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Article

Nutritional Components of Millet Porridge Cooked by Different Electric Cookers based on Principal Component and Cluster Analyses

Jiali Zhang, Pengliang Li , Aixia Zhang, Wei Zhao, Shaohui Li, Yingying Liu and Jingke Liu*

Institue of Biotechnology and Food Science, Hebei Academy of Agriculture and Forestry Sciences, 598 Heping West Road, Xinhua District, Shijiazhuang, Hebei 050031, People's Republic of China ; zhangjiali416@126.com

* Correspondence: liujingke@haafs.org; Tel.: +86 311 87269088

Abstract: (1) Background: In order to study the effects of different electric cookers on the nutritional components of millet porridge, five different electric cookers were selected to cook millet porridge, and sensory and nutritional components in millet porridge, millet soup, and millet grains were analyzed. (2) Methods: Using principal component and cluster analysis, a variety of nutritional components were comprehensively compared. (3) Results: The results showed that among the different cooked samples, the content of amylose and reducing sugar was the highest in the samples cooked by electric cooker no. 3. The electric cooker no. 4 samples had the highest sensory evaluation score, crude fat, and protein content. The contents of ash, fatty acids, bound amino acids, and minerals were the highest in the electric cooker no. 5 samples. The sensory evaluation score and content of crude fat, ash, reducing sugar, direct starch, and Cu were higher in millet grains than in millet soup or porridge. The content of fatty acid, protein, amino acid, Zn, Fe, Mg, Mn, and Ca was highest in millet soup. Different electric cookers produced millet porridge with varying nutritional levels. (4) Conclusions: This study provides a reference for the further development of new electric cookers.

Keywords: millet porridge; electric cooker; nutritional composition; principal component analysis; cluster analysis

1. Introduction

Foxtail millet (*Setaria italica (L.) P. Beauv.*), a gramineous dogtail crop, originated in the Yellow River Basin of China. It has the advantages of a short growth period, drought resistance. It is widely planted in northern China [1,2]. Millet contains highly nutritional components such as carbohydrates, vitamins, fats, and proteins [3-5], which play a very important role in improving people's dietary structure. Millet is mainly eaten as a cooked porridge. Millet porridge, which is highly tasty and has nutritional characteristics, is loved by most consumers [6]. At present, the research on millet porridge mainly includes functional components [7,8], volatile components [9], and antioxidant capacity [10].

With the development of society and the accelerated pace of life, electric cookers are used as the first tool for cooking porridge because of their simple, convenient, and fast operation. People are more and more fond of millet porridge cooked in rice cookers, because the aroma and quality of millet porridge cooked in electric cookers are different.The taste characteristics and nutritional quality of millet porridge are influenced by the specific heating mode, pressure, and temperature of the electric cooker. At present, the research on electric cookers mainly focuses on the aroma, taste, and quality of rice after cooking [11, 12]. Some scholars use automatic rice cookers to study the cooking processes of different forms of rice [13]. The results show that the cooking performance of rice depends on the shape of the rice, water-to-rice ratio, and preset cooking method. One study analyzed the cooking technology of rice by using electric rice cookers. The results showed that the taste of rice was different under different heating rates [14]. However, there are

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few reports on the differences in nutritional components of millet porridge cooked by different electric cookers. Therefore, this study is of great significance for the development of new electric cookers.

Because electric cookers are developed rapidly and there are many nutritional components in millet porridge, the data can be processed with the help of principal component analysis and cluster analysis. Principal component analysis (PCA) is a multivariate statistical analysis method that reduces the dimension of data, linearly transforms multiple variables into a few comprehensive variables, and uses simplified data to reflect the original data. Cluster analysis is a mathematical statistical method to classify data according to certain characteristics of observations. Such methods have been widely used in the screening of quality indexes and comprehensive evaluations of fruits and vegetables, medicinal materials, and grains [15-17].

In this study, five different electric cookers were selected to cook millet porridge. The sensory evaluation, basic components, amino acids, fatty acids, and minerals of millet porridge, millet soup, and millet grains were measured and analyzed. The differences between nutritional components of millet porridge cooked by different electric cookers were analyzed by principal component and cluster analysis to provide a theoretical basis for the study of new electric cookers.

2. Materials and Methods

2.1. Chemicals

Millet was purchased from Jianjun agricultural andagricultural products processing plant (Shijiazhuang, China). High-temperature-resistant amylase was purchased from Novozyme (Denmark). Anhydrous glucose was purchased from Sigma (China). Methyl palmitate, methyl stearate, methyl oleate, methyl linoleate, and methyl linolenate were obtained from Sigma (China). Calcium, zinc, manganese, copper, iron, and magnesium standard stock solutions (10 mg/mL) were purchased from the national center of analysis and testing for nonferrous metals and electronic materials. Amino acids were purchased from Hitachi (Japan). Boron trifluoride-methanol solution (14% BF_3-methanol) was purchased from CNW Technologies (Dusseldorf, Germany). N-hexane (chromatographic purity) was purchased from Fisher Chemical.

2.2. Preparation of millet porridge, millet soup, and millet grains

70 g of millet were weighed and washed it twice with purified wate. The millet was placed into five electric cookers (No. 1: multistage induction heating (IH) electromagnetic heating; No. 2: pressure IH electromagnetic heating; No. 3: IH electromagnetic heating; No. 4: pressure IH electromagnetic heating; and No. 5: pressure chassis heating). The cookers were filled with purified water at a millet-to-water mass ratio of 1:14, the same ratio used in previous rice experiments [12], and boiled for 40 min to obtain millet porridge. Millet porridge was filtered with a sieve to obtain millet soup and millet grains. The millet porridge, millet soup, and millet grains were dried in a freeze-dryer (ALPHA1-2, Christ, Germany), and pressed through an 80-mesh sieve, then stored in a refrigerator at −20°C until analysis.

2.3. Sensory evaluation

Sensory evaluation was performed according to the methods of Yang [18] and others with slight modifications. After cooking the millet porridge in the five electric cookers, 10–13 reviewers evaluated the sensory characteristics of millet porridge, millet soup, and millet grains, and scored each item according to the scoring standard. The comprehensive score was the sum of each index score (Table 1).

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Table 1. Scoring rules for sensory evaluation of millet porridge.

