr Arg Glu Val Glu Arg Pro Leu Ser
 30 145 150 155 160
 Ala Val Leu Ala His Met Glu Ala Thr Gly Val Arg Leu Asp Val Ala
 165 170 175
 35 Tyr Leu Arg Ala Leu Ser Leu Glu Val Ala Glu Glu Ile Ala Arg Leu
 180 185 190
 Glu Ala Glu Val Phe Arg Leu Ala Gly His Pro Phe Asn Leu Asn Ser
 195 200 205
 40 Arg Asp Gln Leu Glu Arg Val Leu Phe Asp Glu Leu Gly Leu Pro Ala
 210 215 220
 Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg Ser Thr Ser Ala Ala Val
 45 225 230 235 240

Leu Glu Ala Leu Arg Glu Ala His Pro Ile Val Glu Lys Ile Leu Gln
 245 250 255
 Tyr Arg Glu Leu Thr Lys Leu Lys Ser Thr Tyr Ile Asp Pro Leu Pro
 5 260 265 270
 Asp Leu Ile His Pro Arg Thr Gly Arg Leu His Thr Arg Phe Asn Gln
 275 280 285
 Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser Ser Asp Pro Asn Leu Gln
 10 290 295 300
 Asn Ile Pro Val Arg Thr Pro Leu Gly Gln Arg Ile Arg Arg Ala Phe
 305 310 315 320
 15 Ile Ala Glu Glu Gly Trp Leu Leu Val Ala Leu Asp Tyr Ser Gln Ile
 325 330 335
 Glu Leu Arg Val Leu Ala His Leu Ser Gly Asp Lys Asn Leu Ile Arg
 20 340 345 350
 Val Phe Gln Glu Gly Arg Asp Ile His Thr Glu Thr Ala Ser Trp Met
 355 360 365
 Phe Gly Val Pro Arg Glu Ala Val Asp Pro Leu Met Arg Arg Ala Ala
 25 370 375 380
 Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly Met Ser Ala His Arg Leu
 385 390 395 400
 30 Ser Gln Glu Leu Ala Ile Pro Tyr Glu Glu Ala Gln Ala Phe Ile Glu
 405 410 415
 Arg Tyr Phe Gln Ser Phe Pro Lys Val Arg Ala Trp Leu Ser Lys Thr
 35 420 425 430
 Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val Glu Thr Leu Phe Gly Arg
 435 440 445
 Arg Arg Tyr Val Pro Asp Leu Glu Ala Arg Val Lys Ser Val Arg Glu
 40 450 455 460
 Ala Ala Glu Arg Met Ala Phe Asn Met Pro Val Gln Gly Thr Ala Ala
 465 470 475 480
 45 Asp Leu Met Lys Leu Ala Met Val Lys Leu Phe Pro Arg Leu Glu Glu

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485 490 495
 Met Gly Ala Arg Met Leu Leu Gln Val His Asp Glu Leu Val Leu Glu
 500 505 510
5
 Ala Pro Lys Glu Arg Ala Glu Ala Val Ala Arg Leu Ala Lys Glu Val
 515 520 525
 Met Glu Gly Val Tyr Pro Leu Ala Val Pro Leu Glu Val Glu Val Gly
10 530 535 540
 Ile Gly Glu Asp Trp Leu Ser Ala Lys Glu
 545 550

15 SEQ ID NO: 7

F-12

Met Gly Leu Leu His Glu Phe Gly Leu Leu Glu Ser Pro Lys Ala Leu
 1 5 10 15
20
 Glu Glu Ala Pro Trp Pro Pro Pro Glu Gly Ala Phe Val Gly Phe Val
 20 25 30
 Leu Ser Arg Lys Glu Pro Met Trp Ala Asp Leu Leu Ala Leu Ala Ala
25 35 40 45
 Ala Arg Gly Gly Arg Val His Arg Ala Pro Glu Pro Tyr Lys Ala Leu
 50 55 60
 Arg Asp Leu Lys Glu Ala Arg Gly Leu Leu Ala Lys Asp Leu Ser Val
30 65 70 75 80
 Leu Ala Leu Arg Glu Gly Leu Gly Leu Pro Pro Gly Asp Asp Pro Met
 85 90 95
35
 Leu Leu Ala Tyr Leu Leu Asp Pro Ser Asn Thr Thr Pro Glu Gly Val
 100 105 110
 Ala Arg Arg Tyr Gly Gly Glu Trp Thr Glu Glu Ala Gly Glu Arg Ala
40 115 120 125
 Ala Leu Ser Glu Arg Leu Phe Ala Asn Leu Trp Gly Arg Leu Glu Gly
 130 135 140

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Glu Glu Arg Leu Leu Trp Leu Tyr Arg Glu Val Glu Arg Pro Leu Ser
 145 150 155 160

5 Ala Val Leu Ala His Met Glu Ala Thr Gly Val Arg Leu Asp Val Ala
 165 170 175

Tyr Leu Arg Ala Leu Ser Leu Glu Val Ala Glu Glu Ile Ala Arg Leu
 180 185 190

10 Glu Ala Glu Val Phe Arg Leu Ala Gly His Pro Phe Asn Leu Asn Ser
 195 200 205

Arg Asp Gln Leu Glu Arg Val Leu Phe Asp Glu Leu Gly Leu Pro Ala
 15 210 215 220

Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg Ser Thr Ser Ala Ala Val
 225 230 235 240

20 Leu Glu Ala Leu Arg Glu Ala His Pro Ile Val Glu Lys Ile Arg Gln
 245 250 255

Tyr Arg Glu Leu Thr Lys Leu Lys Ser Thr Tyr Ile Asp Pro Leu Pro
 260 265 270

25 Asp Leu Ile His Pro Arg Thr Gly Arg Leu His Thr Arg Phe Asn Gln
 275 280 285

Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser Ser Asp Pro Asn Leu Gln
 30 290 295 300

Asn Ile Pro Val Arg Thr Pro Leu Gly Gln Arg Ile Arg Arg Ala Phe
 305 310 315 320

35 Ile Ala Glu Glu Gly Trp Leu Leu Val Ala Leu Asp Tyr Ser Gln Ile
 325 330 335

Glu Leu Arg Val Leu Ala His Leu Ser Gly Asp Glu Asn Leu Ile Arg
 340 345 350

40 Val Phe Gln Glu Gly Arg Asp Ile His Thr Glu Thr Ala Ser Trp Met
 355 360 365

Phe Gly Val Pro Arg Glu Ala Val Asp Pro Leu Met Arg Arg Ala Ala
 45 370 375 380

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Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly Met Ser Ala His Arg Leu
 385 390 395 400
 Ser Gln Glu Leu Ala Ile Pro Tyr Glu Glu Ala Gln Ala Phe Ile Glu
 5 405 410 415
 Arg Tyr Phe Gln Ser Phe Pro Lys Val Arg Ala Trp Ile Glu Lys Thr
 420 425 430
 Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val Glu Thr Leu Phe Gly Arg
 10 435 440 445
 Arg Arg Tyr Val Pro Asp Leu Glu Ala Arg Val Lys Ser Val Arg Glu
 450 455 460
 15 Ala Ala Glu Arg Met Ala Phe Asn Met Pro Val Gln Gly Thr Ala Ala
 465 470 475 480
 Asp Leu Met Lys Leu Ala Met Val Lys Leu Phe Pro Arg Leu Glu Glu
 20 485 490 495
 Met Gly Ala Arg Met Leu Leu Gln Val His Asp Glu Leu Val Leu Glu
 500 505 510
 Ala Pro Lys Glu Arg Ala Glu Ala Val Ala Arg Leu Ala Lys Glu Val
 25 515 520 525
 Met Glu Gly Val Tyr Pro Leu Ala Val Pro Leu Glu Val Glu Val Gly
 530 535 540
 30 Ile Gly Glu Asp Trp Leu Ser Ala Lys Glu
 545 550

SEQ ID NO: 8

35 E-12
 Met Gly Leu Leu His Glu Phe Gly Leu Leu Glu Ser Pro Lys Ala Leu
 1 5 10 15
 Glu Glu Ala Pro Trp Pro Pro Pro Glu Gly Ala Phe Val Gly Phe Val
 20 25 30
 Leu Ser Arg Lys Glu Pro Met Trp Ala Asp Leu Leu Ala Leu Ala Ala

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	35		40		45	
	Ala Arg Gly Gly Arg Val His Arg Ala Pro Glu Pro Tyr Lys Ala Leu					
	50		55		60	
5	Arg Asp Leu Lys Glu Ala Arg Gly Leu Leu Ala Lys Asp Leu Ser Val					
	65		70		75	80
	Leu Ala Leu Arg Glu Gly Leu Gly Leu Pro Pro Gly Asp Asp Pro Met					
10		85		90		95
	Leu Leu Ala Tyr Leu Leu Asp Pro Ser Asn Thr Thr Pro Glu Gly Val					
		100		105		110
15	Ala Arg Arg Tyr Gly Gly Glu Trp Thr Glu Glu Ala Gly Glu Arg Ala					
		115		120		125
	Ala Leu Ser Glu Arg Leu Phe Ala Asn Leu Trp Gly Arg Leu Glu Gly					
		130		135		140
20	Glu Glu Arg Leu Leu Trp Leu Tyr Arg Glu Val Glu Arg Pro Leu Ser					
	145		150		155	160
	Ala Val Leu Ala His Met Glu Ala Thr Gly Val Arg Leu Asp Val Ala					
25		165		170		175
	Tyr Leu Arg Ala Leu Ser Leu Glu Val Ala Glu Glu Ile Ala Arg Leu					
		180		185		190
30	Glu Ala Glu Val Phe Arg Leu Ala Gly His Pro Phe Asn Leu Asn Ser					
		195		200		205
	Arg Asp Gln Leu Glu Arg Val Leu Phe Asp Glu Leu Gly Leu Pro Ala					
		210		215		220
35	Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg Ser Thr Ser Ala Ala Val					
	225		230		235	240
	Leu Glu Ala Leu Arg Glu Ala His Pro Ile Val Glu Lys Ile Leu Gln					
40		245		250		255
	Tyr Arg Glu Leu Thr Lys Leu Lys Ser Thr Tyr Ile Asp Pro Leu Pro					
		260		265		270
45	Asp Leu Ile His Pro Arg Thr Gly Arg Leu His Thr Arg Phe Asn Gln					
		275		280		285

Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser Ser Asp Pro Asn Leu Gln
 290 295 300

5 Asn Ile Pro Val Arg Thr Pro Leu Gly Gln Arg Ile Arg Arg Ala Phe
 305 310 315 320

Ile Ala Glu Glu Gly Trp Leu Leu Val Ala Leu Asp Tyr Ser Gln Ile
 325 330 335

10 Glu Leu Arg Val Leu Ala His Leu Ser Gly Asp Glu Asn Leu Ile Arg
 340 345 350

Val Phe Gln Glu Gly Arg Asp Ile His Thr Glu Thr Ala Ser Trp Met
 15 355 360 365

Phe Gly Val Pro Arg Glu Ala Val Asp Pro Leu Met Arg Arg Ala Ala
 370 375 380

20 Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly Met Ser Ala His Arg Leu
 385 390 395 400

Ser Gln Glu Leu Ala Ile Pro Tyr Glu Glu Ala Gln Ala Phe Ile Glu
 405 410 415

25 Arg Tyr Phe Gln Ser Phe Pro Lys Val Arg Ala Trp Ile Glu Lys Thr
 420 425 430

Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val Glu Thr Leu Phe Gly Arg
 30 435 440 445

Arg Arg Tyr Val Pro Asp Leu Glu Ala Arg Val Lys Ser Val Arg Glu
 450 455 460

35 Ala Ala Glu Arg Met Ala Phe Asn Met Pro Val Gln Gly Thr Ala Ala
 465 470 475 480

Asp Leu Met Lys Leu Ala Met Val Lys Leu Phe Pro Arg Leu Glu Glu
 485 490 495

40 Met Gly Ala Arg Met Leu Ile Gln Val His Asp Glu Leu Val Leu Glu
 500 505 510

Ala Pro Lys Glu Arg Ala Glu Ala Val Ala Arg Leu Ala Lys Glu Val
 45 515 520 525

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Met Glu Gly Val Tyr Pro Leu Ala Val Pro Leu Glu Val Glu Val Gly
 530 535 540

Ile Gly Glu Asp Trp Leu Ser Ala Lys Glu
 5 545 550

SEQ ID NO: 9

C-6

10 Met Arg Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu Leu
 1 5 10 15
 Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys Gly
 20 25 30
 15 Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe Ala
 35 40 45
 20 Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile Val
 50 55 60
 Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly Gly
 65 70 75 80
 25 Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln Leu
 85 90 95
 Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu Glu
 100 105 110
 30 Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys Lys
 115 120 125
 Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Lys Asp
 130 135 140
 35 Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro Glu Gly
 145 150 155 160
 40 Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg Pro
 165 170 175
 Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp Asn
 180 185 190
 45 Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu Leu
 195 200 205
 Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp Arg Leu
 210 215 220
 50 Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp Leu Lys
 225 230 235 240
 55 Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu Glu Val
 245 250 255
 Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg Ala Phe
 260 265 270
 60

Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu Leu
 275 280 285
 5 Glu Ser Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu Gly
 290 295 300
 Ala Phe Val Gly Phe Val Leu Ser Arg Lys Glu Pro Met Trp Ala Asp
 305 310 315 320
 10 Leu Leu Ala Leu Ala Ala Ala Arg Gly Gly Arg Val His Arg Ala Pro
 325 330 335
 Glu Pro Tyr Lys Ala Leu Arg Asp Leu Lys Glu Ala Arg Gly Leu Leu
 340 345 350
 15 Ala Lys Asp Leu Ser Val Leu Ala Leu Arg Glu Gly Leu Gly Leu Pro
 355 360 365
 20 Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser Asn
 370 375 380
 Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr Glu
 385 390 395 400
 25 Glu Ala Gly Glu Arg Ala Ala Leu Ser Glu Arg Leu Phe Ala Asn Leu
 405 410 415
 Trp Gly Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Arg Glu
 420 425 430
 30 Val Glu Arg Pro Leu Ser Ala Val Leu Ala His Met Glu Ala Thr Gly
 435 440 445
 Val Arg Leu Asp Val Ala Tyr Leu Arg Ala Leu Ser Leu Glu Val Ala
 450 455 460
 Glu Glu Ile Ala Arg Leu Glu Ala Glu Val Phe Arg Leu Ala Gly His
 465 470 475 480
 40 Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe Asp
 485 490 495
 Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg
 500 505 510
 45 Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro Ile
 515 520 525
 Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser Thr
 530 535 540
 Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg Leu
 545 550 555 560
 55 His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser
 565 570 575
 Ser Glu Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly Gln
 580 585 590
 60 Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val Ala
 595 600 605
 Leu Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser Gly
 610 615 620
 65 Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His Thr
 625 630 635 640

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Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp Pro
 645 650 655
 5 Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly
 660 665 670
 Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu Glu
 675 680 685
 10 Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val Arg
 690 695 700
 Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val
 705 710 715 720
 15 Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Glu Ala Arg
 725 730 735
 Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met Pro
 740 745 750
 Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys Leu
 755 760 765
 25 Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val His
 770 775 780
 Asp Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val Ala
 785 790 795 800
 30 Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val Pro
 805 810 815
 35 Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys Glu
 820 825 830

SEQ ID NO: 10

C-12

40 Met Arg Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu Leu
 1 5 10 15
 Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys Gly
 20 25 30
 45 Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe Ala
 35 40 45
 50 Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile Val
 50 55 60
 Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly Gly
 65 70 75 80
 55 Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln Leu
 85 90 95
 Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu Glu
 100 105 110
 60 Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys Lys
 115 120 125

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	Ala	Glu	Lys	Glu	Gly	Tyr	Glu	Val	Arg	Ile	Leu	Thr	Ala	Asp	Lys	Asp
	130						135					140				
5	Leu	Tyr	Gln	Leu	Leu	Ser	Asp	Arg	Ile	His	Val	Leu	His	Pro	Glu	Gly
	145					150					155					160
	Tyr	Leu	Ile	Thr	Pro	Ala	Trp	Leu	Trp	Glu	Lys	Tyr	Gly	Leu	Arg	Pro
					165					170					175	
10	Asp	Gln	Trp	Ala	Asp	Tyr	Arg	Ala	Leu	Thr	Gly	Asp	Glu	Ser	Asp	Asn
				180					185					190		
	Leu	Pro	Gly	Val	Lys	Gly	Ile	Gly	Glu	Lys	Thr	Ala	Arg	Lys	Leu	Leu
15			195					200					205			
	Glu	Glu	Trp	Gly	Ser	Leu	Glu	Ala	Leu	Leu	Lys	Asn	Leu	Asp	Arg	Leu
	210						215					220				
20	Lys	Pro	Ala	Ile	Arg	Glu	Lys	Ile	Leu	Ala	His	Met	Asp	Asp	Leu	Lys
	225					230					235					240
	Leu	Ser	Trp	Asp	Leu	Ala	Lys	Val	Arg	Thr	Asp	Leu	Pro	Leu	Glu	Val
					245					250					255	
25	Asp	Phe	Ala	Lys	Arg	Arg	Glu	Pro	Asp	Arg	Glu	Arg	Leu	Arg	Ala	Phe
				260					265					270		
	Leu	Glu	Arg	Leu	Glu	Phe	Gly	Ser	Leu	Leu	His	Glu	Phe	Gly	Leu	Leu
30			275					280					285			
	Glu	Ser	Pro	Lys	Ala	Leu	Glu	Glu	Ala	Pro	Trp	Pro	Pro	Pro	Glu	Gly
	290						295					300				
35	Ala	Phe	Val	Gly	Phe	Val	Leu	Ser	Arg	Lys	Glu	Pro	Met	Trp	Ala	Asp
	305					310					315					320
	Leu	Leu	Ala	Leu	Ala	Ala	Ala	Arg	Gly	Gly	Arg	Val	His	Arg	Ala	Pro
					325					330					335	
40	Glu	Pro	Tyr	Lys	Ala	Leu	Arg	Asp	Leu	Lys	Glu	Ala	Arg	Gly	Leu	Leu
				340					345					350		
	Ala	Lys	Asp	Leu	Ser	Val	Leu	Ala	Leu	Arg	Glu	Gly	Leu	Gly	Leu	Pro
45			355					360					365			
	Pro	Gly	Asp	Asp	Pro	Met	Leu	Leu	Ala	Tyr	Leu	Leu	Asp	Pro	Ser	Asn
	370						375					380				
50	Thr	Thr	Pro	Glu	Gly	Val	Ala	Arg	Arg	Tyr	Gly	Gly	Glu	Trp	Thr	Glu
	385					390					395					400
	Glu	Ala	Gly	Glu	Arg	Ala	Ala	Leu	Ser	Glu	Arg	Leu	Phe	Ala	Asn	Leu
					405					410					415	
55	Trp	Gly	Arg	Leu	Glu	Gly	Glu	Glu	Arg	Leu	Leu	Trp	Leu	Tyr	Arg	Glu
				420					425					430		
	Val	Glu	Arg	Pro	Leu	Ser	Ala	Val	Leu	Ala	His	Met	Glu	Ala	Thr	Gly
60			435					440					445			
	Val	Arg	Leu	Asp	Val	Ala	Tyr	Leu	Arg	Ala	Leu	Ser	Leu	Glu	Val	Ala
	450						455					460				
65	Glu	Glu	Ile	Ala	Arg	Leu	Glu	Ala	Glu	Val	Phe	Arg	Leu	Ala	Gly	His
	465					470					475					480
	Pro	Phe	Asn	Leu	Asn	Ser	Arg	Asp	Gln	Leu	Glu	Arg	Val	Leu	Phe	Asp
					485					490						495

Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg
 500 505 510
 5 Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro Ile
 515 520 525
 Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser Thr
 530 535 540
 10 Tyr Ile Asp Pro Leu Pro Gly Leu Ile His Pro Arg Thr Gly Arg Leu
 545 550 555 560
 His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser
 565 570 575
 15 Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly Gln
 580 585 590
 20 Arg Ile Arg Arg Ala Phe Val Ala Glu Glu Gly Trp Leu Leu Val Ala
 595 600 605
 Leu Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser Gly
 610 615 620
 25 Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His Thr
 625 630 635 640
 Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp Pro
 645 650 655
 30 Gln Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly
 660 665 670
 35 Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu Glu
 675 680 685
 Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val Arg
 690 695 700
 40 Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val
 705 710 715 720
 Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Glu Ala Arg
 725 730 735
 45 Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met Pro
 740 745 750
 50 Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys Leu
 755 760 765
 Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val His
 770 775 780
 55 Asp Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val Ala
 785 790 795 800
 Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val Pro
 805 810 815
 60 Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys Glu
 820 825 830

SEQ ID NO: 11

C-66

5	Met	Arg	Gly	Met	Leu	Pro	Leu	Phe	Glu	Pro	Lys	Gly	Arg	Val	Leu	Leu
	1			5					10						15	
	Val	Asp	Gly	His	His	Leu	Ala	Tyr	Arg	Thr	Phe	His	Ala	Leu	Lys	Gly
			20						25					30		
10	Leu	Thr	Thr	Ser	Arg	Gly	Glu	Pro	Val	Gln	Ala	Val	Tyr	Gly	Phe	Ala
			35					40					45			
	Lys	Ser	Leu	Leu	Lys	Ala	Leu	Lys	Glu	Asp	Gly	Asp	Ala	Val	Ile	Val
15		50					55				60					
	Val	Phe	Asp	Ala	Lys	Ala	Pro	Ser	Phe	Arg	His	Glu	Ala	Tyr	Gly	Gly
	65					70				75					80	
	Tyr	Lys	Ala	Gly	Arg	Ala	Pro	Thr	Pro	Glu	Asp	Phe	Pro	Arg	Gln	Leu
20					85					90					95	
	Ala	Leu	Ile	Lys	Glu	Leu	Val	Asp	Leu	Leu	Gly	Leu	Ala	Arg	Leu	Glu
				100					105					110		
25	Val	Pro	Gly	Tyr	Glu	Ala	Asp	Asp	Val	Leu	Ala	Ser	Leu	Ala	Lys	Lys
			115					120					125			
	Ala	Glu	Lys	Glu	Gly	Tyr	Glu	Val	Arg	Ile	Leu	Thr	Ala	Asp	Lys	Asp
30		130					135					140				
	Leu	Tyr	Gln	Leu	Leu	Ser	Asp	Arg	Ile	His	Val	Leu	His	Pro	Glu	Gly
	145					150				155					160	
	Tyr	Leu	Ile	Thr	Pro	Ala	Trp	Leu	Trp	Glu	Lys	Tyr	Gly	Leu	Arg	Pro
35					165					170					175	
	Asp	Cln	Trp	Ala	Asp	Tyr	Arg	Ala	Leu	Thr	Cly	Asp	Glu	Ser	Asp	Asn
			180						185					190		
40	Leu	Pro	Gly	Val	Lys	Gly	Ile	Gly	Glu	Lys	Thr	Ala	Arg	Lys	Leu	Leu
			195					200					205			
	Glu	Glu	Trp	Gly	Ser	Leu	Glu	Ala	Leu	Leu	Lys	Asn	Leu	Asp	Arg	Leu
45		210					215					220				
	Lys	Pro	Ala	Ile	Arg	Glu	Lys	Ile	Leu	Ala	His	Met	Asp	Asp	Leu	Lys
	225					230				235					240	
	Leu	Ser	Trp	Asp	Leu	Ala	Lys	Val	Arg	Thr	Asp	Leu	Pro	Leu	Glu	Val
50					245					250					255	
	Asp	Phe	Ala	Lys	Arg	Arg	Glu	Pro	Asp	Arg	Glu	Arg	Leu	Arg	Ala	Phe
			260						265					270		
55	Leu	Glu	Arg	Leu	Glu	Phe	Gly	Ser	Leu	Leu	His	Glu	Phe	Gly	Leu	Leu
			275					280					285			
	Glu	Ser	Pro	Lys	Ala	Leu	Glu	Glu	Ala	Pro	Trp	Pro	Pro	Pro	Glu	Gly
60		290					295					300				
	Ala	Phe	Val	Gly	Phe	Val	Leu	Ser	Arg	Lys	Glu	Pro	Met	Trp	Ala	Asp
	305					310					315				320	
	Leu	Leu	Ala	Leu	Ala	Ala	Ala	Arg	Gly	Gly	Arg	Val	His	Arg	Ala	Pro
65					325					330					335	

Glu Pro Tyr Lys Ala Leu Arg Asp Leu Lys Glu Ala Arg Gly Leu Leu
 340 345 350
 5 Ala Lys Asp Leu Ser Val Leu Ala Leu Arg Glu Gly Leu Gly Leu Pro
 355 360 365
 Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser Asn
 370 375 380
 10 Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr Glu
 385 390 395 400
 Glu Ala Gly Glu Arg Ala Ala Leu Ser Glu Arg Leu Phe Ala Asn Leu
 405 410 415
 15 Trp Gly Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Arg Glu
 420 425 430
 Val Glu Arg Pro Leu Ser Ala Val Leu Ala His Met Glu Ala Thr Gly
 435 440 445
 Val Arg Leu Asp Val Ala Tyr Leu Arg Ala Leu Ser Leu Glu Val Ala
 450 455 460
 25 Glu Glu Ile Ala Arg Leu Glu Ala Glu Val Phe Arg Leu Ala Gly His
 465 470 475 480
 Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe Asp
 485 490 495
 30 Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg
 500 505 510
 Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro Ile
 515 520 525
 Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser Thr
 530 535 540
 40 Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg Leu
 545 550 555 560
 His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser
 565 570 575
 45 Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly Gln
 580 585 590
 Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val Ala
 595 600 605
 Leu Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser Gly
 610 615 620
 55 Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His Thr
 625 630 635 640
 Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp Pro
 645 650 655
 60 Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly
 660 665 670
 Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu Glu
 675 680 685
 65 Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val Arg
 690 695 700

Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val
705 710 715 720

5 Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Glu Ala Arg
725 730 735

Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met Pro
740 745 750

10 Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys Leu
755 760 765

Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val His
770 775 780

15 Asp Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val Ala
785 790 795 800

20 Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val Pro
805 810 815

Leu Val Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys Glu
820 825 830

25 **SEQ ID NO: 12**

H-2

Met Arg Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu Leu
1 5 10 15

30 Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys Gly
20 25 30

35 Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe Ala
35 40 45

Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile Val
50 55 60

40 Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly Gly
65 70 75 80

Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln Leu
85 90 95

45 Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu Glu
100 105 110

50 Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys Lys
115 120 125

Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Lys Asp
130 135 140

55 Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro Glu Gly
145 150 155 160

Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg Pro
165 170 175

60 Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp Asn
180 185 190

Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu Leu
 195 200 205
 5 Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp Arg Leu
 210 215 220
 Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp Leu Lys
 225 230 235 240
 10 Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu Glu Val
 245 250 255
 Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg Ala Phe
 260 265 270
 15 Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu Leu
 275 280 285
 20 Glu Ser Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu Gly
 290 295 300
 Ala Phe Val Gly Phe Val Leu Ser Arg Lys Glu Pro Met Trp Ala Asp
 305 310 315 320
 25 Leu Leu Ala Leu Ala Ala Ala Arg Gly Gly Arg Val His Arg Ala Pro
 325 330 335
 Glu Pro Tyr Lys Ala Leu Arg Asp Leu Lys Glu Ala Arg Gly Leu Leu
 340 345 350
 30 Ala Lys Asp Leu Ser Val Leu Ala Leu Arg Glu Gly Leu Gly Leu Pro
 355 360 365
 35 Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser Asn
 370 375 380
 Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr Glu
 385 390 395 400
 40 Glu Ala Gly Glu Arg Ala Ala Leu Ser Glu Arg Leu Phe Ala Asn Leu
 405 410 415
 Trp Gly Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Arg Glu
 420 425 430
 45 Val Glu Arg Pro Leu Ser Ala Val Leu Ala His Met Glu Ala Thr Gly
 435 440 445
 50 Val Arg Leu Asp Val Ala Tyr Leu Arg Ala Leu Ser Leu Glu Val Ala
 450 455 460
 Glu Glu Ile Ala Arg Leu Glu Ala Glu Val Phe Arg Leu Ala Gly His
 465 470 475 480
 55 Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe Asp
 485 490 495
 Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg
 500 505 510
 60 Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro Ile
 515 520 525
 Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser Thr
 530 535 540
 65 Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg Leu
 545 550 555 560

His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser
 565 570 575
 5 Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly Gln
 580 585 590
 Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val Ala
 595 600 605
 10 Leu Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser Gly
 610 615 620
 Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His Thr
 625 630 635 640
 15 Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp Pro
 645 650 655
 20 Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly
 660 665 670
 Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu Glu
 675 680 685
 25 Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val Arg
 690 695 700
 30 Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val
 705 710 715 720
 Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Glu Ala Arg
 725 730 735
 35 Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met Pro
 740 745 750
 Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys Leu
 755 760 765
 40 Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val His
 770 775 780
 Asp Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val Ala
 785 790 795 800
 45 Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val Pro
 805 810 815
 50 Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys Glu
 820 825 830

