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# COMPARATIVE STUDY OF THE NUTRITIONAL POTENTIAL OF SOME STARCHY FOOD (POTATO, YAM, CASSAVA, SWEET POTATO AND TARO) IN RATS

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**ABSTRACT**

The objective of this study is to compare the chemical composition and nutritional quality of potato, yam, cassava, sweet potato and taro. For this purpose, the rats of *wistar* strain, weighing on average 67.5±2.94 g, were fed diets based on these starchy foods. 30 growing rats were used for the experiment, with 6 rats per diet containing herring fish as protein source (10 %). Energy value ranges from 137.44±2.40 Kcal/100 g (yam) to 396.15±0.01 Kcal/100 g (cassava). Lipids contents are between 0.08±0.01 % DM (potato) and 1.07±0.01 % DM (cassava). Protein contents are between 0.90±0.03 % DM (sweet potato) and 4.38±0.06 % DM (taro). Ash contents are between 0.43±0.01% DM (cassava) and 3.72±0.19% DM (taro). This study allowed to appreciate the good nutritional quality of all these roots and tubers through high dry matter intake of rats which is ranging from 8.08±1.32 (sweet potato diet) to 22.18±4.72% DM (potato diet). Body weight gain of rats is between 4.93±0.51 g (cassava) and 6.01±0.57 g (potato). Digestibility of starch ranges from 92.65±1.32 % DM (cassava) to 99.01±0.28 % DM (potato). Under these experimental conditions, growth of rats can be supported by all food tested, even though potato diet is better for growth.



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## INTRODUCTION

Roots and tubers belong to the group of foods that essentially provide energy in the form of carbohydrates in the human diet in tropical countries. This designation is applied to all plants whose roots, rhizomes or tubers underground contain edible material (FAO, 1991). Edible roots and tubers such as potato (*Solanumtuberosum*), yam (*Dioscorea sp.),* cassava (*Manihotesculenta*), sweet potato (*Ipomoea batata*) and taro (*Colocasiaesculenta*) are grown in tropical and subtropical areas (Amani and Kamenan, 2003; Sahoré*et al*., 2007). They are not easily digested in their raw state, and are better when cooked, before consumption. These roots and tubers are cooked in different ways, and used in a wide variety of dishes. Their starches are used in a variety of culinary preparations, *namely, foufou, foutou, attiéké, attoukpou, kokondé, boullie, gari, tapioca, mashed potatoes, braised potatoes, French fries, croquettes, placali, stew* (coursey and Ferber, 1979; Dumont, 1995, Amani *et al.,* 2003). These dishes are the main sources of energy in the diet of Ivorians. The objective of this study is to compare the nutritional value of tubers commonly consumed in Côte d'Ivoire such as yam, cassava, sweet potato and taro with that of potato, which is a tuber grown much more in temperate countries (Europe, America).

## MATERIALS AND METHODS

### *Materials*

The plant materials used in this work are potato (*Solanumtuberosum*), yam (*Discoreaspp*, variety Kponan), cassava (*Manihotesculenta*, variety IAC), sweet potato (*Ipomoea batata*) and taro (*Colocasiaesculenta L. SCHOTT*). They were bought in the markets of Abidjan. The experiment involved 30 growing rats between 55 and 65 days old. These animals came from the Vivarium of the École Normal Supérieur (ENS) of Abidjan. The technical equipment consisted of laboratory glassware to carry out the various chemical assays. An electronic precision balance (1/100), brand Denver instrument (Germany) is used for the different weighing. An oven (MEMMERT, 854 Schwalbach W, Germany) was used for dehydration of the food samples.

## Methods

***Chemical analyses:*** Different methods were used to perform proximate analyses of food materials. The method used for the determination of moisture is based on that proposed by the AOC (1990), the principle of which is based on the loss of water mass in the sample up to a constant mass at 105 °C. The protein level is determined according to the Kjeldah method (AOC, 1990). Nitrogen in the dry matter is determined by the Kjeldah method after sulphuricmineralisation in the presence of selenium catalyst. The nitrogen content is multiplied by 6.25 (nitrogen to protein conversion coefficient). Lipids were determined with Soxhlet (Unidtecator, system HT2 1045, Sweden) by extraction of lipids with hexane, during 24 hours, according to AFNOR (1986). The digestible carbohydrate (DC) and the energy value were determined on dry matter (DM) basis by calculation (FAO, 1998) as following:

