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Retention of nutrients of pearl millet using conventional and solar cooking

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Comparative estimation of nutrients of pearl millet was studied by adopting two methods of cooking, that is, conventional cooking on liquefied petroleum gas (LPG) stoves and solar cooking. Starch, total soluble carbohydrate, protein, calcium and iron were determined for raw, conventional and solar cooked pearl millet. It was found that retention of starch was 98.58% for solar cooked and 74.51% for conventional cooked pearl millet. Retention of total soluble carbohydrate was 31.22% for solar cooked and 28.96% for conventional cooked pearl millet. Retention of protein was 98.00% for solar cooked and 97.24% for conventional cooked pearl millet. Retention of calcium was 83.3% for solar cooked and 77.8% for conventional cooked pearl millet. Retention of iron was 98.27% for solar cooked and 95.66% for conventional cooked pearl millet. The results in the study revealed that solar cooking is better than conventional cooking because more nutrients are retained in solar cooking than conventional cooking.

Key words: Solar cooking, retention of nutrient, pearl millet.

INTRODUCTION

The genus *Pennisetum* is distributed throughout the tropics and subtropics of the world. It includes about 140 species. One African species, *Pennisetum purpurevm* Schumach became widely distributed as a tropical forage grass (Bruken, 1977). *Pennisetum glaucum* is widely distributed in south of Sahara, in the semi-arid Sahel and bush from Senegal to Eritrea in Ethiopia. It was domesticated along the southern margins of the Saharan central highlands at the onset of the present dry phase some 4000-5000 years ago (Clark, 1962; Davies, 1968; Munson, 1975). Pearl millet is the most drought tolerant of all domesticated cereals, and soon after its domestication it became widely distributed across the semi-arid tropics of Africa and Asia. It is the principal food crop across sub-Saharan Africa and North-Western India. It is a premier crop of Rajasthan. Of the Kharif crop grown in the state, this crop alone accounts for 47% area and contributes 37% to the total Kharif production in the state. Of the Kharif cereals nearly 71 and 56% production is shared by pearl millet. It is important for Rajasthan agriculture chiefly because it is highly adapted to harsh environmental conditions in the vast dry land areas; it succeeds as a fodder crop for sustaining livestock health and productivity which in turn, sustains the livelihood of resource-poor farmers in most parts of the state. It is, therefore, of permanent importance for food and fodder

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security in the state. For this reason alone, the crop has stayed in Rajasthan agriculture for hundreds of years. And it will continue to remain important for the state for hundreds of years to come as well. Pearl millet as a grain crop occupies an important position in the national context. It is the fourth important cereal crop in the country, next to rice, wheat and sorghum. Major states growing pearl millet are Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana. The two states, Rajasthan and Maharashtra, together occupy 65% of the total area under pearl millet cultivation in the country. Rajasthan alone occupies 49% of the area and contributes nearly 30% of the total pearl millet production in the country. Total area under pearl millet cultivation is 9.1 million hectare and production is 7.3 million tons and the productivity is 780 kg/ha. Pearl millet flour is eaten in the form of chapati and broken pearl millet is eaten in the form of *daliya*.

George and Ogale (1987) found that protein retention in selected cereals, pulses and vegetables that were solar cooked were higher than those cooked by absorption method in saucepan. Solar cooked green gram dhal, red gram dhal, brinjal, kavai and cluster beans contained thiamine in a higher percentage than the same foods cooked in saucepan. Protein retention in selected pulses, vegetables, cereals that were solar cooked was higher than those cooked by pressure cooker (Devdas and Venmathi, 1992). Solar cooker was superior due to better retention of carotene and vitamin C ascompared to microwave oven (Eswaran and Kalpana ,1998). Study was conducted by Chandrasekhar and Kowsalya (1998) on nutrient retention cooked taking two methods (conventional cooking and solar cooking) as compared to the raw amaranths, the percent loss of protein and riboflavin in both methods of cooking was found to be similar, while there was no loss of phosphorus in the solar cooking, percentage loss of calcium and ascorbic acid in the solar cooked sample was more as compared to that of the cooked sample by absorption method. Srivastava and Aakanksha (2009) measured retention of nutrient in moth bean in conventional and solar cooking and found that retention of starch was 81.26%for solar cooked and 76.30% for conventional cooked moth bean. Retention of total soluble carbohydrate was 45.41% for solar cooked and 40.34% for conventional cooked moth bean. Retention of protein was 99.48% for solar cooked and 97.23% for conventional cooked moth bean. Retention of calcium was 84.7% for solar cooked and 80.0% for conventional cooked moth bean. Retention of iron was 96.9% for solar cooked and 94.08% for conventional cooked moth bean. The results of the study revealed that solar cooking is better than conventional cooking because more nutrients are retained in solar cooking than conventional cooking. In this paper, retention of nutrient viz., starch, total soluble carbohydrates, protein, calcium and iron in pearl millet has been studied using conventional and solar cooking.

