

CHANGES IN THE SUGARS AND AMINO ACIDS IN CHIPS
MADE FROM FRESH, STORED AND RECONDITIONED
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INTRODUCTION

Color is one of the most important physical properties of potato chips, and is generally conceded to develop when the chip slices are subjected to the high temperatures of chip preparation. Significant losses in reducing sugars at these high temperatures led to the obvious conclusion that color formation was due to "caramelization." More recently, however, even though the exact mechanism of the reaction is not known, it is widely accepted that a Maillard reaction between the reducing sugars and amino acids plays a major role in the browning of potato chips. The chemistry of the Amidori rearrangement has been reviewed by Hodge (6), who pointed out the significance of this reaction in the non-enzymatic browning of foods. This reaction involves sugar-amine condensation with subsequent Amidori rearrangement followed by sugar and amino acid degradation, aldol condensation and aldehyde-amine polymerization. Anet and Reynolds (2), working with freeze-dried peach and apricot puree that had been stored for several months, isolated several different sugar-amino acid reaction products (1-amino-1-deoxy-2-ketoses) which accounted for most of the accompanying decrease in amino acids and reducing sugars.

In a previous study (3), the frying of chips, made from stored potatoes having a high reducing sugar content, resulted in a drastic reduction in both reducing sugars and free amino acids. There was very little change in total nitrogen. It was concluded that amino acid-sugar reaction products had been formed.

Working with a different variety of potatoes from another geographical source, this study was carried out with three objectives: First, to determine the effects on the sugars and amino acids in chips after long term cold storage of the potatoes; second, to attempt to recover, by means of hydrolysis, the free amino acids which had reacted with the reducing sugars and; third, to determine the sugar-amino acid pattern of chips made from tubers which had been reconditioned following prolonged storage in the cold.

MATERIALS AND METHODS

Kennebec potatoes were received from the University of Wisconsin shortly after harvest. Sampling and testing of these potatoes were carried out in accordance with the techniques developed and reported in a preliminary publication (3).

Essentially, the approximate per cent solids of the potatoes was determined from specific gravity measurements. The tubers were then graded and separated into six specimen samples. Two samples were retained for the analysis of fresh potatoes and of chips made from fresh

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potatoes. The remaining four samples were stored at 36 F. After five months, two samples were withdrawn for analysis of stored potatoes and of chips made from stored potatoes. After ten months, the two remaining samples were withdrawn from cold storage for reconditioning at room temperature. The decrease in reducing sugars of the potatoes during reconditioning was approximated by periodically frying a small sample of tuber slices and observing the color. In three weeks, the color had lightened appreciably. After four weeks, the chips fried quite light except for a brown center. At this point the tubers had sprouted. Therefore, without further delay, analyses were carried out on these reconditioned potatoes and on chips made from them.

The potatoes and chips from all three stages (fresh, stored and reconditioned) were analyzed in the same manner. After abrasion peeling, direct total solids and total nitrogen determinations (by Kjeldahl) were made on the tubers. Chips were fried batchwise in a basket-type fryer at 350 F for about four minutes until dehydration was complete. After fat extraction, direct total solids and total nitrogen content were determined on the fat-free chips. Amino acids and sugars were extracted from samples of both tubers and chips according to the procedure of Talley et al (14). Kjeldahl nitrogen, total and reducing sugars by the method of Spengler et al. (11) and amino acid analysis by the method of Spackman et al (10) using a Phoenix Model K-5000 amino acid analyzer³ were carried out on these extracts. All of the potato and chip alcoholic extracts were hydrolyzed in the following manner: portions of each extract were evaporated to dryness on a rotary evaporator to remove the alcohol. The samples were taken up in a volume of 4 N HCl equivalent to the evaporated alcohol solution, then hydrolyzed in an oil bath for three hours at 120 C. After cooling, the humin was filtered off and the samples were evaporated to dryness at least three times to remove the hydrochloric acid. (At this point it was possible to have lost some ammonia from the samples as ammonium chloride. Replicate runs on the amino acid analyzer reproduced the ammonia value within reasonable limits, but this figure must be considered in the light of possible losses.) The samples were finally taken up in a quantity of water equivalent to the original volume of the sample and the amino acids were determined.