DC (% DM) = 100 - [proteins (% DM) + lipids (% DM) + fibers (% DM) + ash (% DM)]

The starch content is determined by FAO (1947):

Energy (Kcal / 100 g DM) = 2.44 × proteins (% DM) + 8.37 × lipids (% DM) + 3.57 × carbohydrates (% DM)

Starch content = 0.9 × (% total carbohydrates - % total Sugars)

Ethanosoluble sugars are extracted according to the method of Agbo*et al.* (1985). The total sugar content is determined by the phenol-sulphuric method as described by Dubois *et al.* (1956). Fiber content is determined by the method of Van Soest (1963). The method used for the determination of ash is that described by AOC (1990), which consists of incinerating a sample until white ash is obtained. The capsule containing the sample is placed in a muffle furnace (PYROLABO) and then subjected to 550 °C for 12 hours. After removal of the capsule from the muffle furnace and cooling in a desiccator, the capsule is weighed again. After incineration of the dry matter, the minerals (Mg, Fe, Na, K, Ca, and P) are determined using a scanning electron microscope coupled with SEM/EDS (Scanning Electron Microscope / Energy Diffusion Spectrometry).

***Growth experiment:*** Thirty *Wistar* rats were used for the experiment. These rats ranged in age from 55 to 65 days and had an average weight of 67.84 ± 2.94 g. The rats were alloted into 5 batches: batch 1, control diet (*solanumtuberosum*), batches 2, 3, 4 and 5 experimental diets containing powders of *Dioscorea spp L., Manihotesculenta, Ipomoea batata, Colocasiaesculenta L. SCHOTT*, respectively. The experiment lasted 21 days.

***Formulation of diets:*** The control dietcomposition (Table I) was inspired by Garcin *et al*. (1984), and modified by amoikon *et al*. (2010). The preparation was made with 1 kg of powder from each root and tuber, mixed with sunflower oil and fish powder (herring), then supplemented with vitamin and mineral premix (Biacalcium, Laboratoires Biové, France). The next day, the remaining food is also weighed to determine the amount of food ingested. The animals are weighed once every three days. The different nutritional characteristics are obtained by calculation, according to table II.

***Statistical analyses:*** The statistical data (means, standard deviation) are calculated using STATISTICA software version 7.1 and GraphPad Prism 7 software. The comparison of the observed means was based on the analysis of variance (ANOVA) followed by the Newman-Keuls test (at the 5% threshold). Two means are significantly different if the probability resulting from the statistical tests is less than or equal to 0.05 ($P \leq 0.05$). The letters a, b, c, d, e etc. in superscript follow the means from the comparison tests in the tables. Means followed by different letters on the same line are significantly different ($P \leq .5$).

## RESULTS

***Chemical composition:*** Table III shows the chemical composition of the different roots and tubers. Moisture content ranges from 43.73±0.17% fresh matter (taro) to 76.90±1.68% fresh matter (potato). Protein contents are low for the roots and tubers studied (less than 5% DM). Sweet potato has the lowest protein content (0.90±0.03 % DM) and taro has the highest protein content (4.38±0.06 % DM) ($p \leq 0.05$). Lipid contents range from 0.08±0.01 % DM (potato) to 1.07±0.01 % DM (cassava). The starch contents range from 16.79±0.01 % DM and 75.11±0.01 % DM for potato and cassava respectively. The carbohydrate contents range from 18.87±2.61 % DM (potato) to 47.95±2.00 % DM (cassava). Total sugars contents range from 0.48±0.33 % DM to 6.66±2.00 % DM for taro and cassava respectively. The energy value ranges from 82.23±0.21 Kcal/100 g DM to 396.15±0.01 Kcal/100 g DM for potato and cassava respectively. Fibers contents range from 1.33±0.11 % DM to 4.03±0.25 % DM for potato and yam respectively. Total ash values range from 0.43±0.01 % DM to 3.72±0.19 % DM for cassava and taro respectively.