MATERIALS AND METHODS

Conventional cooking

100 g fresh pearl millet sample (three replications) were cooked with distilled water in stainless steel saucepan on LPG stove. Fresh samples as well as cooked samples were dried at 48°C in an infrared oven. Dried samples were grounded to powdered form and sealed in a polythene bag.

Solar cooking

100 g fresh pearl millet samples (three replications) were cooked with distilled water in stainless steel cooking utensil. Hot box solar cooker with double reflector was used for cooking so that tracking towards the sun was avoided for three hours. The device consisted of a double walled hot box. The outer and inner boxes were made of aluminium. The space between them was filled with glass wool insulation and separated by a wooden frame. The inner box was painted with black board paint. Two clear window glass panes of 4 mm thickness were fixed over it with a wooden frame, which can be opened. Two 4 mm thick plane mirror reflectors were fixed over it. Fresh samples as well as cooked samples were dried at 48°C in an infrared oven. Dried samples were grounded to powdered form and sealed in a polythene bag.

Biochemical analysis

Determination of total soluble carbohydrates and starch by anthrone method

The concentration of pentoses, hexoses, disaccharides including sucrose, lactose, maltose and hexuronic acids present either freely or along with polysaccharides can be estimated using this method. Anthrone, 10-keto-9, 10-di hydro anthracene, a reduction product of anthroquinone, reacts by condensing with carbohydrate furfural derivative to produce a green colour in a dilute solution and a blue colour in a concentrated solution.

50 mg of oven dried samples (three replications) were extracted in 80% ethanol. The homogenate was centrifuged at 5000 rpm for 10 min and the residue was re-extracted and the supernatants were pooled. Final volume was made up to 25 ml. The supernatant was used for estimation of total soluble carbohydrates, while residue was used for the estimation of starch (Yemn and Wills, 1954).

1.0 ml of aliquot of supernatant was evaporated to dryness in the test tube at 60°C in a water bath. After allowing it to cool the residue was dissolved in 1.0 ml distilled water. To this, 4 ml of Anthrone reagent (0.2 g/100 ml concentrated sulphuric acid) was added and heated in boiling water bath for 10 min. The tubes were removed and allowed to cool before recording the optical density (OD) at 620 nm by spectrophotometer (Figure 3) against a reagent blank. The amount of soluble carbohydrate present in the extract was calculated by using a standard curve prepared with graded levels of glucose (10-100 mg/l).

Procedure for starch

Residue left after 80% ethanol extraction was used for starch analysis by anthrone method after its acid hydrolysis following the method (Clegg, 1955). Four milliliters of 26% perchloric acid was added to the tubes containing pellets left after ethanol extraction and left overnight at 4°C. These were then centrifuged at 5000 rpm for 15 min. Supernatant was collected in the test tube while the residue was washed with 26% perchloric acid and centrifuged again. Supernatants were pooled and the volume was made to 10 ml with 26% perchloric acid. 0.2 ml of the supernatant was diluted

to 1.0 ml with distilled water and then 4.0 ml of anthrone reagent (0.2 g/100 ml concentrated sulphuric acid) was added. This reaction mixture was heated in a boiling water bath for 10 min, cooled to room temperature and the optical density (OD) was recorded at 620 nm. Concentration of starch was calculated using standard curve prepared by using graded quantity of glucose and then multiplying the values by 0.9. Results were expressed as mg g^{-1} dry weight of tissue.