Index	Percent	Standard Score
Color and luster	25	The color is golden yellow and slightly shiny (21–25 points) The color is light yellow with a slight luster (16–20 points) The color is dark and dull (10–15 points)
Uniformity	25	The millet porridge is not layered, the millet soup is evenly distributed, the millet grains are moderately expanded, and there is almost no damage, or the damage rate is very low (21–25 points) The millet porridge is slightly layered, the millet soup is turbid, the millet grains have a certain degree of expansion and a certain damage rate (16–20 points) The millet porridge has obvious stratifications, the millet soup is clear, the water absorption and expansion of the millet grains are low, and the damage rate is high (10–15 points)
Smell	25	There is a unique and strong aroma (21–25 points) There is a light fragrance with no peculiar odor (16–20 points) There is no fragrance but there is a peculiar odor (10–15 points)
Texture	25	The taste is pleasing with a smooth texture (21–25 points) The taste is average with a slightly rough texture (16–20 points) There is a rough texture (10–15 points)
Total score	100	

2.4. Determination of basic components

2.4.1. Determination of total fat

Total fat in the samples was determined by Soxhlet extraction. Briefly, a 1-g sample was wrapped in filter paper and extracted by petroleum ether at 50°C for 5 h. The lost weight of the sample was the total fat content.

2.4.2. Determination of ash

Ash was produced by incinerating dried samples at 850°C for 1 h in a laboratory oven [19].

2.4.3. Determination of protein

Protein content in samples was determined by the Kjeldahl method [20]. A Tecator digestion system (Hilleroed, Denmark) and a K9860 automatic Kjeldahl nitrogen analyzer (Jinan Haineng Instrument Co., Ltd.), were used for the analysis. The sample size used in the Kjeldahl procedure was approximately 0.50 g. Samples were weighed and transferred into the Kjeldahl digestion flask containing 1.0 g of catalyst (prepared by mixing 0.6 g of K_2SO_4 and 0.4 g of $CuSO_4.5H_2O$) and 10 mL of concentrated H_2SO_4. The samples were digested in a digestion furnace for about 4 h, and then analyzed for total Kjeldahl nitrogen. Total nitrogen was determined by titration with standardized Hcl to a mixed indicator endpoint (1 mg/mL bromocresol green and 1 mg/mL methyl red, in ethanol w volume concentration r = 950 mL/L).

2.4.4. Determination of amylose

Amylose content was determined using a previously published method by Zhu [21,22] with modifications. 100 mg of a degreased sample was dissolved in 10 mL

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potassium hydroxide (1 mol/L) in an 85°C water bath, adjusted the volume to 50 mL with distilled water, and filtered the sample through filter paper after standing for 20 min. Next, 3 mL of filtrate was added to 25 mL of distilled water. The pH was adjusted to 3.0 with hydrochloric acid solution, and 0.5 mL of iodine reagent was added to the sample. Sample volumes were adjusted to 50 mL with distilled water. After standing at room temperature in the dark for 25 min, the absorbance of amylose was measured at 620 nm and 415 nm by UV spectrophotometer (SP-752, Shanghai, China), with distilled water as blank control. The amylose content of the sample was calculated according to the dual-wavelength standard curve of amylose.

2.4.5. Determination of reducing sugar

The dinitrosalicylic acid (DNS) method with slight improvements based on the method of Stawski [23] was used for the determination of reducing sugar.2 g of sample and 30 mL water were added to a 50 ml centrifuge tube, and thoroughly mix the mixture with an oscillator for 1 min. The sample was incubated in a 50°C water bath for 60 min, then centrifuged (Avanti j-301, Beckman Kool, USA) at 5000 rpm for 20 min and filtered. Next, 1 mL of supernatant was reacted with DNS, and the absorbance at 540 nm was measured with an ultraviolet spectrophotometer. The reducing sugar content of the sample was calculated according to the linear equation.

2.5. Determination of fatty acid

Fatty acid determination was based on a previously described method [24]. Briefly, 1 g of each sample was added to 30 mL of a solution of diethyl ether and petroleum ether (1:1, v/v) and thoroughly mixed in a 50-mL centrifuge tube for 2 h at 250 rpm using a shaker (MAXQ 4000, Thermo Scientific, CA, USA). Then, the mixture was centrifuged at 4000 rpm for 10 min, and the supernatant was dried in a rotavapor at 35°C (Buchi R215, Flawil, Switzerland). The dried residuals were redissolved in 1 mL of a 14% BF_3-methanol solution and placed in a water bath at 80°C for 2 min. The derivative reaction was terminated by placing the sample on ice, and the fatty acid methyl ester was extracted with 2 mL n-hexane.

The fatty acid methyl esters of palmitic acid, stearic acid, oleic acid, linoleic acid, and linolenic acid were determined by a method described in a previous study with slight modifications [24] using a gas chromatography-flame ionization detector (GC-FID) (7820A, Agilent Technologies, Santa Clara, CA, USA). The injector temperature was 260°C with splitless injection. An HP-INNOWAX column (30 m×0.25 mm inner diameter and 0.25-μm film thickness, Agilent Technologies, Santa Clara, CA, USA) was used for analysis. The column initial temperature was 50°C. The column was heated at 10°C/min to 150°C and held for 3 min. The column was then heated at 4°C/min to 205°C and held for 1 min , then heated at 8°C/min to the final temperature of 235°C and held for 2 min. The carrier gas (nitrogen, purity > 99.999%) was at a constant flow rate of 1 mL/min. The detector temperature was 260°C. The airflow and hydrogen flow were 400 and 30 mL/min, respectively. A total of five external standard calibration curves were generated to quantify the fatty acids.

2.6. Determination of amino acids

Amino acid content was determined using a previously published method [25] with a slight modification. Two grams of each sample were added into a hydrolysis tube, and then 10 mL hydrochloric acid solution (6 mol/L) and four drops of phenol were mixed with the sample. Next, the sample was hydrolyzed for 22 h in a hydrolysis furnace, then removed and cooled to room temperature. The hydrolysate was filtered into a 50-mL volumetric flask, adjusted to a constant volume with distilled water, and shaken to mix evenly. Then, 1.0 mL of the filtrate was transferred into a 15-mL test tube and dried under reduced pressure with an evaporator. After drying, the residue was dissolved in 2 mL of distilled water, then dried under reduced pressure, and evaporated to dry. The dried

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sample was dissolved with 2.0 mL of a sodium citrate buffer solution (pH 2.2), mixed well by shaking, and filtered through a 0.2-μm membrane. Finally, the sample was transferred into the instrument injection bottle for sample determination by the amino acid analyzer (L8900, Hitachi, Japan). The chromatographic column used sulfonic acid cationic resin, with detection wavelengths of 570 nm and 440 nm.