RESULTS AND DISCUSSION

In an attempt to minimize variables and to suppress the changes in potato metabolism due to wide fluctuations in climate, a single potato variety from a specific geographical location, viz., Keennebec potatoes from Wisconsin, was employed. This sample contrasted well with the Red LaSoda potatoes from Florida used in a previous study (3). However, potatoes in any particular lot are not exactly similar in composition, and vary within limits from each other. It would be coincidental if exact duplication of results was obtained on both original potatoes and on chips made from similar potatoes.

Nitrogen.—Table 1 shows that on a moisture free basis the total nitrogen of the potatoes and on chips made from them remained constant,

³Mention of a specific piece of commercial equipment does not imply endorsement by the U. S. Department of Agriculture over similar equipment available.

TABLE 1.—Solids and nitrogen content of Wisconsin Kennebec potatoes and chips.¹

Sample	% Solids		Total N (Kjeldahl) μmols/g Dry Wt.	% Total N (Kjeldahl)		
	From Sp. Gr.	Direct		Original	In extract	Extract- able
Fresh potatoes	18.56	18.92	1255.3	.3325	.1838	55.28
Chips from fresh potatoes	18.29	18.56	1285.8	.3341	.1515	45.36
Stored potatoes	18.93	18.03	1248.7	.3152	.1947	61.77
Chips from stored potatoes ..	19.70	19.53	1156.9	.3163	.1549	48.97
Reconditioned potatoes	18.37	20.55	1281.9	.3688	.2738	74.24
Chips from reconditioned potatoes	18.37	20.51	1414.3	.4061	.1809	44.55

¹Calculated on a fresh tuber basis.

TABLE 2.—Changes in extractable potato nitrogen on storing, reconditioning and frying.

Sample	N (Kjeldahl) μmols/g Dry Wt.	N (Free amino acid) ¹		% of Kjeldahl N As free amino acids ¹		
		% Loss on frying	Recovery μmols/g Dry Wt.	% Loss on frying	Recovery Loss	
Fresh potato extract	693.90		583.48		84.09	15.91
Hydrolyzed extract			505.72		72.88	27.12
Fresh chip extract	583.05	15.98	237.20	59.35	40.68	59.32
Hydrolyzed extract			346.38		59.41	40.59
Stored potato extract	771.36		655.98		85.04	14.96
Hydrolyzed extract			588.15		76.25	23.75
Stored chip extract ²	566.50	26.56	75.98	88.42	13.41	86.59
Hydrolyzed extract			157.29		27.77	72.23
Reconditioned potato extract .	951.71		923.24		97.01	2.99
Hydrolyzed extract			835.18		87.76	12.24
Reconditioned chip extract ³ ..	711.93	25.19	54.12	94.14	7.60	92.40
Hydrolyzed extract			232.68		32.68	67.32

¹Includes amides and unknown peaks on analyzer.

²Extract of chips made from stored potatoes.

³Extract of chips made from stored and reconditioned potatoes.

within experimental and sampling limits, both on prolonged cold storage and on reconditioning after storage. This verifies the observations of Talley et al (16) on the relationships between storage and on the nitrogenous constituents. Table 1 also shows that the amount of extractable nitrogen (by Kjeldahl) from the tubers increased on storage and reconditioning which indicates a degree of protein degradation during this period. An increasing amount of this extractable nitrogen could be recovered as free amino acids and amides. This is in agreement with the findings of Tagawa and Okazawa (12). It may be interesting to note, however, that the amount of extractable nitrogen from chips fried from these potatoes, remained quite constant. This may be due to an increasing amount of the

non-protein nitrogen being tied up in the form of higher molecular weight polymeric materials which can no longer be extracted. This loss in extractable nitrogen is not restricted to any specific amino acid or amide but is a contribution of the entire spectrum as indicated in Table 3. Although the Kjeldahl nitrogen of the chip extracts remained constant, a decreasing amount of this extractable nitrogen (from the chips of fresh stored and reconditioned potatoes) could be recovered as free amino acids and amides, as indicated by the per cent frying loss. These nitrogen relationships are expressed in Table 2.