***Mineral composition of tubers:*** Table IV shows the mineral composition of roots and tubers. Magnesium concentrations range from 5.08±1.00 mg/100 g DM to 61.63±2.30 mg/100 g DM for cassava and taro respectively. The magnesium contents of taro and sweet potato (58.33±1.52 mg/100 g DM) are higher ($p \leq 0.05$) than those of yam (49.33±2.08 mg/100 g DM) and potato (18.70±1.99 mg/100 g DM). Cassava has the lowest magnesium content. Sodium values range from 5.00±1.00 mg/100 g DM to 18.33±2.08 mg/100 g DM for yam and sweet potato respectively. Potassium values range from 208.60±3.00 mg/100 g DM (cassava) to 2240.66±44.28 mg/100 g DM (taro). The potassium value of taro is higher ($p \leq 0.05$) than that of sweet potato (1820.33±26.65 mg/100 g DM), yam (1970.00±10.00 mg/100 g DM), potato (324.00±2.00 mg/100 g DM) and cassava. Calcium valuesare between 0.02±0.01 mg/100 g DM and 0.34±0.39 mg/100 g DM for potato and cassava respectively. The calcium value of potato is lower and cassava has the highest calcium value. Phosphorus concentrations range from 0.04±0.02 mg/100g DM to 0.24±0.03 mg/100g DM for cassava and potato respectively. The phosphorus contents of sweet potato (0.19±0.01 mg/100g DM), taro (0.18±0.02 mg/100g DM) and yam (0.16±0.02 mg/100g DM) are not different ($p>0.05$) and are statistically higher than that of cassava but lower than that of potato ($p \leq 0.05$). The iron contents range from 0.21±0.02 mg/100g DM to 5.27±0.03 mg/100g DM for cassava and

**Table I. Centesimal composition of different diets (1 kg of dry food)**

| Ingredients | Diets (1 kg of dry food) | | | | |
|---|---|---|---|---|---|
| | Potato | Yam | Cassava | Sweet potato | Taro |
| Starch powder (g) | 576.50 | 573.60 | 581.90 | 565.90 | 595.30 |
| fish powder (g) | 122.50 | 125.40 | 117.10 | 133.10 | 103.70 |
| Sugar (g) | 250.00 | 250.00 | 250.00 | 250.00 | 250.00 |
| Sunflower oil (ml) | 50.00 | 50.00 | 50.00 | 50.00 | 50.00 |
| Premix (g) | 1.00 | 1.00 | 1.00 | 10.00 | 1.00 |
| Water (ml) | 1000.00 | 1000.00 | 1000.00 | 1000.00 | 1000.00 |
| Total (g) | 1000.00 | 1000.00 | 1000.00 | 1000.00 | 1000.00 |
| Gross energy (Kcal) | 4226.00 | 4226.00 | 4226.00 | 4226.00 | 4226.00 |

Calculated values: dietary crude protein: 10.00 %; gross energy: 4226 Kcal.kg$^{-1}$ DM; premix:Biacalcium, LaboratoiresBiové, France
Source: Garcin *et al*. (1984)

**Table II. Nutritional Characteristics of rats**

| Nutritional characteristics | Mathematical expressions |
|---|---|
| Feed intake (FI) (g) | Feed given – Feed refused |
| Matter moisture content (MMC) % | [(Fresh matter–Dry matter)/Fresh matter]× 100 |
| Dry matter ratio (DM) % | 100 – MMC |
| Dry matter intake (DMI) (g) | (FI × DM) / 21 days / 6 rats |
| Protein intake (PI) | DMI × % proteins in diet |
| Average weight gain (AWG) (g) | (Final weight – Initial weight)/21 days/ 6 rats |
| Feedefficiency (FE) | AWG / DMI |
| Proteinefficiency (PE) | AWG / PI |