2.7. Determination minerals

Minerals were determined according to a previously published method [26] and slightly modified. 500 mg of each sample were added into a conical flask, and then 10 mL H_2NO_3, 5 mL H_2O_2, and two drops H_2SO_4 were mixed with the sample, and incubated for 12 h.The flask funnel was covered and the sample evaporated to 1 mL using an adjustable electric heating plate. Next, 6 mL of nitric acid were added, and the sample was again evaporated to 1 mL and cooled, resulting in a colorless or yellowish solution. Next, 20 mL of ultrapure water was added. The sample was cooled, then diluted to 100 mL with ultrapure water. Flame atomic absorption spectrometry was used for mineral content determination (PinAAcle 900T, thermoelectricity, USA).

2.8. Data processing method

All experiments were repeated three times, and the data were expressed as mean ± standard error, which were calculated by dry mass. SPSS Statistics 25 was used to analyze for significance differences, SIMPCA-P software was used for PCA, and Multiexperience viewer software was used for cluster analysis.

3. Results and Discussion

3.1. Sensory evaluation

Sensory evaluation of food is an intuitive index to describe and judge product quality [18]. Here, a sensory evaluation was performed on millet porridge, millet soup, and millet grains cooked by different electric cookers (Table 2). There were significant differences between millet porridge, millet soup, and millet grains cooked in the same electric cooker ($P<0.05$), among which the uniformity, smell, texture, and total score of millet soup were higher. There were significant differences between millet soup, millet grains, and millet porridge cooked by different electric cookers ($P<0.05$). Millet porridge sample 4 had a higher uniformity(19.81±0.24)g/100 g, smell(21.52±0.44)g/100 g, texture(21.07±0.40)g/100 g, and total score(81.21±1.39)g/100 gcompared to the porridge prepared in the other cookers. The color and Luster(20.36 ±0.91)g/100 g, texture(22.27± 0.24)g/100 g, and total score(84.72 ±1.06)g/100 g of millet soup sample 4 were higher than the other millet soup samples. The color and Luster(21.10 ±0.85)g/100 g , uniformity(20.53 ±0.07)g/100 g, and total scores(80.55±1.89)g/100 g of millet grain were higher in sample 4 than the other millet grain samples. The probable reason for these results is that electric cooker no. 4 operated at the highest power and pressure of all the cookers. Under high temperature and high pressure, millet fully absorbed water and expanded, and lipids dissolved out of the grain, producing a millet porridge bright in color, sticky, and with a better taste. At the same time, high temperature and high pressure also promoted easier oxidation of free fatty acids to produce volatile odor substances, so that the aroma of millet porridge was rich [27]. Similar studies found that the sensory score of high-pressure cooked rice was also the highest compared to other cooking methods, which may be related to the high temperature and high pressure [13]. Some scholars have found that food cooked under high pressure had higher sensory scores [28], consistent with the results of this experimental study.

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Table 2. Sensory evaluation results of samples cooked in different electric cookers (n=3, mean ± standard deviation, g/100 g dry basis).

Number	Color and Luster	Uniformity	Smell	Texture	Total Score
Millet porridge 1	19.53±0.39^{bA}	17.20±0.18^{dC}	19.33±0.21^{bB}	19.35±0.18^{cB}	75.41 ±1.22^{cB}
Millet porridge 2	19.90±0.76^{aB}	17.82±0.29^{cC}	17.66±0.22^{cC}	18.83±0.57^{dB}	74.21± 1.02^{dC}
Millet porridge 3	18.61±0.44^{dC}	16.23±0.30^{eC}	17.05±0.32^{dC}	18.90±0.32^{dA}	70.78± 1.59^{eB}
Millet porridge 4	18.82±0.88^{cC}	19.81±0.24^{aC}	21.52±0.44^{aA}	21.07±0.40^{aB}	81.21 ±1.39^{aB}
Millet porridge 5	18.83±0.85^{cC}	18.63±0.13^{bC}	19.62±0.29^{bB}	19.72±0.35^{bB}	76.79± 1.33^{bC}
Millet soup 1	19.27±0.74^{cB}	19.73± 0.20^{bA}	19.27 ±0.87^{cB}	20.74±0.26^{bA}	79.02 ±1.40^{dA}
Millet soup 2	18.09 ±0.72^{dC}	21.55± 0.46^{aA}	20.08 ±0.14^{bA}	22.26 ±0.24^{aA}	81.98 ±1.32^{cA}
Millet soup 3	16.82 ±0.23^{eB}	17.09 ±0.77^{cA}	19.74 ±0.90^{bA}	17.02 ±0.65^{cC}	70.68 ±1.30^{eB}
Millet soup 4	20.36 ±0.91^{aB}	21.51 ±0.46^{aA}	20.55 ±0.34^{aB}	22.27± 0.24^{aA}	84.72 ±1.06^{aA}
Millet soup 5	19.55 ±0.69^{bA}	21.64 ±0.29^{aA}	20.73 ±0.37^{aA}	21.99 ±0.08^{aA}	83.92±1.50^{bA}
Millet grain 1	18.62 ±0.28^{eC}	18.82±0.71^{eB}	20.12 ±0.46^{aA}	17.42±0.28^{cC}	74.99±1.08^{dB}
Millet grain 2	20.92 ±0.47^{bA}	19.12 ±0.31^{dB}	19.42 ±0.43^{bB}	18.22±0.17^{bC}	77.68±1.80^{cB}
Millet grain 3	18.67 ±0.85^{dC}	19.78 ±0.10^{cB}	18.37± 0.93^{cB}	18.08 ±0.32^{bB}	74.90±1.36^{dA}
Millet grain 4	21.10 ±0.85^{aA}	20.53 ±0.07^{aB}	19.70± 0.70^{bC}	19.22±0.53^{aC}	80.55±1.89^{aB}
Millet grain 5	19.40 ±0.17^{cB}	20.20 ±0.69^{bB}	19.51± 0.57^{bB}	19.30±0.20^{aC}	78.42±0.88^{bB}

Note: Different lowercase letters in the same column indicate that there were significant differences when cooking the same sample in different electric cookers (P<0.05). Different capital letters in the same column indicate that the samples cooked in the same electric cooker had significant differences (P<0.05).

3.2. Content analysis of basic components

Protein, fat, and sugar are common nutrients in millet, and they are also indispensable substances for the human body[29]. There were significant differences in these nutrients between millet porridge, millet soup, and millet grains cooked in the same electric cooker (P<0.05) (Table 3). The content of ash, total fat, amylose, and reducing sugar in millet soup was high, and the content of protein in millet grains was high. This indicates that during the cooking process, most of the water-soluble nutrients in millet were transferred from the millet grains to the millet soup [30,31]. Denatured and inactivated proteins do not have good water solubility do not easily transfer to the millet soup, and therefore remained in the millet grains.