Amino acids.—The complete amino acid analysis of the fresh, stored and reconditioned potato extracts, and extracts of chips made from these tubers, revealed several unknown ninhydrin active peaks of minor magnitude. These are expressed as leucine equivalents in Table 3. At least some of these materials could be amino acid-fructose condensation products. The effluent volumes of many of them were in close agreement with those reported by Ingles and Reynolds (7) for amino acid fructoses although there were minor differences in the methods of separation. It is likely that potato chips, especially those fried from potatoes with a high reducing sugar content, would contain products of this type. However, the appearance of these suspected unknowns, even in fresh tubers, adds credence to recent preliminary work at this Laboratory (13) which indicates that amino acid-sugar reaction products may be formed even at room temperature during short reaction periods. It can be observed from Table 3 that chip frying caused a general decrease in almost all of the different types of amino acids. There was a very marked loss in the amides. Only in chips made from fresh potatoes was this loss partially offset by an increase in ammonia. Losses in methionine are reasonably offset by increases in the sulfoxides but again only in chips from unstored tubers. An increase of β -alanine in chips made from potatoes stored in the cold could be due, in part, to a decarboxylation of aspartic acid, but more probably, the enlarged peak contains, in addition to β -alanine, a sugar-amine condensation product of a basic amino acid. (Ingles and Reynolds (7) reported a similar elution volume for 1-(*n*- γ -amino butyric acid)-1-deoxyfructose.) This is substantiated by a decrease in the β -alanine peak on hydrolysis with a considerable increase in γ -amino butyric acid. See Table 3.

Habib and Brown (4) reported no change in amino nitrogen of potatoes on storage at 40 F, but a great reduction after reconditioning at 75 F. In a later publication (5) these workers reported a complete disappearance of the basic amino acids after reconditioning. The data reported in this study shows a general increase in all of the amino acids and amides. Since these tubers had sprouted during the latter stages of the reconditioning period, this increase could be attributed to metabolic degradation of protein.

Hydrolysis.—In some cases the unknown materials reported in Table 3 as leucine equivalents, decreased when both the tuber and chip extracts were hydrolyzed. While some of these materials could be amino acid-fructoses, the increase in amino acids (some of significant magnitude) which took place when all of the extracts were hydrolyzed cannot be attributed to cleavage of these minor constituents alone. Small increases in some amino acids are within the limits of experimental error, particu-

TABLE 3.—Amino acid analysis of potato and chip extracts and their hydrolysates.¹

Amino acid	Vol. ²	Fresh		Chips		Hydroly		Stored		Hydroly		Conditioned	
		Tubers	Hydroly	Tubers	Hydroly	Tubers	Hydroly	Tubers	Hydroly	Tubers	Hydroly	Tubers	Hydroly
Unknown ⁵	40	0.60	0.23	0.56	0.56	0.56	0.56	0.43	0.94	0.58	0.26	0.34	0.29
Unknown	45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.28
Unknown	52	0.41	0.00	0.36	0.00	0.30	0.00	0.30	0.00	0.33	0.00	0.25	0.00
Unknown	58	0.13	0.00	0.40	0.09	0.52	0.68	0.52	0.68	0.54	0.07	0.31	0.21
Unknown	68	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.09	0.15
Levulinic Acid ⁶	84	0.00	5.94	0.00	4.30	0.00	51.44	0.00	51.44	0.00	13.78	0.42	32.16
Unknown	93	0.65	0.70	1.56	0.62	1.35	1.78	1.35	1.78	1.26	0.92	2.05	1.63
Methionine Sulfoxides	115	0.57	3.99	2.94	2.90	1.63	4.51	1.63	4.51	0.56	0.82	0.20	4.29
Aspartic Acid	130	14.55	131.19	13.88	66.65	21.98	127.51	21.98	127.51	4.19	20.15	45.70	177.18
Threonine	144	4.30	5.81	2.26	3.23	5.36	6.75	5.36	6.75	0.36	0.91	8.05	10.99
Serine	155	4.34	8.44	3.54	5.17	18.71	21.13	18.71	21.13	1.60	2.92	17.80	18.87
Asparagine	165	173.17	0.00	37.39	0.00	147.15	0.00	147.15	0.00	7.72	0.00	223.78	0.00
Glutamine ⁷	205	4.04	6.18	5.61	6.59	9.44	12.15	9.44	12.15	1.50	1.97	31.75	29.77
Proline	218	19.13	108.44	2.28	89.47	25.19	99.55	25.19	99.55	0.68	38.01	17.50	86.04
Glutamic Acid	258	1.72	6.77	1.27	3.94	2.45	9.23	2.45	9.23	0.32	2.50	6.87	9.17
Glycine	270	4.07	6.17	3.61	5.37	11.94	14.75	11.94	14.75	2.90	4.72	24.77	22.53
Alanine	290	0.25	0.28	0.00	0.00	0.65	0.72	0.65	0.72	0.00	0.00	0.08	0.00
Unknown	325	16.92	17.41	11.14	12.96	22.81	23.32	22.81	23.32	2.81	3.91	27.02	26.85
Valine													
Buffer Change													
+ Unknown	420	0.88	0.71	0.81	0.92	0.85	0.74	0.85	0.74	0.67	0.69	0.57	0.46
Unknown	425	0.00	0.66	0.00	0.00	0.00	0.62	0.00	0.62	0.00	0.57	0.00	0.35
Methionine	433	5.86	2.65	1.18	1.19	4.29	3.86	4.29	3.86	0.00	0.59	5.95	3.69
Iso-Leucine	442	6.28	7.68	6.79	5.28	10.13	11.33	10.13	11.33	1.03	1.89	12.66	13.37
Leucine	456	3.03	5.47	2.06	2.54	8.76	11.12	8.76	11.12	0.21	0.71	12.03	12.45
Tyrosine	527	6.82	7.49	4.21	4.82	11.93	11.79	11.93	11.79	0.95	1.46	18.92	17.87
Phenylalanine	544	6.19	7.18	2.86	3.63	9.55	10.51	9.55	10.51	0.35	0.83	12.12	12.73