**Table III. Chemical composition of roots and tubers (potato, yam, cassava, sweet potato and taro)**

| Parameters | Roots and tubers | | | | |
|---|---|---|---|---|---|
| | Potato | Yam | Cassava | Sweet potato | Taro |
| Humidity (%) | 76.90±1.68$^{e}$ | 63.97±0.45$^{c}$ | 68.41±0.92$^{d}$ | 58.60±0.73$^{b}$ | 43.73±0.17$^{a}$ |
| Protein (% DM) | 2.17±0.01$^{c}$ | 1.84±0.07$^{b}$ | 2.84±0.01$^{d}$ | 0.90±0.03$^{a}$ | 4.38±0.06$^{e}$ |
| Fat (% DM) | 0.08±0.01$^{a}$ | 0.29±0.07$^{b}$ | 1.07±0.01$^{c}$ | 0.37±0.06$^{b}$ | 0.28±0.06$^{b}$ |
| Starch (% DM) | 16.79±0.01$^{a}$ | 27.29±0.48$^{b}$ | 75.11±0.01$^{e}$ | 30.25±0.74$^{c}$ | 42.49±0.14$^{d}$ |
| Carbohydrate (%DM) | 18.87±2.61$^{a}$ | 31.86 ± 0.48$^{b}$ | 47.95 ± 2.00$^{d}$ | 38.08±0.70$^{c}$ | 47.80±0.22$^{d}$ |
| TS (mg/100 g DM) | 1.10±0.10$^{b}$ | 1.23±0.47$^{b}$ | 6.66±2.00$^{d}$ | 3.63±1.32$^{c}$ | 0.48±0.33$^{a}$ |
| DF (% DM) | 1.33±0.11$^{a}$ | 4.03±0.25$^{e}$ | 1.73±0.20$^{b}$ | 3.06 ± 0.12$^{c}$ | 3.63±0.15$^{d}$ |
| EV (Kcal/100 g ) | 82.23±0.21$^{a}$ | 137.44±2.40$^{b}$ | 396.15±0.01$^{e}$ | 159.32±2.81$^{c}$ | 211.20±0.40$^{d}$ |
| Ash (% DM) | 1.12±0.01$^{b}$ | 2.03±0.05$^{c}$ | 0.43±0.01$^{a}$ | 2.03±0.04$^{c}$ | 3.72±0.19$^{d}$ |

The averages are based on three samples per starchy substance. The means are followed by superscript letters a, b, c, d, e; on the same line, means followed by different letters, are significantly different ($p \leq 0.05$). DM: Dry matter; EV: Energy value, TS: Total sugars, DF: Dietary fibers.

**Table IV. Mineral content of roots and tubers powders**

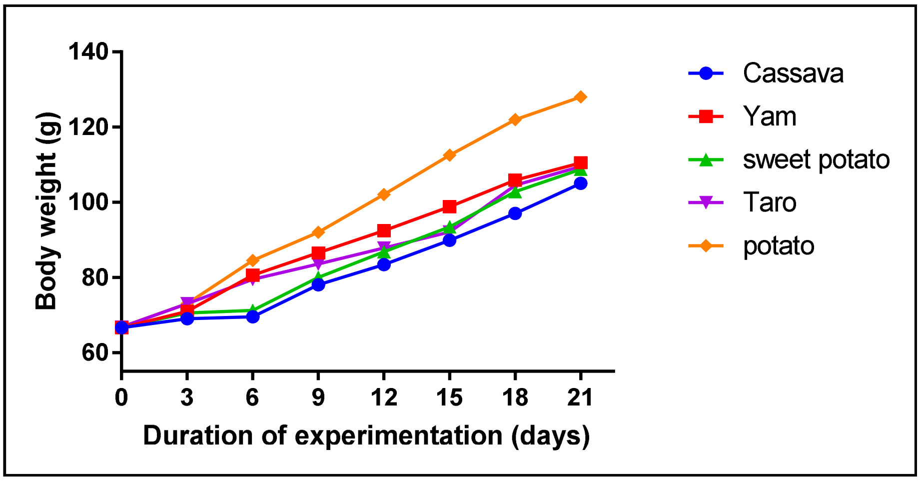
| Paramètres | Roots and tubers | | | | |
|---|---|---|---|---|---|
| | Potato | Yam | Cassava | Sweet potato | Taro |
| Mg | 18.70±1.99$^{b}$ | 49.33 ± 2.08$^{c}$ | 5.08±1.00$^{a}$ | 58.33±1.52$^{d}$ | 61.33±2.30$^{d}$ |
| Na | 6.00±2.00$^{a}$ | 5.00 ±1.00$^{a}$ | 17.41±2.00$^{c}$ | 18.33 ±2.08$^{c}$ | 14.33 ±1.52$^{b}$ |
| K | 324.00±2.00$^{b}$ | 1970.00±10.00$^{d}$ | 208.60±3.00$^{a}$ | 1820.33±26.65$^{c}$ | 2240.66±44.28$^{e}$ |
| Ca | 0.08±0.02$^{b}$ | 0.02±0.01$^{a}$ | 0.34±0.39$^{d}$ | 0.13±0.01$^{c}$ | 0.06±0.02$^{b}$ |
| P | 0.24±0.03$^{c}$ | 0.16±0.02$^{b}$ | 0.04±0.02$^{a}$ | 0.19±0.01$^{b}$ | 0.18±0.02$^{b}$ |
| Fe | 0.43±0.02$^{b}$ | 2.72±0.02$^{d}$ | 0.21±0.02$^{a}$ | 5.27±0.03$^{e}$ | 2.19±0.01$^{c}$ |