There were significant differences in millet porridge, millet soup, and millet grains cooked by different electric cookers (P<0.05). The ash content of millet porridge, millet soup sample 3 was higher than the other samples. The content of amylose and reducing sugar in all forms of sample 3 was high. The content of total fat and protein in all forms of sample 4 was high. Electric cooker no. 3 had no pressure and the lowest power of all the cookers. Due to the long, low temperature holding time and the precipitation of amylose [32], the content of amylose and reducing sugar in all forms of sample 3 was high. The power of electric cooker no. 4 was the highest. High temperature and high pressure made the starch in the millet grains pyrolyze to form glucose. Glucose is prone to the Maillard reaction, resulting in its decreased content. At the same time, the gelatinization effect of starch increased, but the binding effect with lipids decreased, which freed the fat, so the content of protein and crude fat was higher in all forms of sample 4.

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Table 3. Content of basic components of millet preparations cooked in different electric cookers (n=3, mean ± standard deviation, g/100 g dry basis).

Sample Name	Ash	Total fat	Amylose	Protein	Reducing Sugar
Millet porridge 1	0.75±0.03^{bA}	3.48±0.06^{bB}	17.47±0.18^{abB}	8.63±0.19^{bcB}	0.36±0.04^{cA}
Millet porridge 2	0.77±0.06^{abB}	3.70±0.16^{bC}	16.47±0.18^{bcB}	8.82±0.01^{bB}	0.44±0.03^{bB}
Millet porridge 3	0.82±0.03^{aB}	3.71±0.11^{aAB}	16.18±0.03^{cB}	8.55±0.12^{cB}	0.64±0.03^{aB}
Millet porridge 4	0.73±0.07^{bA}	4.33±0.10^{aA}	16.50±0.19^{bcB}	9.27±0.03^{aB}	0.43±0.01^{bA}
Millet porridge 5	0.78±0.06^{abA}	3.67±0.07^{bB}	17.88±0.19^{aB}	9.14±0.06^{aB}	0.26±0.04^{dB}
Millet soup 1	0.92±0.02^{bA}	5.46±0.03^{bA}	24.41±0.16^{cA}	2.94±0.06^{aC}	0.41±0.04^{cA}
Millet soup 2	0.85±0.05^{cA}	5.28±0.28^{cA}	26.75±0.17^{bA}	2.85±0.01^{bC}	0.51±0.02^{bA}
Millet soup 3	0.97±0.01^{aA}	5.41±0.33^{bcA}	27.64±0.20^{aA}	2.80±0.01^{bC}	0.78±0.01^{aA}
Millet soup 4	0.81±0.06^{dA}	4.84±0.16^{dA}	24.77±0.10^{cA}	3.00±0.04^{aC}	0.43±0.02^{cA}
Millet soup 5	0.75±0.02^{eA}	6.12±0.16^{aA}	24.31±0.13^{cA}	2.86±0.05^{bC}	0.42±0.03^{cA}
Millet grain 1	0.62±0.04^{bB}	3.81±0.15^{bB}	9.20 ±0.14^{bC}	15.03±0.22^{bA}	0.21±0.04^{cB}
Millet grain 2	0.63±0.02a^{bC}	4.20 ±0.05^{abB}	8.82 ±0.10^{cC}	16.28±0.21^{aA}	0.25±0.01^{bC}
Millet grain 3	0.74 ±0.02^{abC}	3.85 ±0.18^{bB}	10.84 ±0.22^{aC}	14.61±0.22^{bA}	0.30±0.01^{aC}
Millet grain 4	0.70 ±0.05^{abA}	4.77± 0.10^{aA}	7.27± 0.22^{dC}	16.71±0.13^{aA}	0.23±0.01^{bcB}
Millet grain 5	0.79 ±0.02^{aA}	3.72 ±0.21^{bB}	7.26 ±0.19^{dC}	16.16±0.09^{aA}	0.22±0.02^{cB}

Note: Significant differences between table entries are explained in the footnote of Table 2.

3.3. Fatty acid content analysis

The fatty acids in millet are mainly unsaturated fatty acids, accounting for 85.54% of the total fatty acids. Fatty acids have physiological functions such as strengthening the brain, supporting intelligence, and delaying aging [33]. Five fatty acids were detected in millet porridge: palmitic acid, stearic acid, oleic acid, linoleic acid, and linolenic acid (Table 4). The content of oleic acid and linoleic acid was high, and the volatile components produced by the reaction of oleic acid and linoleic acid during heating have been shown to be an important component of the aroma of millet porridge [9]. There were significant differences among millet porridge, millet soup, and millet grains cooked in the same electric cooker ($P<0.05$). The content of all five fatty acids in millet grains, especially linoleic acid and oleic acid, was higher than in millet porridge or soup. This shows that most fatty acids remained in millet grains during the cooking process of millet porridge.

There were significant differences in millet porridge, millet soup, and millet grains cooked by different electric cookers ($P<0.05$), and the content was higher in sample 5. Electric cooker no 5 had pressure. Because of the high temperature and high pressure, millet grains absorbed water and expanded, and lipids dissolved out of the grains. Lipid hydrolysis was enhanced, so fatty acid content was increased. Some scholars found that the content of fatty acids was apparently increased due to heat degradation during food heating [34], consistent with the findings of this experiment.

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Table 4. Content of fatty acids in millet porridge cooked in different electric cookers (n=3, mean ± standard deviation, mg/100 g dry basis).