Determination of protein by Kjeldahl method

The nitrogenous compounds were converted into ammonium sulphate by boiling with concentrated sulphuric acid. It is subsequently decomposed by addition of excess of alkali and liberated ammonia absorbed into a boric acid solution containing bromocresol green and alcoholic methyl red mixed indicator by steam distillation. Ammonia forms a loose compound, ammonium borate with boric acid which is titrated directly against standard sulphuric acid. Protein (N x 6.25) content of food samples can be determined by Kjeldahl method using Tecator's Kjeltec System-II. For the analysis, 0.5 g oven dried food samples were taken in digestion tubes and digested with 10 ml concentrated sulphuric acid and a digestion tablet (containing 3.5 g potassium sulphate and 3.5 mg selenium) in Tecator's 1015- Digestion system (block digester) for two hours [First at moderate (250°C), followed by a high temperature (350°C). The digested samples are cooled at room temperature and 75 ml of distilled water is then added in each tube. The content of each digested samples were allowed to cool and sample tubes were individually transferred to the Tecator's Kjeltec system-II, 1003- distillation unit, where 50 ml of 40% sodium hydroxide (NaOH) was automatically added into the tube. The contents of the tube were steam distilled and about 50 ml distillate containing evolved ammonia, was collected in 25 ml of 2% boric acid, which was later titrated against 0.1 N sulphuric acid.

The protein content in the sample was calculated as follows:

1ml of 0.1 N H_2SO_4 = 1.4 mg of nitrogen or 0.0014 g nitrogen

Protein of such type of vegetable material, on an average contain 16% of nitrogen (100/16 = 6.25)
Protein content = 6.25 x nitrogen

$$\text{Protein, g/100 g sample} = \frac{A \times 0.0014 \times 6.25 \times 100}{B}$$

Where, A = volume (ml) of 0.1 N sulphuric acid consumed; B = weight of sample taken for analysis (0.5 g)

Determination of minerals

Preparation of ash for calcium and iron

Wet ash method was used for the preparation of ash solution because this method is most suitable for estimation of minerals, as it is less time consuming and gives more accurate results.
   1.0 g of oven dried powered materials were (three replications) taken into a dry 100 ml micro Kjeldahl flask. 5.0 ml of concentrated nitric acid (HNO_3)) was added and kept on a digestion rack. The food samples were heated and then these were dissolved, 5.0 ml of perchloric acid was added and heated till the particles were completely digested and cleared. The flask was removed after digestion was completed from the heating source and the volume was made to 30 ml with double distilled water. The solution

prepared was kept in dry glass bottles and kept in a dust free chamber. This solution was used for estimation of minerals like calcium and iron.

Determination of calcium by titrimeteric method

Calcium is precipitated as oxalate and is titrated with ethylene diamine tetra acetate (EDTA) (Cheng and Bray, 1951). The calcium content was calculated by using the following formula:

Meq./litre of Ca^{++} = ml versanate solution (EDTA) required x normality of versanate solution (define Meq) (Meq is a unit of concentration of an ion in the solution that is defined as a measure of concentration of a solute in a solution obtained by dividing the concentration in mg per litre by equivalent weight of the ion.)

Determination of iron by atomic absorption spectrophotometer

Computer attached atomic absorption spectrophotometer model GBC 932AA was used. Standard blank solutions were aspirated into the flame directly. Optimum operating conditions recommended by the instrument manufacturer was used. Standard solutions were read before and after the sample readings. Burner was flushed with deionised water between samples and checked for 0 setting. Calibration curve was prepared from readings of standards. The concentration of samples were determined from the standard graph.

Calculation

$$\text{ppm minerals} = \frac{(\mu\,g\ mineral\ /ml)\ x\ dilution\ factor}{ml\ aliquots\ x\ g\ sample}$$

RESULTS AND DISCUSSION

Time taken for cooking

Average time (three replication) taken for cooking 100 gm broken pearl millet by conventional cooking was 30 min while it was 90 min by solar cooking.

Temperature variation while cooking in solar cooker

The average temperature (three replications) at the time of loading in solar cooker was 115°C, which was reduced to 90°C after loading and again increased to 110°C when cooking was complete.

Biochemical analysis of nutrient values of pearl millet

Carbohydrates

Carbohydrates are a class of energy yielding substances by the process of respiration and include starch, glucose, sucrose, lactose, etc. Calcium foods and roots and tubers

Table 1. Starch present in pearl millet, with regards to raw, conventional and solar cooking.