The averages are based on three samples per starchy substance. The means are followed by superscript letters a, b, c, d, e; on the same line, means are followed by different letters, are significantly different (p ≤

sweet potato respectively. Sweet potato has an iron concentration that is statistically higher ($p \leq 0.05$) than that of yam (2.72±0.02 mg/100g DM), taro (2.19±0.01 mg/100g DM), potato (0.43±0.02 mg/100g DM) and cassava.

***Growth performance:*** During animal experiment (Figure 1), growth curves relative to weight change show that the curve of rats fed with potato diet is visibly above all others. At the end of the experiment (Table V), rats fed with cassava, yam, taro and sweet potato diets showed a body weight gain different ($P>0.05$). Values are respectively, 4.93±0.51 g/d; 5.17±0.47 g/d; 5.12±0.07 g/d and 5, 11±0.47 g/d, although these values are significantly lower than those of rats fed with the potato diet (6.01±0.57 g/d) ($p \leq 0.05$). Table V presents the mean value of rat growth characteristics according to root and tuber diets.

Dry matter ingested of rats subjected to potato diet (22.18±4.72 g) is higher than those of other groups of rats. The Feed efficiency (FE) through food consumption of rats consuming cassava (0.54±0.26), taro (0.62±0.08) and sweet potato (0.63±0.09) shows no significant difference (p>0,05) and are statistically greater than that of rats consuming the yam diet (0.45±0.11) and potato diet (0.27±0.05) ($p \leq 0.05$). The Protein efficiency (PE) ranges from 0.16±0.03 g/d (potato) to 0.38±0.09 g/d (cassava). The protein efficiency of rats on the cassava and sweet potato diet (0.38±0.06 g/d) and taro (0.36±0.04 g/d) showed no significant difference and was statistically superior ($p \leq 0.05$) to rats on the yam (0.27±0.07 g/d) and potato diet. The Starch efficiency coefficient (SEC) of rats on the diets ranged from 1.03±3.00 to 2.67 ± 0.41 for the cassava diet and the sweet potato diet, respectively. The starch efficiency of rats on the cassava diet is lower and the starch




(n=6): Number of rats per treatment. Diet based on cassava, yam, sweet potato, taro and potato.

**Figure 1. Change in body weight of rats consuming roots and tubers**

**Table V. Mean value of growth characteristics of rats**

| Parameters | Diets | | | | |
|---|---|---|---|---|---|
| | Potato (n=6) | Yam (n=6) | Cassava (n=6) | Sweet potato (n=6) | Taro (n=6) |
| AWG (g) | 6.01±0.57$^{b}$ | 5.17±0.82$^{a}$ | 4.93±0.51$^{a}$ | 5.11±0.47$^{a}$ | 5.12±0.07$^{a}$ |
| DMI (g) | 22.18±4.72$^{c}$ | 12.15±4.09$^{b}$ | 8.08±2.40$^{a}$ | 8.08±1.32$^{a}$ | 8.18±1.09$^{a}$ |
| FE | 0.27±0.05$^{a}$ | 0.45±0.11$^{ab}$ | 0.54±0.26$^{b}$ | 0.63±0.09$^{b}$ | 0.62±0.08$^{b}$ |
| PE | 0.16±0.03$^{a}$ | 0.27±0.07$^{b}$ | 0.38±0.09$^{c}$ | 0.38±0.06$^{c}$ | 0.36±0.04$^{c}$ |
| SEC | 2.09±0.30$^{bc}$ | 2.10±0.55$^{bc}$ | 1.03±3.00$^{a}$ | 2.67±0.41$^{c}$ | 1.78±0.32$^{b}$ |
| SD (%) | 99.01±0.28$^{c}$ | 98.10±0.56$^{c}$ | 92.65±1.32$^{a}$ | 95.86±1.2$^{b}$ | 96.42±1.8$^{b}$ |