Sample Name	Palmitic	Stearic	Oleic	Linoleic	Linolenic
Millet porridge 1	5.09±0.03^{bB}	4.71±0.02^{aB}	10.72±0.02^{cB}	22.31±0.17^{cB}	1.47±0.06^{bB}
Millet porridge 2	4.36±0.03^{dB}	4.37±0.03^{bB}	10.03±0.03^{bB}	19.26±0.20^{bB}	1.17±0.02^{abB}
Millet porridge 3	3.91±0.05^{eA}	4.02±0.02^{cB}	9.38±0.03^{bcB}	13.37±0.16^{aB}	1.06±0.04^{abB}
Millet porridge 4	4.58±0.04^{cA}	4.47±0.03^{bB}	10.58±0.02^{bcB}	13.86±0.22^{aB}	1.05±0.01^{abB}
Millet porridge 5	6.53±0.06^{aB}	4.73±0.03^{aB}	11.23±0.04^{aB}	26.08±0.04^{aB}	1.56±0.05^{aB}
Millet soup 1	3.16±0.04^{bC}	1.39±0.01^{aC}	1.64±0.02^{aC}	5.18±0.04^{bC}	0.29±0.01^{cB}
Millet soup 2	3.05±0.05^{bC}	1.34±0.01^{aC}	1.62±0.01^{aC}	5.21±0.03^{bC}	0.31±0.05^{cC}
Millet soup 3	3.43±0.03^{aC}	1.50±0.01^{aC}	1.69±0.02^{aC}	5.44±0.06^{aC}	0.32±0.04^{cC}
Millet soup 4	3.50±0.02^{aB}	1.46±0.02^{aC}	1.64±0.03^{aC}	5.42±0.02^{aC}	0.37±0.03^{bC}
Millet soup 5	3.57±0.02^{aC}	1.37±0.03^{aC}	1.71±0.02^{aC}	5.24±0.01^{bC}	0.42±0.05^{aC}
Millet grain 1	6.88±0.02^{bA}	7.96±0.02^{aA}	19.77±0.02^{bA}	39.48±0.09^{bA}	2.21±0.05^{bA}
Millet grain 2	5.69±0.03b^{cA}	7.44±0.03^{abA}	18.47±0.03^{bcA}	31.10±0.03^{cA}	1.96±0.07^{cA}
Millet grain 3	4.51±0.02^{cB}	6.67±0.01^{bA}	17.21±0.02^{cA}	22.02±0.01^{dA}	1.71±0.08^{dA}
Millet grain 4	5.69±0.02b^{cA}	7.88±0.03^{aA}	19.70±0.02^{abA}	28.83±0.06^{cA}	1.69±0.03^{dA}
Millet grain 5	9.05±0.04^{aA}	8.10±0.05^{aA}	21.06±0.10^{aA}	46.79±0.09^{aA}	2.60±0.01^{aA}

Note: Significant differences between table entries are explained in the footnote of Table 2.

3.4. Amino acid content analysis

Amino acids are not only the basic components of proteins, but also promote insulin secretion and function in digestion and the nervous system [35]. Here, the content of 17 amino acids was analyzed, including seven essential amino acids (Table 5). There were significant differences between millet porridge, millet soup, and millet grains cooked in the same electric cooker ($P<0.05$). The content of total amino acids and essential amino acids in millet grains was high, especially glutamate and leucine. Some scholars found that the content of leucine was the highest when detecting the content of amino acids in millet [36]. The proportion of essential amino acids in millet porridge and millet grain was high, and was close to the essential amino acid (EAA)/total amino acid (TAA) ratio proposed by the Food and Agriculture Organization of the United Nations/World Health Organization (FAO/WHO), which is 0.400. This shows that the protein in millet porridge and millet grain is high-quality protein with high nutritional value [37].

There were significant differences in millet porridge, millet soup, and millet grains cooked by different electric cookers ($P<0.05$). The content of **TAA in m**illet soup(2.53±0.11)g/100 g and **m**illet grain (16.87±0.23)g/100 g of sample 5 was higher than the other samples. It may be that during the heating process of electric cooker no. 5, the grains absorbed water and expanded under high temperature and high pressure, and the protein was thermally degraded into amino acids, so the content was higher. Some scholars have shown that high cooking s increased the content of amino acids in food, especially glutamate, consistent with the results of this experimental study [38].

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Table 5-1. Amino acid content of millet porridge cooked in different electric cookers (n=3, mean ± standard deviation, g/100 g dry basis)

Sample Name	Aspartic Acid	Serine	Glutamate	Glycine	Alanine	Cystine	Tyrosine	Proline	Arginine	Threonine
Millet porridge 1	0.62±0.01^{aB}	0.46±0.01^{aB}	2.00±0.03^{aB}	0.23±0.01^{aB}	0.23±0.05^{bB}	0.12±0.01^{abA}	0.54±0.02^{aA}	0.66±0.01^{aB}	0.17±0.01^{bB}	0.35±0.01^{aB}
Millet porridge 2	0.62±0.01^{aB}	0.46±0.01^{aB}	2.00±0.06^{aB}	0.23±0.01^{aB}	0.25±0.11^{bB}	0.16±0.03^{aA}	0.55±0.05^{aA}	0.67±0.01^{aB}	0.16±0.01^{bB}	0.36±0.01^{aB}
Millet porridge 3	0.60±0.02^{aB}	0.45±0.01^{aB}	1.96±0.06^{aB}	0.22±0.01^{bB}	0.32±0.01^{abB}	0.11±0.01^{bA}	0.51±0.02^{aA}	0.66±0.01^{aB}	0.16±0.01^{bB}	0.35±0.01^{aB}
Millet porridge 4	0.62±0.01^{aB}	0.45±0.01^{aB}	1.98±0.01^{aB}	0.23±0.01^{aB}	0.27±0.11^{bB}	0.14±0.02^{abA}	0.52±0.03^{aB}	0.66±0.01^{aB}	0.16±0.01^{bB}	0.35±0.01^{aB}
Millet porridge 5	0.62±0.02^{aB}	0.46±0.02^{aB}	2.04±0.07^{aB}	0.23±0.01^{aB}	0.41±0.04^{aB}	0.11±0.04^{bA}	0.53±0.06^{aB}	0.67±0.03^{aB}	0.20±0.04^{aB}	0.36±0.01^{aB}
Millet soup 1	0.20±0.01^{bC}	0.13±0.01^{abC}	0.53±0.02^{abC}	0.10±0.01^{aC}	0.24±0.01^{aB}	0.01±0.01^{cC}	0.09±0.02^{cC}	0.17±0.01^{aC}	0.06±0.01^{bC}	0.11±0.01^{aC}
Millet soup 2	0.20±0.01^{bC}	0.12±0.01^{bcC}	0.50±0.03^{bcC}	0.09±0.01^{bC}	0.21±0.02^{abB}	0.01±0.01^{cC}	0.08±0.02^{cB}	0.16±0.02^{aC}	0.06±0.01^{bC}	0.10±0.01^{bC}
Millet soup 3	0.19±0.01^{bC}	0.11±0.01^{cC}	0.47±0.01^{cC}	0.09±0.01^{bC}	0.18±0.02^{bcC}	0.01±0.01^{cB}	0.09±0.01^{cB}	0.13±0.01^{bC}	0.06±0.01^{bC}	0.09±0.01^{bC}
Millet soup 4	0.21±0.01^{abC}	0.13±0.01^{abC}	0.54±0.01^{aC}	0.10±0.01^{aC}	0.14±0.04^{cB}	0.03±0.01^{bB}	0.14±0.02^{bC}	0.15±0.01^{aC}	0.06±0.01^{bC}	0.11±0.01^{aC}
Millet soup 5	0.22±0.01^{aC}	0.14±0.01^{aC}	0.54±0.02^{aC}	0.10±0.01^{aC}	0.14±0.04^{cC}	0.04±0.01^{aB}	0.20±0.03^{aC}	0.15±0.02^{aC}	0.07±0.01^{aC}	0.11±0.01^{aC}
Millet grain 1	0.96±0.01^{bcA}	0.75±0.01^{bcA}	3.30±0.03^{bcA}	0.34±0.01^{abA}	1.56±0.01^{aA}	0.04±0.01^{cB}	0.40±0.03^{cB}	1.15±0.01^{bcA}	0.27±0.01^{abA}	0.57±0.01^{bcA}
Millet grain 2	0.94±0.12^{cA}	0.74±0.09^{cA}	3.21±0.01^{cA}	0.33±0.04^{bA}	1.42±0.19^{abA}	0.07±0.03^{bcB}	0.54±0.09^{bA}	1.09±0.05^{cA}	0.27±0.03^{abA}	0.56±0.07^{cA}
Millet grain 3	0.87±0.04^{cA}	0.68±0.03^{cA}	2.95±0.03^{cA}	0.31±0.02^{bA}	1.28±0.02^{bA}	0.09±0.02^{abA}	0.54±0.09^{bA}	1.01±0.03^{cA}	0.24±0.02^{bA}	0.52±0.02^{cA}
Millet grain 4	1.07±0.06^{abA}	0.84±0.05^{abA}	3.68±0.20^{abA}	0.38±0.02^{aA}	1.59±0.14^{aA}	0.11±0.01^{aA}	0.71±0.03^{aA}	1.26±0.08^{abA}	0.30±0.01^{aA}	0.64±0.03^{abA}
Millet grain 5	1.09±0.01^{aA}	0.85±0.01^{aA}	3.75±0.07^{aA}	0.38±0.01^{aA}	1.62±0.02^{aA}	0.11±0.01^{aA}	0.70±0.02^{aA}	1.30±0.02^{aA}	0.30±0.01^{aA}	0.65±0.01^{aA}