SEQ ID NO: 13

A-111

55 Met Arg Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu Leu
 1 5 10 15
 Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys Gly
 20 25 30
 60 Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe Ala
 35 40 45

Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile Val
 50 55 60
 5 Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly Gly
 65 70 75 80
 Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln Leu
 85 90 95
 10 Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu Glu
 100 105 110
 Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys Lys
 115 120 125
 15 Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Lys Asp
 130 135 140
 Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro Glu Gly
 145 150 155 160
 Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg Pro
 165 170 175
 25 Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp Asn
 180 185 190
 Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu Leu
 195 200 205
 30 Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp Arg Leu
 210 215 220
 Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp Leu Lys
 225 230 235 240
 Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu Glu Val
 245 250 255
 40 Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg Ala Phe
 260 265 270
 Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu Leu
 275 280 285
 45 Glu Ser Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu Gly
 290 295 300
 Ala Phe Val Gly Phe Val Leu Ser Arg Lys Glu Pro Met Trp Ala Asp
 305 310 315 320
 Leu Leu Ala Leu Ala Ala Ala Arg Gly Gly Arg Val His Arg Ala Pro
 325 330 335
 55 Glu Pro Tyr Lys Ala Leu Arg Asp Leu Lys Glu Ala Arg Gly Leu Leu
 340 345 350
 Ala Lys Asp Leu Ser Val Leu Ala Leu Arg Glu Gly Leu Gly Leu Pro
 355 360 365
 60 Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser Asn
 370 375 380
 Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr Glu
 385 390 395 400
 Glu Ala Gly Glu Arg Ala Ala Leu Ser Glu Arg Leu Phe Ala Asn Leu
 405 410 415

Trp Gly Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Arg Glu
 420 425 430
 5 Val Glu Arg Pro Leu Ser Ala Val Leu Ala His Met Glu Ala Thr Gly
 435 440 445
 Val Arg Leu Asp Val Ala Tyr Leu Arg Ala Leu Ser Leu Glu Val Ala
 450 455 460
 10 Glu Glu Ile Ala Arg Leu Glu Ala Glu Val Phe Arg Leu Ala Gly His
 465 470 475 480
 Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe Asp
 485 490 495
 15 Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg
 500 505 510
 20 Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro Ile
 515 520 525
 Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser Thr
 530 535 540
 25 Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg Leu
 545 550 555 560
 His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser
 565 570 575
 30 Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly Gln
 580 585 590
 35 Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val Ala
 595 600 605
 Leu Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser Gly
 610 615 620
 40 Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His Thr
 625 630 635 640
 Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp Pro
 645 650 655
 45 Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly
 660 665 670
 50 Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu Glu
 675 680 685
 Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val Arg
 690 695 700
 55 Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val
 705 710 715 720
 Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asn Leu Glu Ala Arg
 725 730 735
 60 Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met Pro
 740 745 750
 65 Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys Leu
 755 760 765
 Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val His
 770 775 780

Asp Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val Ala
 785 790 795 800
 5 Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val Pro
 805 810 815
 Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys Glu
 820 825 830

SEQ ID NO: 14

10 H-101
 Met Gly Leu Leu His Glu Phe Gly Leu Leu Glu Ser Pro Lys Ala Leu
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 15 Glu Glu Ala Pro Trp Pro Pro Pro Glu Gly Ala Phe Val Gly Phe Val
 20 25 30
 Leu Ser Arg Lys Glu Pro Met Trp Ala Asp Leu Leu Ala Leu Ala Ala
 35 40 45
 20 Ala Arg Gly Gly Arg Val His Arg Ala Pro Glu Pro Tyr Lys Ala Leu
 50 55 60
 Arg Asp Leu Lys Glu Ala Arg Gly Leu Leu Ala Lys Asp Leu Ser Val
 25 65 70 75 80
 Leu Ala Leu Arg Glu Gly Leu Gly Leu Pro Pro Gly Asp Asp Pro Met
 85 90 95
 30 Leu Leu Ala Tyr Leu Leu Asp Pro Ser Asn Thr Thr Pro Glu Gly Val
 100 105 110
 Ala Arg Arg Tyr Gly Gly Glu Trp Thr Glu Glu Ala Gly Glu Arg Ala
 115 120 125
 35 Ala Leu Ser Glu Arg Leu Phe Ala Asn Leu Trp Gly Arg Leu Glu Gly
 130 135 140
 Glu Glu Arg Leu Leu Trp Leu Tyr Arg Glu Val Glu Arg Pro Leu Ser
 40 145 150 155 160
 Ala Val Leu Ala His Met Glu Ala Thr Gly Val Arg Leu Asp Leu Ser
 165 170 175
 45 Tyr Leu Arg Ala Leu Ser Leu Glu Val Ala Glu Glu Ile Ala Arg Leu
 180 185 190

Glu Ala Glu Val Phe Arg Leu Ala Gly His Pro Phe Asn Leu Asn Ser
 195 200 205

5 Arg Asp Gln Leu Glu Arg Val Leu Phe Asp Glu Leu Gly Leu Pro Ala
 210 215 220

Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg Ser Thr Ser Ala Ala Val
 225 230 235 240

10 Leu Glu Ala Leu Arg Glu Ala His Pro Met Val Glu Lys Ile Leu Gln
 245 250 255

Tyr Arg Glu Leu Thr Lys Leu Lys Ser Thr Tyr Ile Asp Pro Leu Pro
 15 260 265 270

Asp Leu Ile His Pro Arg Thr Gly Arg Leu His Thr Arg Phe Asn Gln
 275 280 285

20 Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser Ser Asp Pro Asn Leu Gln
 290 295 300

Asn Ile Pro Val Arg Thr Pro Leu Gly Gln Arg Ile Arg Arg Ala Phe
 305 310 315 320

25 Ile Ala Glu Glu Gly Trp Leu Leu Val Ala Leu Asp Tyr Ser Gln Ile
 325 330 335

Glu Leu Arg Val Leu Ala His Leu Ser Gly Asp Glu Asn Leu Ile Arg
 30 340 345 350

Val Phe Gln Glu Gly Arg Asp Ile His Thr Glu Thr Ala Ser Trp Met
 355 360 365

35 Phe Gly Val Pro Arg Glu Ala Val Asp Pro Leu Met Arg Arg Ala Ala
 370 375 380

Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly Met Ser Ala His Arg Leu
 385 390 395 400