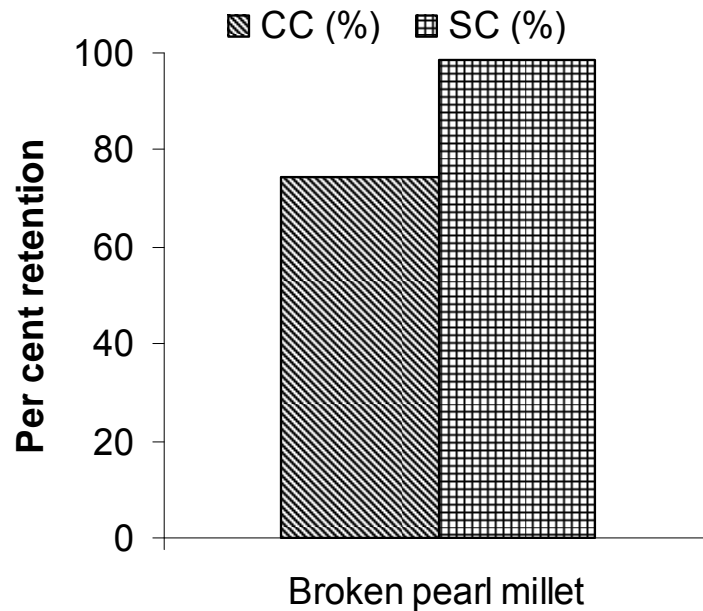| Type of food	Sample no.	Starch (g/100 g)					
		Raw		Conventional cooked		Solar cooked	
		Measured value	Mean value	Measured value	Mean value	Measured value	Mean value
Broken pearl millet	I	39.90	40.96	31.60	30.52 (74.51)*	41.94	40.38 (98.58)
	II	41.46		30.04		39.86	
	III	41.52		29.92		39.34	

*Values in parenthesis indicate percent retention.

Figure 1. Starch retention in conventional cooked (CC) and solar cooked (SC) pearl millet.

are largely composed of starch, a complex carbohydrate. Food ingredients like simple sugars namely cane sugar and glucose are pure carbohydrates. Starch is a complex carbohydrate made up of glucose units. Glucose derived from starch and other sugars present in the diet is the main sources of energy in the body. Carbohydrates derived from cereals are chief source of energy in the Indian diets. Starches when eaten in a cooked form are completely digested in the gastro intestinal tract and the released glucose is absorbed and metabolised in the body to yield energy. Starches are almost completely utilised and there is no difference between starches derived from different sources.

Starch

The results of the proximate analysis of pearl millet for starch estimate are shown in Table 1. The samples were analysed thrice and arithmetic mean of these values are shown in Table 1.

The percent retention of starch in conventional cooking and solar cooking in pearl millet is show in Figure 1. From Table 1 and Figure 1, it is clear that retention of starch is more in solar cooking as compared to conventional cooking. 98.58% starch was retained in solar cooking as compared to 74.51% by conventional cooking on liquefied petroleum gas (LPG) stove.

When raw and conventional cooking is compared for retention of starch as shown in Table 2, calculated values of t was 13.781 which is significantly greater than table value for 4 degrees of freedom at 1%, that is, 4.604 so difference between two means is highly significant, showing significantly lost of starch in cooking.

For retention of starch when conventional cooking and solar cooking were compared (Table 1), calculated values of t was 10.441 which is greater than table value for 4 degrees of freedom at 1%, that is, 4.604, so

Table 2. Total soluble carbohydrates in pearl millet along with percent loss in both method of cooking

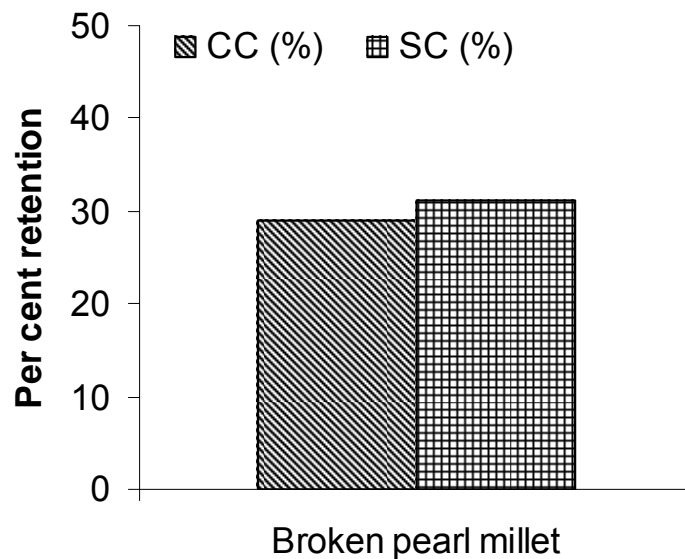| Type of food | Sample No. | Total soluble carbohydrates (g/100 g) | | | | | |
		Raw		Conventional cooked		Solar cooked	
		Measured value	Mean value	Measured value	Mean value	Measured value	Mean value
Broken pearl millet	I II III	2.27 2.19 2.17	2.21	0.660 0.635 0.625	0.64 (28.96)*	0.684 0.710 0.676	0.690 (31.22)

*Values in parenthesis indicate percent retention.