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Table 5-2. Amino acid content of millet porridge cooked in different electric cookers (mean ± standard deviation, g/100 g dry basis)

Sample Name	Valine	Methionine	Isoleucine	Leucine	Phenylalanine	Lysine	Histidine	TAA	EAA	EAA/TAA
Millet porridge 1	0.47±0.01^{abB}	0.20±0.06^{aB}	0.37±0.01^{aB}	1.32±0.02^{aB}	0.80±0.10^{aB}	0.14±0.01^{aB}	0.13±0.01^{aB}	8.81±0.09^{aB}	3.65^{aB}	0.42^{aA}
Millet porridge 2	0.47±0.01^{abB}	0.18±0.01^{aB}	0.37±0.01^{aB}	1.32±0.04^{aB}	0.75±0.09^{aB}	0.14±0.01^{aB}	0.13±0.01^{aB}	8.83±0.19^{aB}	3.59^{aB}	0.41^{aA}
Millet porridge 3	0.46±0.01^{bB}	0.17±0.05^{aB}	0.36±0.01^{aB}	1.30±0.04^{aB}	0.71±0.11^{aB}	0.14±0.01^{aB}	0.12±0.02^{aB}	8.59±0.25^{aB}	3.48^{aB}	0.41^{aA}
Millet porridge 4	0.47±0.01^{abB}	0.21±0.02^{aB}	0.37±0.01^{aB}	1.30±0.01^{aB}	0.74±0.10^{aB}	0.14±0.01^{aB}	0.12±0.01^{aB}	8.73±0.08^{aB}	3.59^{aB}	0.41^{aA}
Millet porridge 5	0.48±0.01^{aB}	0.19±0.05^{aB}	0.38±0.01^{aB}	1.34±0.04^{aB}	0.67±0.03^{aB}	0.15±0.01^{aB}	0.13±0.01^{aB}	8.97±0.29^{aB}	3.57^{aB}	0.40^{aA}
Millet soup 1	0.14±0.01^{aC}	0.01±0.01^{bcC}	0.11±0.01^{aC}	0.32±0.01^{aC}	0.07±0.01^{aC}	0.05±0.01^{aC}	0.07±0.01^{aC}	2.41±0.06^{abC}	0.82^{abC}	0.34^{bC}
Millet soup 2	0.13±0.01^{bC}	0.01±0.01^{cC}	0.10±0.0^{aC}	0.30±0.02^{bC}	0.06±0.02^{aC}	0.05±0.03^{aC}	0.06±0.01^{aC}	2.25±0.17^{bcC}	0.75^{bcC}	0.33^{bB}
Millet soup 3	0.12±0.01^{cC}	0.01±0.01b^{cC}	0.10±0.01^{aC}	0.29±0.01^{bC}	0.05±0.01^{aC}	0.05±0.02^{aC}	0.06±0.01^{aC}	2.11±0.05^{cC}	0.71^{cC}	0.33^{bC}
Millet soup 4	0.14±0.01^{aC}	0.03±0.02^{abC}	0.11±0.02^{aC}	0.34±0.01^{aC}	0.07±0.01^{aC}	0.05±0.01^{aC}	0.06±0.01^{aC}	2.42±0.06^{abC}	0.86^{aC}	0.36^{aC}
Millet soup 5	0.14±0.01^{aC}	0.04±0.01^{aC}	0.11±0.01^{aC}	0.33±0.02^{aC}	0.07±0.04^{aC}	0.05±0.01^{aC}	0.06±0.01^{aC}	2.53±0.11^{aC}	0.85^{aC}	0.34^{bB}
Millet grain 1	0.75±0.01^{bA}	0.40±0.02^{aA}	0.61±0.01^{bA}	2.21±0.02^{bcA}	1.10±0.04^{bA}	0.21±0.01^{abA}	0.25±0.01^{aA}	14.87±0.17^{bcA}	5.85^{aA}	0.39^{aB}
Millet grain 2	0.73±0.09^{bA}	0.35±0.13^{abA}	0.59±0.08^{bA}	2.15±0.27^{cA}	1.17±0.13^{abA}	0.19±0.02^{bcA}	0.25±0.03^{aA}	14.60±0.23^{cA}	5.74^{aA}	0.39^{aA}
Millet grain 3	0.68±0.03^{bA}	0.33±0.04^{bA}	0.55±0.03^{bA}	1.98±0.09^{cA}	1.08±0.10^{bA}	0.18±0.07^{cA}	0.22±0.01^{bA}	13.50±0.34^{cA}	5.31^{aA}	0.39^{aB}
Millet grain 4	0.85±0.04^{aA}	0.37±0.06^{aA}	0.68±0.04^{aA}	2.46±0.13^{abA}	1.23±0.06^{abA}	0.21±0.01^{abA}	0.26±0.02^{aA}	16.62±0.78^{abA}	6.44^{aA}	0.39^{aB}
Millet grain 5	0.85±0.01^{aA}	0.31±0.01^{bA}	0.69±0.01^{aA}	2.51±0.04^{aA}	1.27±0.08^{aA}	0.22±0.01^{aA}	0.25±0.01^{aA}	16.87±0.23^{aA}	6.51^{aA}	0.39^{aA}