40 Ser Gln Glu Leu Ala Ile Pro Tyr Glu Glu Ala Gln Ala Phe Ile Glu
 405 410 415

Arg Tyr Phe Gln Ser Phe Pro Lys Val Arg Ala Trp Ile Glu Lys Thr
 45 420 425 430

```

Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val Glu Thr Leu Phe Gly Arg
    435                      440                      445

Arg Arg Tyr Val Pro Asp Leu Glu Ala Arg Val Arg Ser Val Arg Glu
5    450                      455                      460

Ala Ala Glu Arg Met Ala Phe Asn Met Pro Val Gln Gly Thr Ala Ala
465                      470                      475                      480

10  Asp Leu Met Lys Leu Ala Met Val Lys Leu Phe Pro Arg Leu Glu Glu
    485                      490                      495

Met Gly Ala Arg Met Leu Leu Gln Val His Asp Glu Leu Val Leu Glu
    500                      505                      510

15  Ala Pro Lys Glu Arg Ala Glu Ala Val Ala Arg Leu Ala Lys Glu Val
    515                      520                      525

Met Glu Gly Val Tyr Pro Leu Ala Val Pro Leu Glu Val Glu Val Gly
20  530                      535                      540

Ile Gly Glu Asp Trp Leu Ser Ala Lys Glu
545                      550

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SEQUENCE LISTING IN ELECTRONIC FORM

In accordance with Section 111(1) of the Patent Rules, this description contains a sequence listing in electronic form in ASCII text format (file: 77586-100 Seq 09-07-2015 v1.txt).

A copy of the sequence listing in electronic form is available from the Canadian Intellectual Property Office.

CLAIMS:

1. An isolated polypeptide comprising:
a polypeptide sequence at least 95% identical to SEQ ID NO: 1 and having an E818V substitution, or a functional fragment thereof,
5 wherein the functional fragment has the E818V substitution,
wherein the isolated polypeptide comprises polymerase activity.
2. The isolated polypeptide of claim 1, wherein:
the functional fragment comprises SEQ ID NO: 2 and has the E818V substitution, wherein the amino acid numbering corresponds to the amino acid
10 numbering as set forth in SEQ ID NO: 1, and
the functional fragment retains polymerase activity.