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β-Alanine.....	588	0.54	0.39	0.56	1.37	0.84	0.87	3.80	1.14	1.67	1.63	0.21	0.61
Unknown.....	100	0.00	0.00	0.00	0.00	0.00	0.00	1.45	0.19	0.14	0.00	0.00	0.00
Unknown.....	110	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.12	0.00	0.00	0.10
Unknown.....	130	0.11	0.12	0.00	0.17	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.12
γ-Amino butyric acid.....	150	16.60	16.25	5.56	11.66	16.51	14.73	2.48	5.66	31.56	30.92	0.67	9.56
Ornithine.....	165	0.53	0.90	0.08	0.77	1.29	1.37	0.12	0.42	0.68	1.65	0.06	0.39
Ethanolamine.....	190	0.48	1.57	0.17	0.91	0.77	1.05	0.20	0.60	1.05	2.89	0.10	0.65
Ammonia.....	200	18.69	55.28	38.01	54.41	29.14	56.09	19.74	45.86	9.66	160.20	9.99	54.01
Lysine.....	218	7.99	10.31	3.40	4.50	14.04	15.00	0.36	0.84	21.40	22.30	0.78	1.68
Unknown.....	245	0.00	0.00	0.00	0.23	0.00	0.15	0.51	1.19	0.00	0.00	0.00	0.29
Unknown.....	260	4.08	3.90	1.26	1.52	5.39	4.97	0.23	0.51	8.28	9.33	0.21	0.81
Histidine.....	330	0.86	0.14	0.90	0.00	2.64	0.22	0.33	0.21	3.79	0.32	0.22	0.81
Unknown.....	433	0.00	0.00	0.07	0.12	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00
Unknown.....	480	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.20
Arginine.....	530	17.46	17.60	9.70	11.62	24.17	23.60	2.22	3.58	28.33	28.54	2.47	5.40
Total μmols/g Dry Wt.....		341.25	433.91	164.53	303.21	410.21	491.04	60.66	144.27	575.83	706.95	42.42	212.79
Tot. μmols N/g Dry Wt. ^s		583.48	505.72	237.20	346.38	655.98	588.15	75.98	157.29	923.24	835.18	54.12	232.68

¹Reported as μmols/g Dry Wt. Data is the average of duplicate runs.

²Relative effluent volume. First series = Acid and neutral, second series = basic amino acids.

³Stored chip extract = extract of chips made from stored potatoes.

⁴Conditioned chip extract = extract of chips made from stored and conditioned potatoes.