Note: Significant differences between table entries are explained in the footnote of Table 2.

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3.5. Mineral analysis

Minerals are essential to ensure the normal growth, development, and maintenance of the human body [38]. There were significant differences in Zn, Mn, Fe, and Mg in millet porridge, millet soup, and millet grains cooked in the same electric cooker ($P<0.05$), and the content of minerals in millet grains was high (Table 6). This shows that the minerals were relatively stable and mainly located in the millet grains, with a small amount transferred to the millet soup. There were significant differences in the content of Zn, Mn, Fe, and Mg in millet porridge, millet soup, and millet grains cooked by different electric cookers ($P<0.05$), and the content of all forms of sample 5 was higher overall than the other samples. There was no significant difference in Ca and Cu among millet porridge, millet soup, and millet grain samples ($P>0.05$). A possible reason for this is that the high temperature and high pressure of electric cooker no. 5 led to the breakage of the cell wall, resulting in the easy release of elemental minerals.

Table 6. Mineral content in millet porridge cooked in different electric cookers (n=3, mean ± standard deviation, mg/kg dry basis).

Sample Name	Ca	Zn	Mn	Cu	Fe	Mg
Millet porridge 1	468.53±0.39^{aA}	27.53±0.02^{bB}	13.33±0.00^{aB}	2.13±0.00^{aA}	54.47±0.01^{cB}	554.48±0.32^{aB}
Millet porridge 2	404.67±0.38^{aA}	24.67±0.06^{cB}	13.32±0.00^{aB}	1.87±0.00^{aA}	64.07±0.06^{bB}	515.08±0.40^{aB}
Millet porridge 3	408.13±0.27^{aA}	31.27±0.00^{aB}	13.60±0.00^{aB}	2.60±0.00^{aA}	53.87±0.03^{cB}	521.09±0.50^{aC}
Millet porridge 4	418.33±0.50^{aA}	32.67±0.01^{aB}	14.07±0.00^{aB}	1.67±0.00^{aAB}	68.33±0.07^{bB}	546.28±0.47^{aB}
Millet porridge 5	554.13±0.56^{aA}	33.13±0.01^{aB}	14.20±0.00^{aB}	2.87±0.01^{aA}	77.07±0.02^{aB}	644.43±0.14^{aA}
Millet soup 1	325.87±0.08^{bA}	22.20±0.00^{bC}	16.07±0.01^{aA}	2.07±0.00^{aA}	52.60±0.05^{cB}	424.32±0.04^{cC}
Millet soup 2	416.00±0.16^{aA}	24.40±0.00^{abB}	13.27±0.00^{bB}	1.80±0.00^{abA}	60.13±0.02^{bB}	428.74±0.12^{bcC}
Millet soup 3	436.20±0.09^{aA}	23.53±0.00^{abB}	11.93±0.00^{cdC}	1.40±0.00^{abA}	52.47±0.01^{cB}	583.06±0.10^{aAC}
Millet soup 4	400.20±0.16^{aA}	24.93±0.01^{aC}	13.07±0.00^{bcC}	1.47±0.00^{abB}	46.40±0.04^{cC}	458.47±0.22^{bB}
Millet soup 5	429.00±0.19^{aA}	23.07±0.01^{abC}	11.00±0.01^{dC}	1.27±0.00^{bA}	68.20±0.03^{aB}	587.92±0.21^{aB}
Millet grain 1	252.00±0.12^{bB}	38.20±0.01^{abA}	13.73±0.00^{dB}	2.60±0.00^{aA}	78.53±0.01^{cA}	680.98±0.11^{aA}
Millet grain 2	247.53±0.08^{bB}	37.67±0.00^{bcA}	16.27±0.00^{bA}	2.33±0.01^{aA}	85.53±0.02^{cA}	688.25±0.10^{aA}
Millet grain 3	299.53±0.32^{abB}	36.67±0.00^{cA}	15.40±0.00^{bcA}	2.13±0.01^{aA}	83.47±0.02^{cA}	694.32±0.03^{aA}
Millet grain 4	310.40±0.32^{abB}	38.67±0.00^{abA}	15.27±0.00^{cA}	2.20±0.01^{aA}	99.13±0.05^{bA}	696.39±0.06^{aA}
Millet grain 5	359.87±0.43^{aA}	39.07±0.01^{aA}	17.33±0.00^{aA}	2.53±0.00^{aA}	109.47±0.04^{aA}	697.09±0.40^{aA}

Note: Significant differences between table entries are explained in the footnote of Table 1.

3.6. Principal component analysis

PCA was carried out on the nutritional components in the samples (Figure 1). The first principal component divided the samples into two groups: millet porridge and millet soup as a group, and millet grain as a group. The results showed that most of the nutrients of millet porridge and millet soup were similar. The second principal component divided the samples into two groups: millet grains and millet soup as a group, and millet porridge as a group. These results showed that some nutrients in millet grains and millet soup were similar (Figure 1a). The load diagram shows that the first principal component of millet soup mainly contained sensory evaluation, total fat, amylose, reducing sugar, ash, and Ca, and the samples of millet grain mainly contained protein, amino acids, fatty acids, Fe, Mn, Mg, Zn, and Cu (Figure 1b). This is consistent with the results of the significant difference analysis.