Figure 2. Total soluble carbohydrate retention in conventional cooked (CC) and solar cooked (SC) pearl millet.

difference between two means is highly significant, showing solar cooking is significantly better than conventional cooking for retention of starch in pearl millet.

Total soluble carbohydrates

The results of proximate analysis of total soluble carbohydrates (TSC) in raw, conventional cooked and solar cooked pearl millet are shown in Table 2. The samples were analysed thrice and arithmetic mean is shown in Table 2.

The retention of total soluble carbohydrates by both method of cooking as compared to total soluble carbohydrates present in raw food is shown in Figure 2. The retention of total soluble carbohydrate in broken pearl millet was 31.22% in solar cooking as compared to 28.96% by conventional cooking.

For retention of TSC when raw and conventional cooking is compared as shown in Table 2, calculated values of t were 52.669 which is significantly greater than

table value for 4 degrees of freedom at 1%, that is, 4.604 so difference between two means is highly significant.

When conventional cooking and solar cooking are compared for retention of starch as shown in Table 2, calculated values of t is 3.421 for pearl millet which is significantly greater than table value for 4 degrees of freedom at 5%, that is, 2.776 so difference between two means is significant.

Protein

Proteins are vital to any living organism. Proteins are important constituent of tissues and cells of the body. They form the important component of muscle and other tissues and vital body fluids like blood. The proteins in the form of enzymes and hormones are concerned with a wide range of vital metabolic process in the body. Proteins supply the body building material and reolace the loss due wear and tear. Proteins are antibodies that help the body to defend against infection. Thus, the

Table 3. Proteins present in pearl millet , with regards to raw, conventional and solar cooking.

Type of food	Sample No.	Protein (g/100g)					
		Raw		Conventional cooked		Solar cooked	
		Measured value	Mean Value	Measured value	Mean value	Measured value	Mean value
Broken pearl millet	I	10.55		10.19		10.27	
	II	10.47	10.49	10.23	10.20 (97.24)*	10.31	10.28 (98.00)
	III	10.45		10.18		10.26	

*Values in parenthesis indicate percent retention.
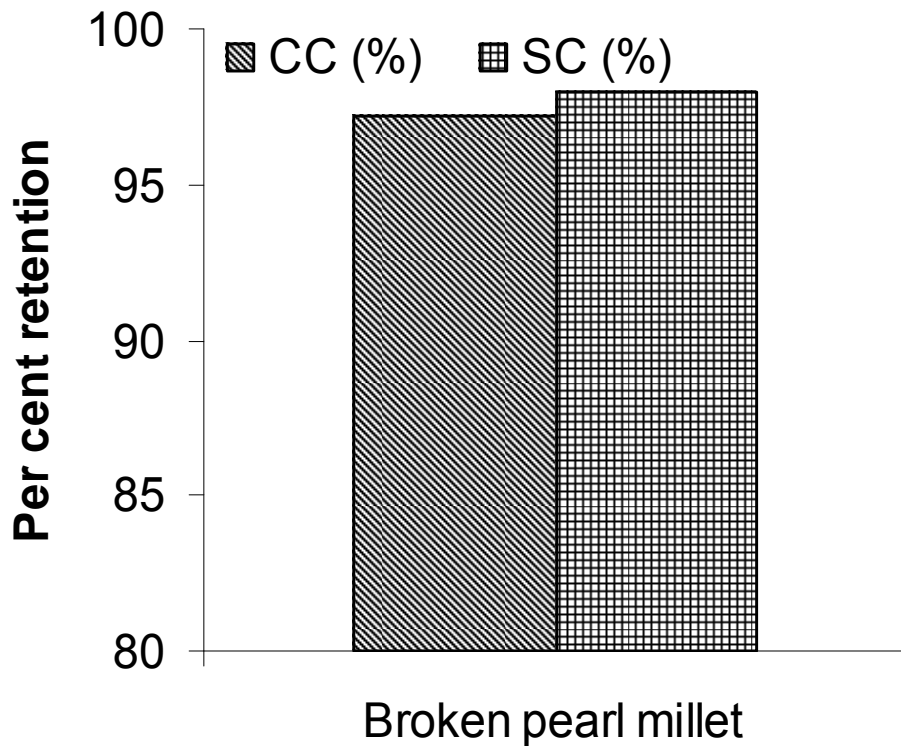