⁵All unknown peaks calculated as Leucine equivalents.

⁶Not included in totals — Calc. as Leucine equivalents but not quantitative.

⁷Reported as Asparagine.

⁸Adjusted for multiple Nitrogen compounds.

larly the product-imposed limits of sampling. More significant increases occurred in the cases of serine, glycine, alanine and leucine. These amino acids are among the more reactive with reducing sugars as indicated by Ingles and Reynolds (7) reporting on the amino acid losses during storage of freeze-dried apricot pureé. Since a quantitative recovery of the extractable potato nitrogen as free amino acids and amides was never achieved (see Table 2), it is also possible that short chain peptides or low molecular weight polyamino acids were present in the extracts which on hydrolysis, contributed their amino acids to the total. Of course, increased methionine sulfoxides, aspartic and glutamic acids and ammonia are primarily due to degradation.

It is shown in Table 3 that while there was an increase of amino acids on hydrolysis of the potato extracts, there was a decrease in the nitrogen recovered from amino acid analysis. The conversion of the amides to their corresponding amino acids appeared to be in excess of a quantitative yield but non-ninhydrin active pyrrolidone carboxylic acid, normally present, would be converted to glutamic acid. The corresponding increase in ammonia from deamidization, however, was less than quantitative. A loss of ammonium chloride is possible when hydrolysates of this type are concentrated on a rotary evaporator.

Conversely, when the three chip extracts were hydrolyzed, the amino acids increased as in the tuber extracts but the nitrogen recovered from amino acid analysis also increased. This observation should be qualified by calling attention to the nitrogen values in Table 3. The large amino acid nitrogen loss, as a result of chip frying particularly when the reducing sugar content of the tubers was high, was recovered to a great extent on hydrolysis, but never back to the level of the original tubers. Some individual amino acids, particularly in chips made from fresh potatoes of a low reducing sugar content, increased on hydrolysis beyond the level reported for the fresh potato extract, up to the level reported for the fresh potato extract after hydrolysis. In chips from the stored and reconditioned potatoes, however, more of the amino acid content had been changed to forms not recoverable by hydrolysis.

Sugars.—Table 4 shows that an eleven-fold increase in total sugars was obtained by storing the tubers in the cold. A reconditioning period reduced the total sugars to a point only seven times that of the original tubers. This large increase on cold storage was primarily (90%) made up of reducing sugars which increased eighteen fold during storage. The extractable non-reducing sugars (as sucrose) increased only 2.5 times in this same period. Reconditioning the tubers reversed the composition of the total sugars. There was a fifteen-fold drop in the reducing sugar content but the high level of total sugars was maintained by the sucrose which increased during reconditioning to eleven-fold or almost 80% of the total sugars. This is in agreement with the work of Treadway et al (17) who pointed out that an increase in sugar is associated with sprouting. It also corroborates the work of Schwimmer et al (9) who reported that after storage at 40 F less than half of the total sugar was accounted for as sucrose, but after reconditioning at 70 F for five weeks, about two thirds of the total sugar was sucrose. There was a loss on frying of both sucrose and reducing sugars, but always greater in the latter. The loss of sucrose was least and the loss of reducing sugars

TABLE 4.—Changes in potato sugars on storing, reconditioning and frying.

Sample	Total sugars ¹		Non-reducing sugars ²		Reducing sugars ³	
	Mg/g Dry Wt.	% Loss on Frying	Mg/g Dry Wt.	% Loss on Frying	Mg/g Dry Wt.	% Loss on Frying
Fresh potato extract	15.86		6.87		8.99	
Fresh chip extract	4.74	70.1	2.69		11.4	77.2
Stored potato extract	176.65		18.03		158.62	
Stored chip extract ⁴	28.16	84.1	10.24		17.92	88.7
Reconditioned potato extract	110.41		79.61		30.80	
Reconditioned chip extract ⁵	28.82	73.9	20.97		5.85	81.0

¹Obtained by acid hydrolysis.

²As sucrose.

³As fructose.

⁴Extract of chips made from stored potatoes.

⁵Extract of chips made from stored and reconditioned potatoes.

greatest in chips made from potatoes stored in the cold. At this point the reducing sugars were present in greatest quantity.