The main components of millet soup were amylose and reducing sugar. Amylose has a good ability to dissolve fat, and therefore the content of amylose and crude fat in millet soup was high. The millet grains absorbed water and expanded at high temperature, the

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lipids and minerals dissolved out of the grain, the hydrolysis of lipids was enhanced, and the content of fatty acids was increased. Therefore, fatty acids and minerals were mainly found in the millet grains.

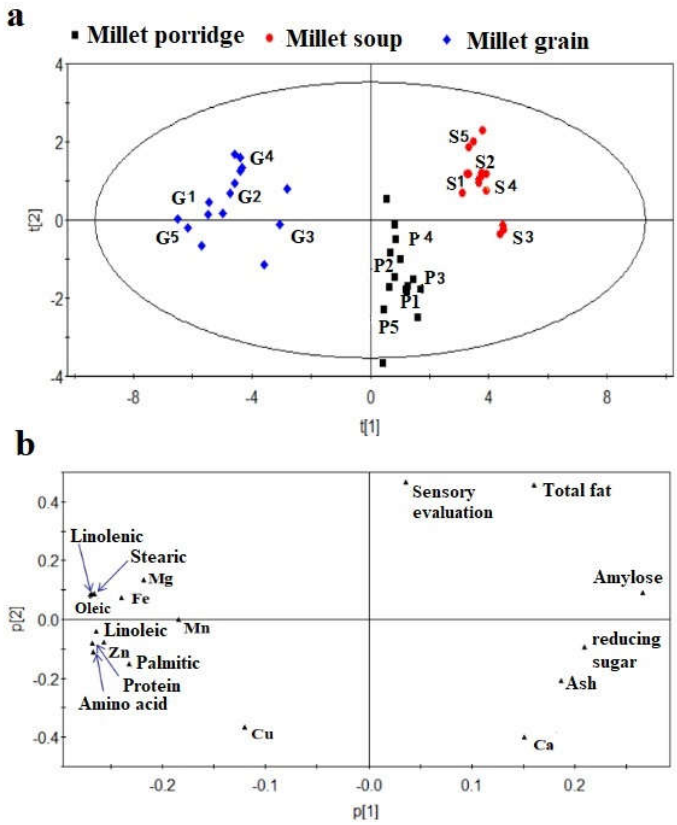

Figure 1. Principal component analysis (PCA) of millet porridge cooked in different electric cookers: (a) PCA score diagram (b) PCA load diagram**.**

3.7. Cluster analysis

Cluster analysis of samples and compounds was carried out, as shown in Figure 2. Cluster analysis divided the samples into two groups. Group I was millet porridge and millet soup, indicating that the two were similar. Group II was millet grain, which showed that there was a great difference between millet grain compared to the millet porridge and soup. This is consistent with the PCA score map, with millet porridge and millet soup as one group and millet grain as another group (Figure 1a). The parameters evaluated for the three millet preparations were then divided into two groups by cluster analysis. Group A was higher in sensory evaluation, total fat, ash, reducing sugar, amylose and Ca, indicating that the content of these components or scores were higher in millet soup and lower in millet grain. Group B mainly contained palmitic acid, linoleic acid, stearic acid, oleic acid, linolenic acid, protein, amino acid, Zn, Fe, Mg, Mn, and Cu, indicating that the content of these components was higher in millet grain and the content of millet soup was the least; the millet porridge content was intermediate between these. These results are consistent with the PCA map of principal components, which shows that the two statistical methods obtained the same analysis results (Figure 1b).

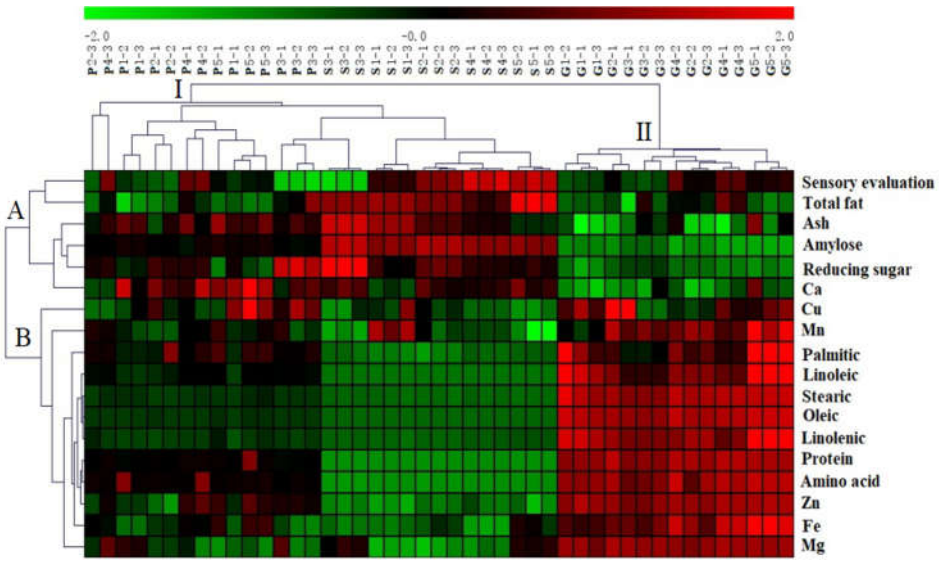

Figure 2. Cluster analysis of millet porridge cooked by different brands of electric cookers. The data are auto-scaled and clustered according to the Pearson correlation coefficients. Green colors indicate that the content level (or score for sensory evaluation) is less than its mean level, while red colors indicate that the content level (or score) is higher than its mean level.

4. Conclusion

In this study, five electric cookers were selected. Under the same cooking conditions, PCA and cluster analysis were used to examine the differences between various nutrients in millet porridge, millet soup, and millet grains cooked by different electric cookers. The results showed that among the samples cooked in different electric cookers, the samples cooked in electric cooker no. 3 had the highest content of amylose and reducing sugar. The sensory evaluation, total fat, and protein content of the samples cooked in electric cooker no. 4 were the highest. The samples cooked in electric cooker no. 5 had the highest content of ash, fatty acids, amino acids, and minerals. The sensory evaluation score and content of total fat, ash, reducing sugar, amylose, and Cu in millet soup were higher than that of millet porridge or grain. The content of fatty acid, protein, amino acid, Zn, Fe, Mg, Mn, and Ca in millet grain was higher than that of porridge or soup. The content of millet porridge was generally between millet soup and grain. The nutritional components of millet grain, millet soup, and millet porridge cooked in different electric cookers varied, which may be related to the different heating modes and power of the electric cookers. This study provides a reference for the further development of new electric cookers.

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