3. The isolated polypeptide of claim 1 or 2, further comprising at least one amino acid substitution selected from the group consisting of E404G, G418E, V453L, A454S, R487G, I528M, L533R, D551G, D578E, 1599V, L609P, E626K, V649I,
15 L657Q, I707L, E708K, E708L, E708N, E708Q, E708I, E708W, E708R, E708V, E708S, D732N, K738R, and L781I, wherein the amino acid numbering corresponds to the amino acid numbering as set forth in SEQ ID NO: 1.
4. The isolated polypeptide of any one of claims 1-3, wherein the isolated polypeptide comprises polymerase activity in the presence of an inhibitory substance
20 in an amount sufficient to cause a wild-type Taq polymerase comprising SEQ ID NO: 1 to fail to amplify a target nucleic acid in a polymerase chain reaction (PCR).
5. The isolated polypeptide of claim 4, wherein the inhibitory substance is selected from the group consisting of chocolate, peanut butter, milk, seafood, meat, egg, plant material, blood, a blood fraction, urine, dye, soil, soil extract, humic acid,
25 guanidinium thiocyanate (GITC), ethanol, and combinations of any thereof.
6. The isolated polypeptide of claim 1 or 2, comprising SEQ ID NO: 11 (mutant C-66).

7. The isolated polypeptide of any one of claims 1-3, comprising SEQ ID NO: 11 (mutant C-66) or a polypeptide sequence at least 95% identical to SEQ ID NO: 11 having 818V and polymerase activity.

8. A method of amplifying a target nucleic acid in a polymerase chain reaction (PCR) comprising:

forming an assay mixture comprising:

a sample comprising the target nucleic acid,

primers specific for the target nucleic acid,

a buffer, and

at least one polymerase comprising the isolated polypeptide of any one of claims 1-7; and

amplifying the target nucleic acid in the assay mixture in the PCR.

9. The method of claim 8, wherein the sample comprises an inhibitory substance in an amount sufficient to cause a wild-type Taq polymerase comprising SEQ ID NO: 1 to fail to amplify the target nucleic acid in the PCR.