Anet (1) reported that the reaction products of glucose and glycine and glucose and β -alanine, when heated with acid decompose slowly, rather than hydrolyze, liberating the parent amino acid and hydroxymethylfurfural, an unstable precursor of levulinic acid in hot acid solutions. Levulinic acid, also an end product of dehydration of aldohexoses, was found in the acid hydrolysates of the fresh, stored and reconditioned tubers and chips. It was also found to be present in lesser quantities, however, in the unhydrolyzed extracts of the reconditioned tubers and chips. Table 3 contains a value for levulinic acid, eluted at ca 84 ml. This material will give qualitative but not quantitative results on the amino acid analyzer. (It was calculated as leucine equivalents by the computer (8) and the results retained to indicate its position but were excluded from the amino acid total.)

General observations. — Twenty-four amino acids and amides were identified and measured in extracts of Wisconsin Kennebec potatoes in the fresh state, after storage in the cold, and after reconditioning following cold storage; and in the extracts of chips made from these potatoes. The qualitative results were common to potatoes and chips from all three conditions of storage and conformed to that of other varieties grown in different areas of the country (3, 15).

When the reducing sugars had accumulated to a high level after storing the tubers in the cold, chip frying caused a loss of 88.7% of the reducing sugars with an accompanying loss of 88.4% of the free amino acid nitrogen. The ratio of this decrease in nitrogen to reducing sugar (as fructose) was 1:1.35 μ mols resp. per gram of dry wt. of potato. When the reducing sugar content was low in relation to the amino acid nitrogen as in fresh and reconditioned potatoes, the ratios of the decrease in nitrogen to reducing sugar on frying were 9:1 and 6.3:1 μ mols respectively per gram of dry weight of potato. It would appear from these results that as the reducing sugars increased to the level of the free amino acid nitrogen, the losses of both on frying would approach an equimolar ratio.

Finally, the ratios herein reported for chips from fresh and stored Wisconsin Kennebec potatoes are in close agreement with those reported for the Florida Red LaSoda variety (3) which were not reconditioned. It would appear that potato variety and diverse growing conditions are unimportant variables in a study of the interaction of amino acids with reducing sugars. However, the loss of sucrose was considerably greater when chips of Wisconsin Kennebecs were fried. Furthermore, reconditioning of these potatoes resulted in a considerable increase in the free amino acids and the greatest decrease in these materials on frying. Amino acid losses on frying in the absence of high reducing sugar cannot be explained at this time. The reasons for such losses are currently being investigated.

SUMMARY

An investigation of the sugars and amino acids in fresh, cold stored, and reconditioned Wisconsin Kennebec potatoes showed a constant level of total nitrogen but an increasing free amino acid nitrogen from protein

degradation. A constant level of free amino acid nitrogen in chips fried from these potatoes indicated an increasing formation of polymeric material. Cold storage increased the reducing sugars to 90% of the total potato sugars. At this point, chip frying caused a decrease of 88.4% of amino acid nitrogen with a corresponding decrease of 88.7% of reducing sugar. The ratio of this decrease was 1:1.35 μ moles. Acid hydrolysis indicated that part of this loss was due to reaction of amino acids with sugars. Twenty-four free amino acids and amides were identified and measured in these potatoes and in their corresponding chips.

RESUMEN

Una investigación de azúcares y amino ácidos en papas Wisconsin Kennebec frescas, almacenadas al frío y reacondicionadas ha indicado un nivel constante de nitrógeno total pero también un incremento de nitrógeno libre de amino ácidos proveniente de la decomposición de proteínas. Un nivel constante de nitrógeno libre de amino ácidos en papas fritas duras indica una creciente formación de materiales polímeros. El almacenado al frío incrementó azúcares reductores hasta a un 90% del total de los azúcares de la papa. A este punto la fritura causó un decremento de 88.4% de nitrógeno de amino ácidos con un correspondiente decremento de 88.7% de azúcares reductores. La proporción de este decremento era 1:1.35 μ moles. La hidrólisis ácida indicó que una parte de esta pérdida se debe a la reacción de los amino ácidos con los azúcares. Veinticuatro amino ácidos y ámidos han sido identificados y medidos en estas papas y en su producto frito correspondiente.

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