(n): number of rats per treatment. The analysis of variance is followed by the multiple comparison tests of Newman-keuls at the 5% threshold. On the same line, the means followed by letters a, b, c, d, etc. in different superscripts are significantly different ($p \leq 0.05$). AWG: Average weight gain; DMI: Dry matter intake; FE: Feed efficiency; PE: Protein efficiency; SEC: Starch efficiency coefficient; SD: Starch digestibility.

efficiency ratio of rats on the sweet potato diet is the highest. Starch digestibility (SD) was measured from the amount of starch ingested and fecal starch. Starch digestibility rates ranged from 92.65±1.32% (cassava) to 99.01±0.28% (potato). The SD of potato ($p \leq 0.05$) is statistically superior to that of sweet potato (95.86±1.2 %), taro (96.42±18 %), yam (98.10±0.56%) and cassava.

## DISCUSSION

The contents of chemical elements, i.e. proteins, lipids and minerals are very low. This means that tubers are essentially carbohydrate food and are poor in protein and other chemical elements. These results are similar to those of Bindelle and Buldgen (2004) who present tubers as purely starchy and low protein food, which can be substituted for cereals in rations, while taking care to balance protein diets.Weight gain represents the growth of the rats relative to their initial weight during the experimental period, and thus better reflects changes in body weight over time. At the end of the 21 days of the experiment, animals fed diets such as potato, yam, cassava, sweet potato, taro had an increase in body weight. The daily weight gain observed in rats fed with the five carbohydrate diets were greater than those observed by Hermann *et al.* (2018) (1.38 to 3.25 g/d/rat).whose studies involved rats consuming carbohydrate diets such as cassava-based foods (attiéké, attoukpou, placali). In addition, the increase in weight of rats fed the five diets shows the good use of proteins during organ development (Bouaffou *et al*., 2007). On the other hand, the good use of energetic nutrients provoked an increase of adipose tissue. An increase in the number of adipocytes can be in rats of various strains, by feeding a highly appreciable diet, high in fat or carbohydrate (Faust *et al.,* 2017). The parameters of this study, such as ingested dry matter, total protein ingested from rats fed the potato diet, are significantly higher than rats fed the other diets. The palatability of the potato diet is higher than that of the other diets. This shows that potato is palatable for rats. The low consumption of the other diets could be explained by their low palatability as well as possible biological variation in the rats that consumed them (Williams *et al.,* 2009). Culinary transformations and carbohydrate energy source influence protein utilization. However, Szylit *et al.* (1977) showed that nitrogen utilization can vary according to the source of starch in the diet of cockerels. The efficiency coefficient of starch through food consumption of rats on the yam diet and that of rats on the potato diet do not vary.Rats fed on the potato diet have significantly lower starch efficiency than rats fed cassava, sweet potato and taro. According to Szlit *et al.* (1977), the chemical transformations of starch have an impact on its dietary efficiency. The changes that influence the digestibility of the starch food could be in parameters such as grain size, crystal organization, amylose content and sensitivity to amylases. The feed efficiency provides the best assessment of the efficiency of feed utilization. The feed efficiency through feed intake of rats consuming cassava, taro and sweet potato shows no significant difference and are statistically greater than those of rats consuming the yam and potato diets. The FE of this study is higher than that of Kouakou *et al.* (2012) whose study was conducted on hybrid banana fruits. The starch digestibility rate reported is close to that (95%) found by Adrian *et al.* (1995) on plantain diets. This variability in starch digestion within these tubers would be due to the modification of the starch that occurs in animals (Tecaliman, 1996).

**Conclusion**

At the end of this work, roots and tubers are high-energy foods, rich in starch and carbohydrates but low in fat, protein and minerals. The formulated diets of these starchy foods, enriched with fish, give under experimental conditions, similar nutritional responses if we consider the rate of growth. Moreover, weight gain is higher in rats consuming the potato diet.

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