10. The method of claim 9, wherein the inhibitory substance is present in the sample and is selected from the group consisting of chocolate, peanut butter, milk, seafood, meat, egg, plant material, blood, a blood fraction, urine, dye, soil, soil extract, humic acid, guanidinium thiocyanate (GITC), ethanol, and combinations of any thereof.

11. The method of claim 8 or 9, wherein the assay mixture comprises one or more of:

a dye up to 100X, where X is a manufacturer unit for concentration for use in PCR;

blood or a blood fraction up to 40% of a total volume of the assay mixture;

soil or soil extract up to 50% of the total volume of the assay mixture or an amount of soil or soil extract that provides up to 0.5 ng of humic acid per μL of the assay mixture volume;

5 a bile salt, or an equivalent amount of bile, up to 2 μg per μL of the assay mixture or up to 20% of the total volume of the assay mixture;

a plant material or a plant extract up to 50% of the total volume of the assay mixture;

urine up to 90% of the total volume of the assay mixture;

GITC up to 200 mM in the assay mixture;

10 ethanol up to 10% of the total volume of the assay mixture;

tea polyphenols up to 12 ng per μL of assay mixture;

tannins up to 0.5 μg per μL of assay mixture;

chocolate up to 20 μg per μL of assay mixture; and

black pepper up to 20 μg per μL of assay mixture.

15 12. The method of any one of claims 8-11, wherein

the PCR is a real-time PCR;

the assay mixture further comprises at least one dye; and

amplifying the target nucleic acid comprises amplifying the target nucleic acid in the assay mixture in the real-time PCR.

20 13. An isolated nucleic acid encoding the isolated polypeptide of any one of claims 1-7.

14. A kit comprising the isolated polypeptide of any one of claims 1-7 or the isolated nucleic acid of claim 13.

15. A kit of claim 14, wherein the kit is for use in the method of any one of
25 claims 8-12.

Performance of H10 Klentaq Mutant with Crude Samples
Containing Chocolate or Black Pepper

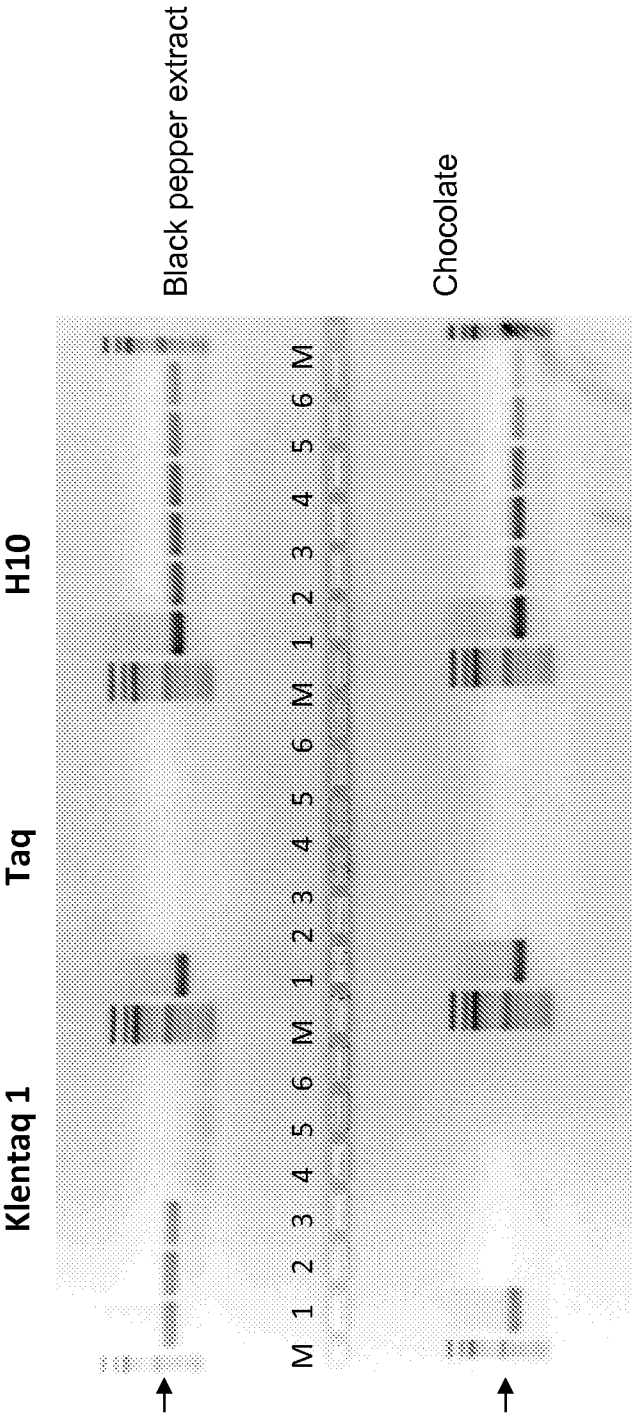


FIG. 1

Resistance of B9 and H10 Klentaq Mutants to Black Pepper Inhibition

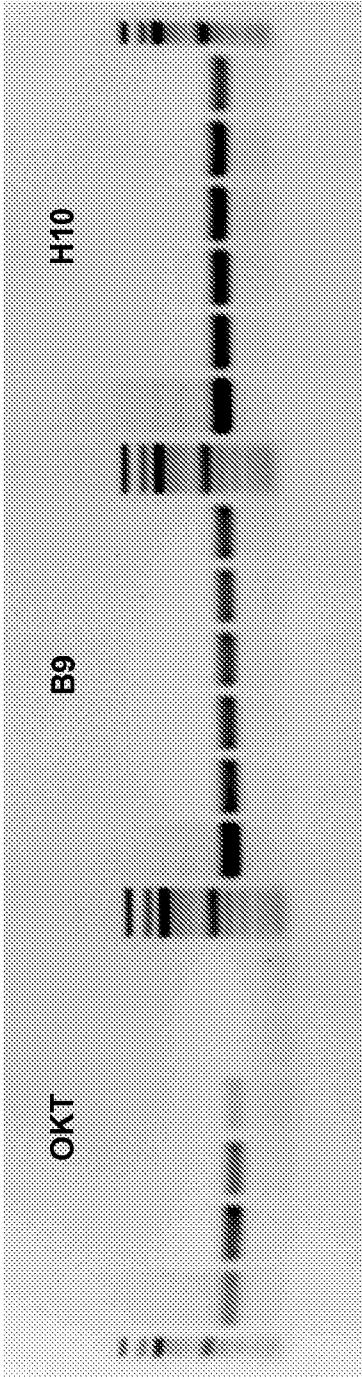


FIG. 2

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Resistance of B9 and H10 Klentaq Mutants to Chocolate Inhibition

OKT B9 H10

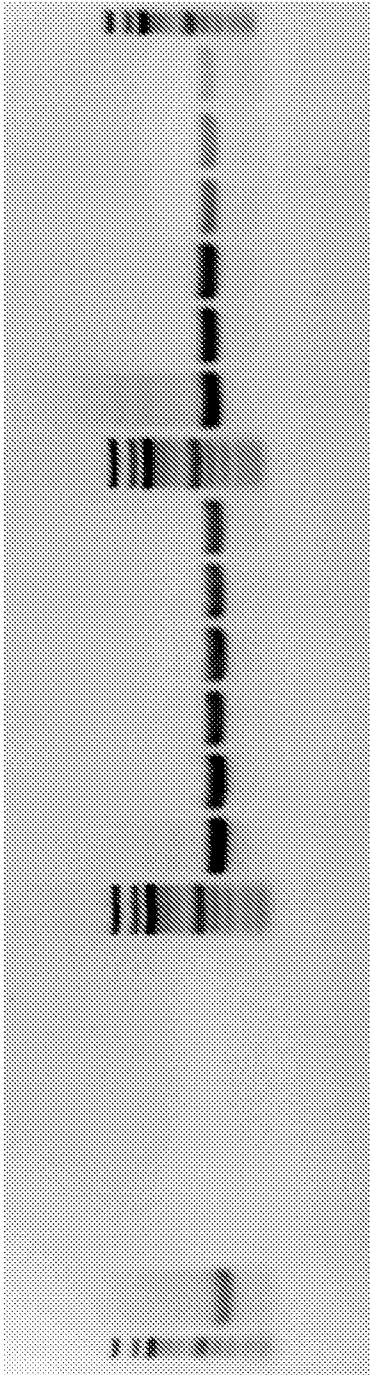


FIG. 3

Resistance of C12 Full-Length Taq Mutant to Chocolate Inhibition

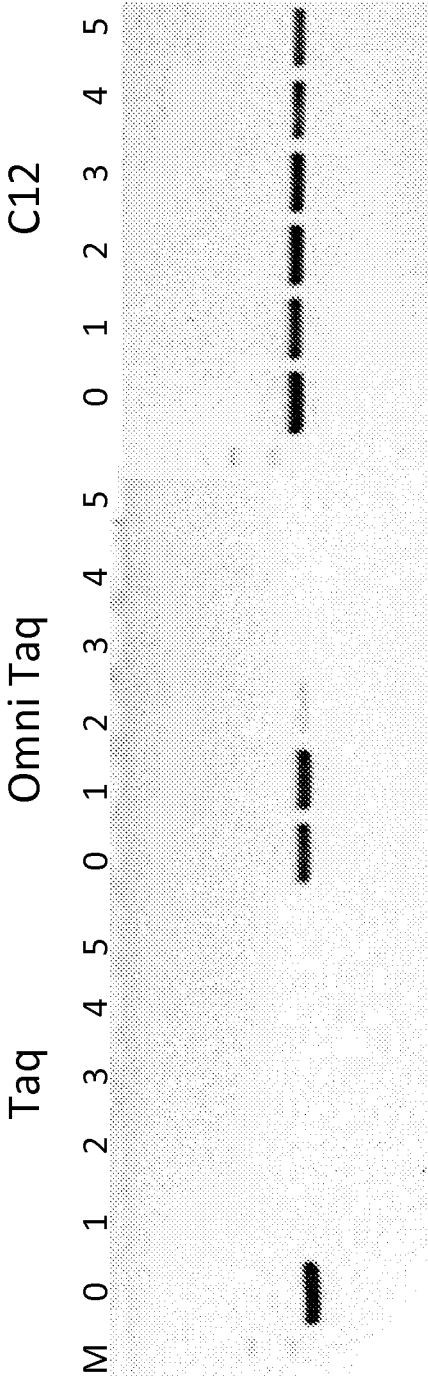


FIG. 4

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Resistance of C12 Full-Length Taq Mutant to Black Pepper Inhibition

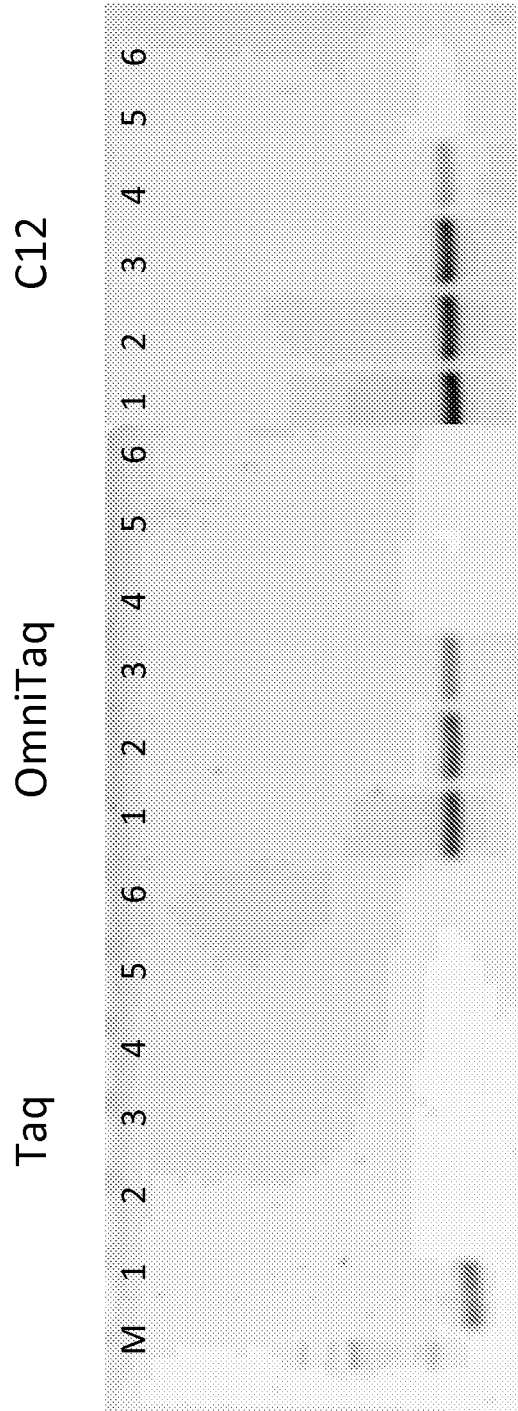
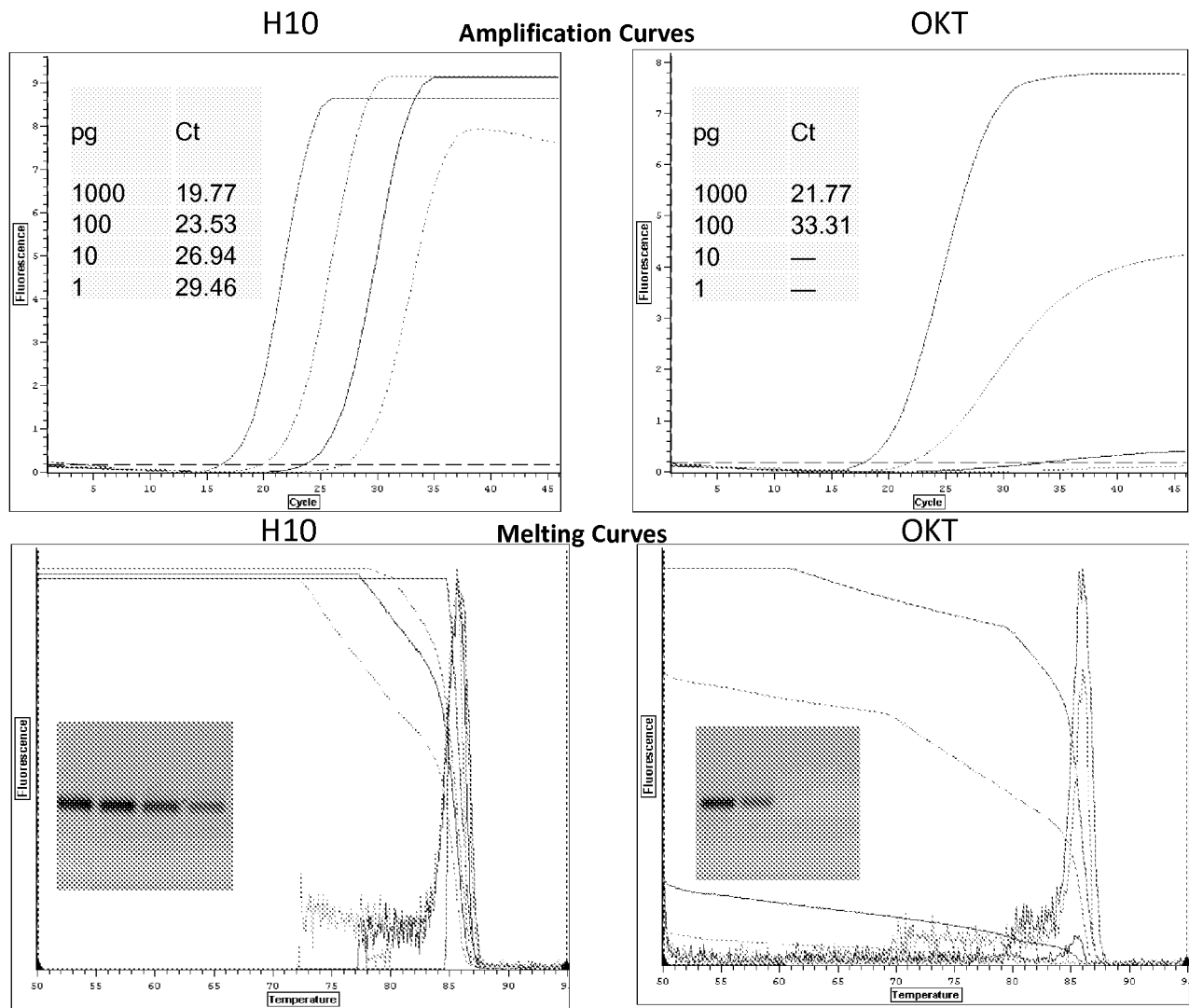


FIG. 5

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Resistance of H10 Klentaq Mutant to Chocolate in qPCR (SYBR Green)

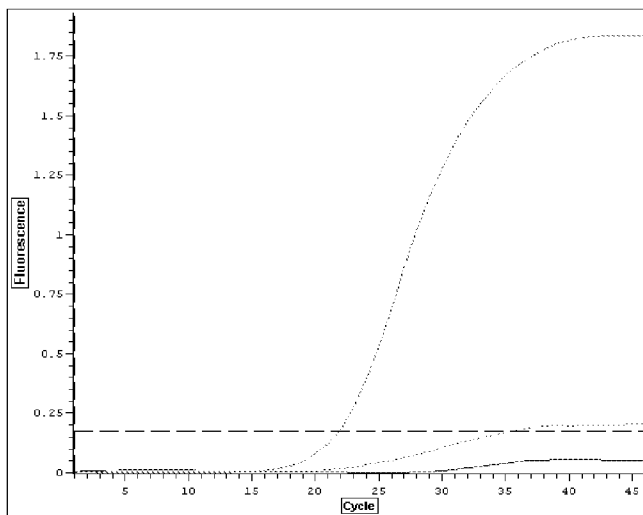
**FIG. 6**

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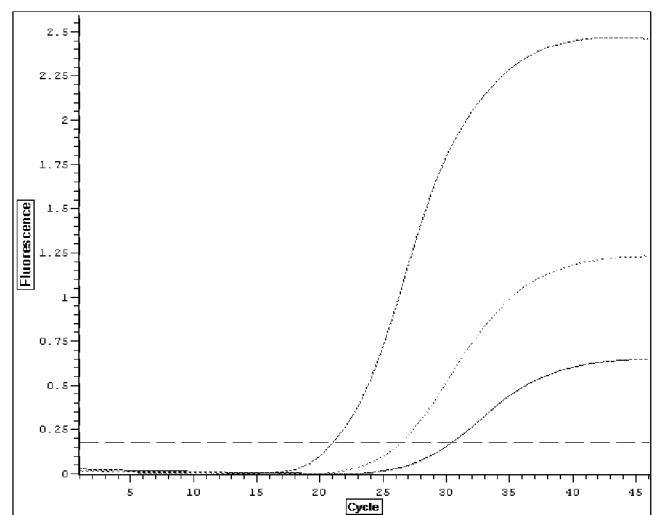
Resistance of C12 Full-Length Taq Mutant to Chocolate in qPCR (SYBR Green)

Amplification Curves

OT

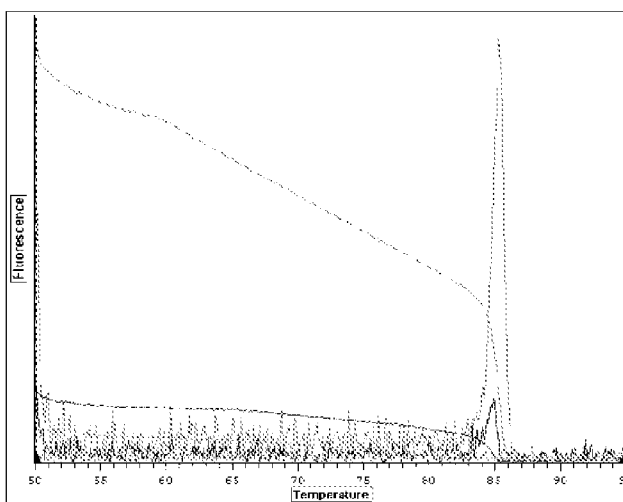


C12



Melting Curves

OT



C12

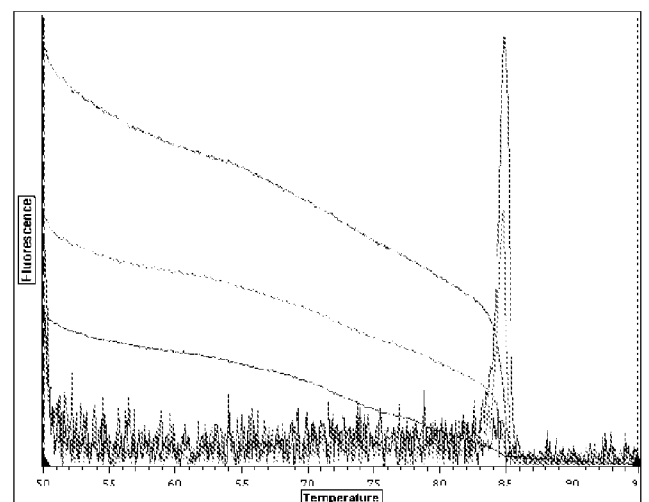


FIG. 7

Performance of the H10 Klentaq Mutant in PCR with Crude Samples
Containing Whole Blood

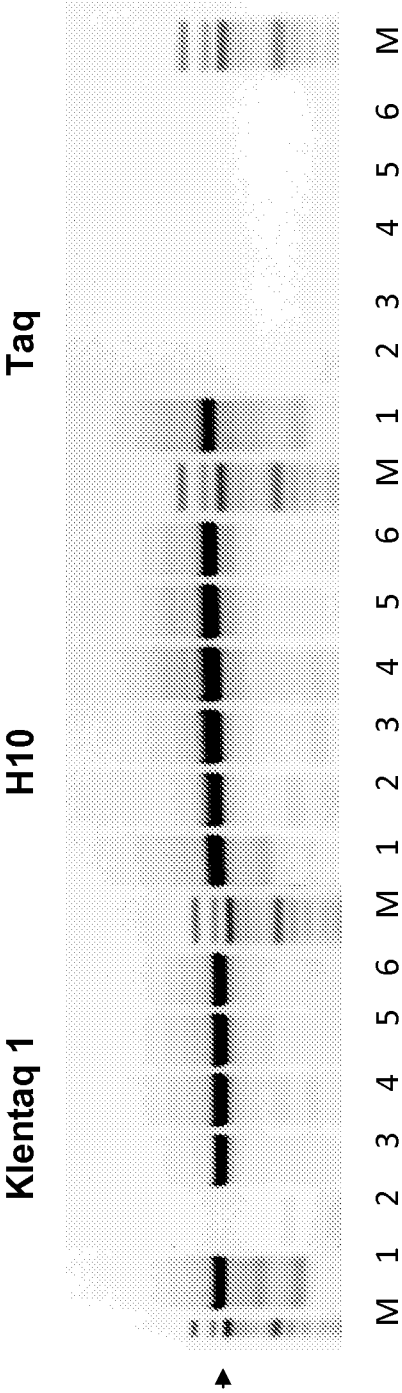


FIG. 8

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Performance of H10 Klentaq Mutant in PCR with Crude Samples Containing Humic Acid

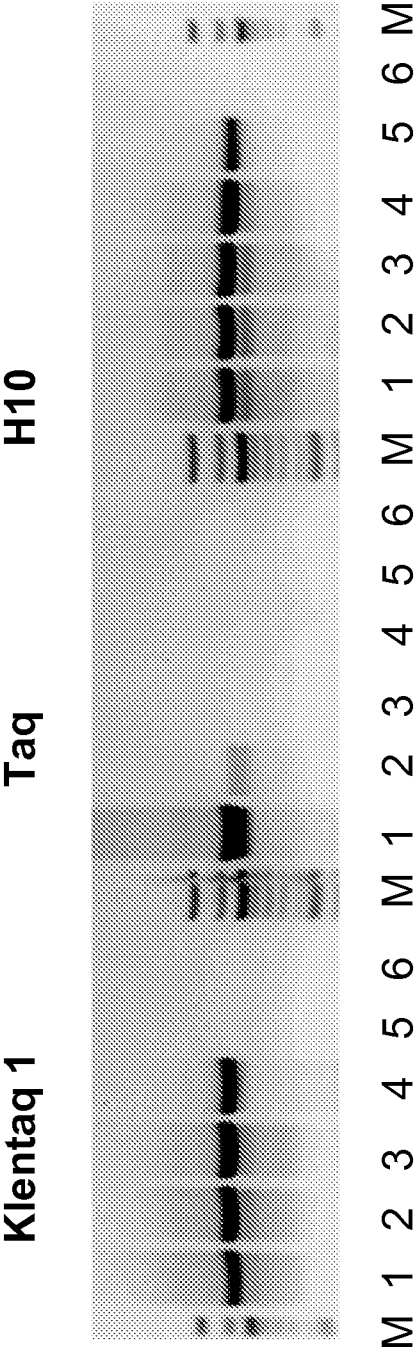
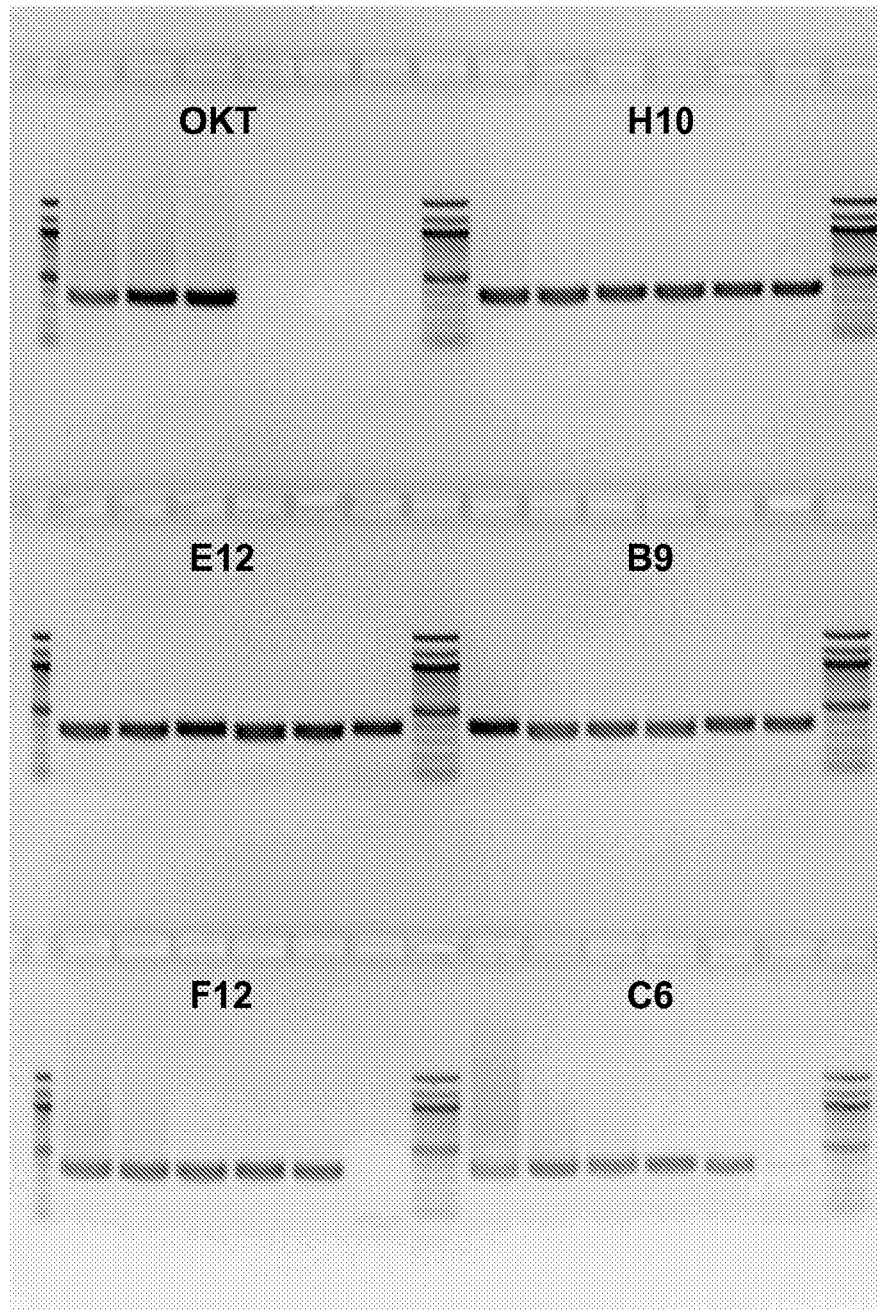


FIG. 9

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Resistance of Klentaq mutants to bile inhibition**FIG. 10**

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Performance of H10 Klentaq Mutant in PCR with Crude Samples
Containing Plant Tissue Extract

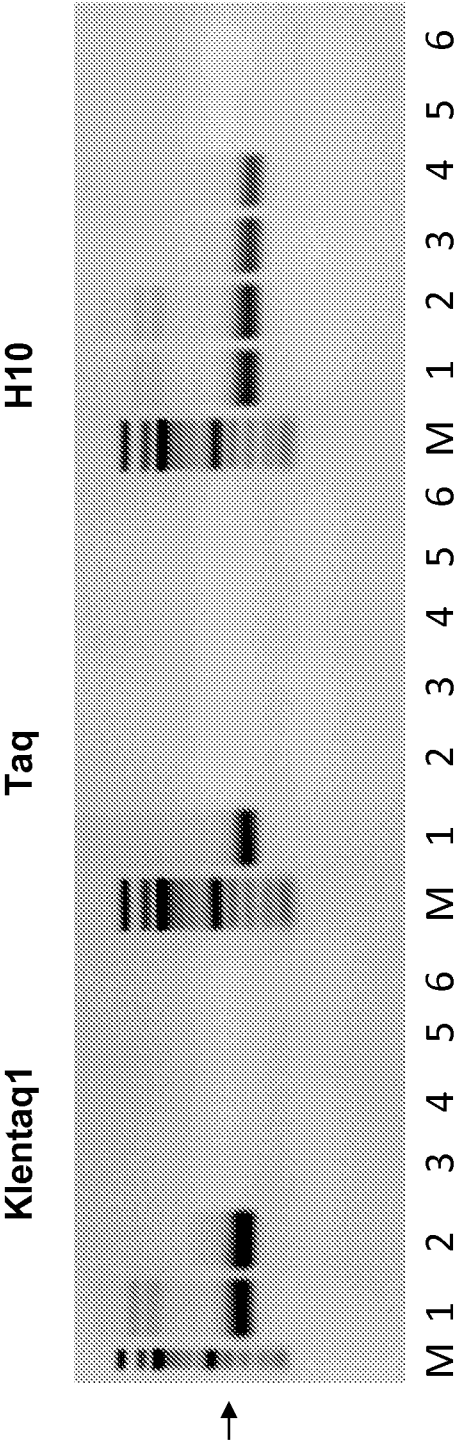


FIG. 11

Resistance of New Full-Length Taq Mutant C66 to
Shrimp Meat Inhibition

C66 OmniTaq Taq

M 1 2 3 4 5 1 2 3 4 5 1 2 3 4 5

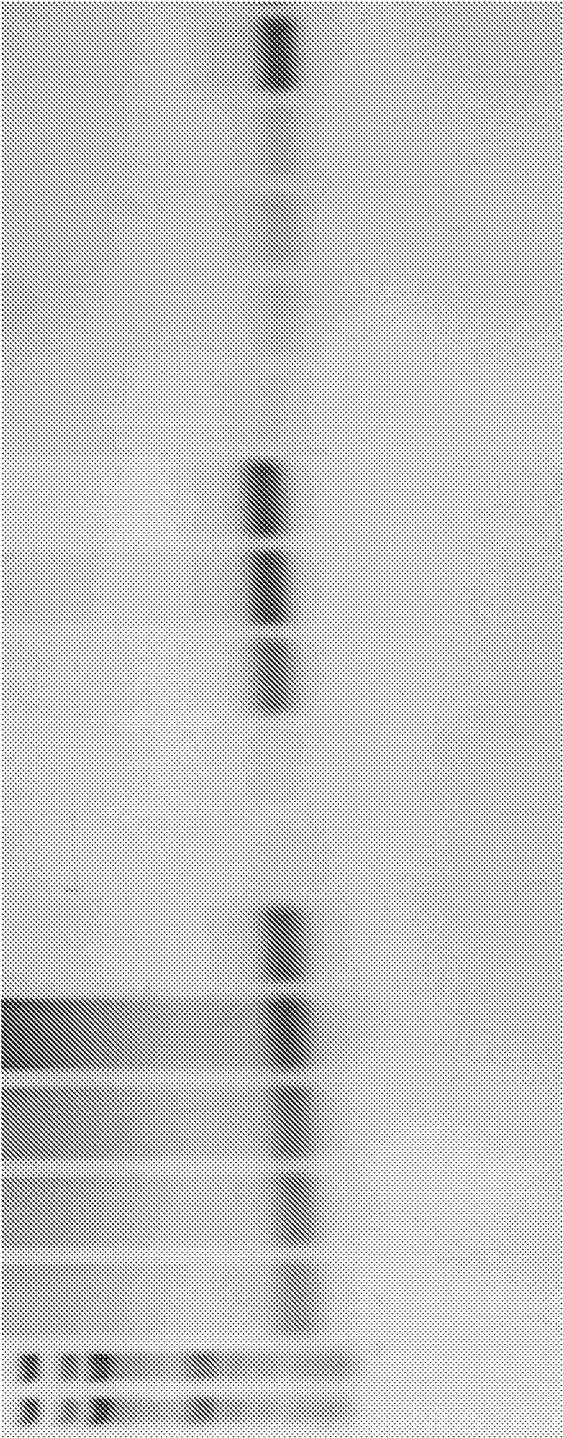
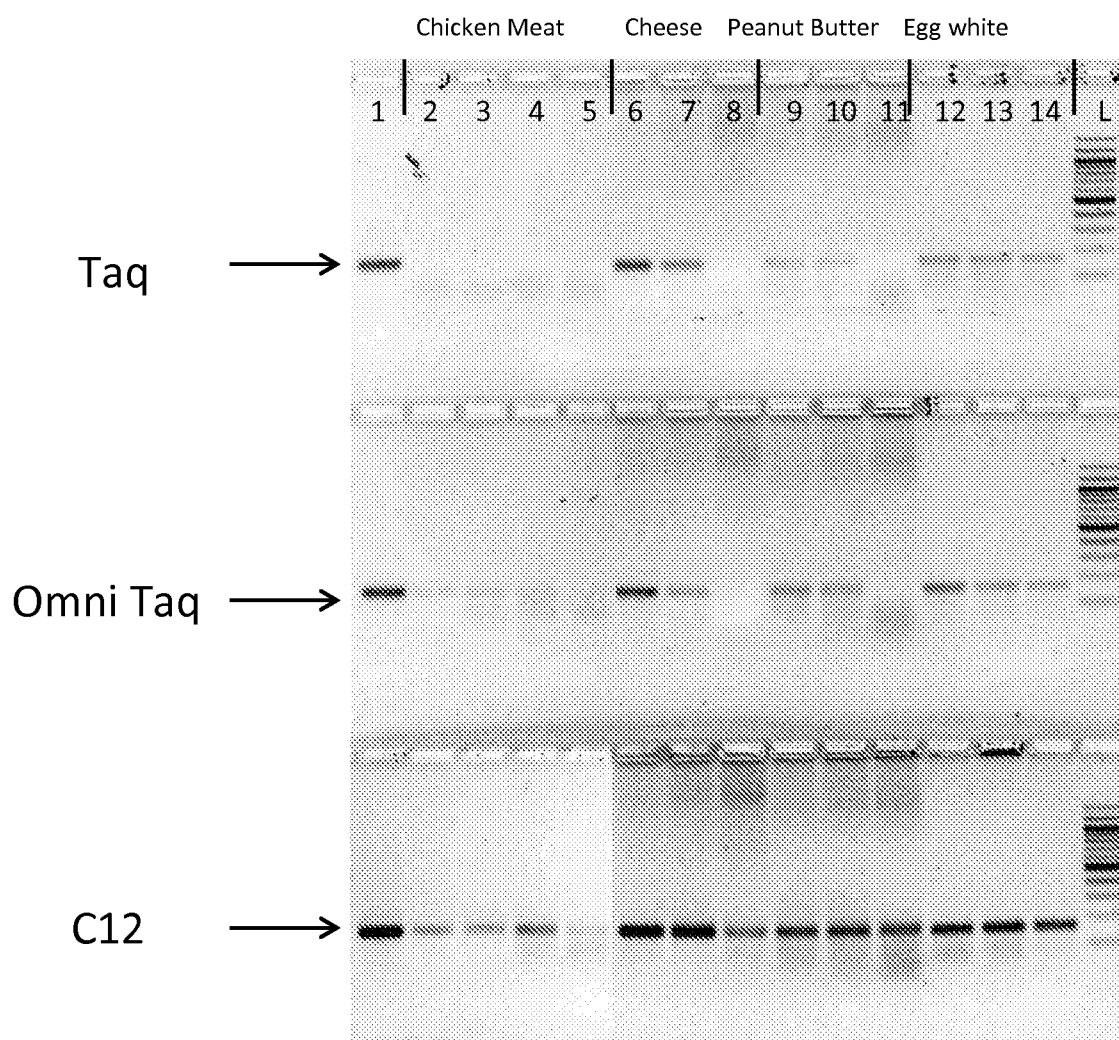


FIG. 12

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Resistance of New Full-Length Taq Mutant C12 to Food Inhibition

**FIG. 13**

Performance of H10 KlenTaq Mutant with Crude Samples Containing Chocolate or Black Pepper