Figure 3. Protein retention in conventional cooked (CC) and solar cooked (SC) pearl millet.

proteins are one of the most important nutrient required by the body and should be supplied in the adequate amounts in the diet. The protein needed by the body has to be supplied through the diet we consume. The adequacy of protein in the diet is an important measure of adequacy and quality of a diet.

The results of proximate analysis of protein in raw, conventional cooked and solar cooked pearl millet are shown in Table 3. The samples were analysed thrice and arithmetic mean is shown in Table 3.

The percent retention of protein in conventional cooked and solar cooked pearl millet is shown in Figure 3. From the Table 3 and Figure 3, it is clear that retention of protein is more in solar cooked food as compared to conventional cooked pearl millet. 98.0% protein was retained in solar cooking while it was 97.2% in conventional cooking. Similar results were obtained by George and Ogale (1987) in green gram, kidney bean; Devdas and Venmathi (1992) in red gram dhal and rice and by Chandrasekhar and Kowsalya (1998) in beans.

When raw and conventional cooking are compared for retention of protein from the Table 3, calculated values of t were 8.950 for pearl millet, which is significantly greater than table value for 4 degrees of freedom at 1%, that is, 4.604 so difference between two means is highly significant, indicating protein is lost in cooking.

For retention of protein when conventional cooking and solar cooking are compared as shown in Table 3,

Table 4. Calcium present in pearl millet in raw form, conventional and solar cooked.

Type of food	Sample No.	Calcium (g/100g)					
		Raw		Conventional cooked		Solar cooked	
		Measured value	Mean value	Measured value	Mean value	Measured value	Mean value
Broken pearl millet	I	44.0	43.2	33.1	33.6 (77.8)*	35.6	36.0 (83.3)
	II	42.2		34.7		35.4	
	III	40.4		33.0		37.0	

*Values in parenthesis indicate percent retention.

Table 5. Iron present in pearl millet in raw form, conventional and solar cooked.

Type of food	Sample No.	Iron (g/100 g)					
		Raw		Conventional cooked		Solar cooked	
		Measured value	Mean Value	Measured value	Mean value	Measured value	Mean v value
Broken pearl millet	I	10.34	10.38	10.02	9.93 (95.66)*	10.16	10.20 (98.27)
	II	10.48		9.88		10.14	
	III	10.32		9.89		10.30	

*Values in parenthesis indicate percent retention.

calculated values of t was 3.135 which is greater than table value for 4 degrees of freedom at 5%, that is, 2.776, so difference between two means is significant, showing solar cooking is significantly better than conventional cooking for retention of protein in pearl millet.

Minerals

A large number of minerals and trace metals are present in the body. Some of these form part of body structural component and some other acts as catalytic agents in many body reactions. Bones and skeleton are made up of mainly calcium, magnesium and phosphorous, and iron is a component of blood.

Calcium

Calcium is an essential element required for several life processes. As the structural component, calcium is required for the formation and maintenance of skeleton and teeth. It is also required for a number of other essential processes. It is required for normal contraction of muscles to make limbs move, contraction of heart for its normal function, nervous activity and blood clotting. These later function are carried out by ionised calcium present in the cells. The calcium levels in cells and plasma are well maintained. Calcium present in bones helps to maintain the calcium level in plasma in the face of dietary calcium deficiency.

The results of analysis of calcium in pearl millet raw form, conventional cooked and solar cooked are shown in Table 4. Samples have been analysed thrice and their arithmetic means of these values are shown in Table 4.

The percent retention of calcium in conventional and solar cooked pearl millet is shown in Figure 4. From Table 5 and Figure 4, it is clear that retention of calcium is more in solar cooked pearl millet as compared to conventional cooked. 83.3% calcium was retained while it was 77.8% in conventional cooking. Similar results were obtained by Chandrasekhar and Kowsalya (1998) in carrot, beans and cabbage.

When raw and conventional cooking is compared for retention of calcium from the Table 4, calculated values of t was 7.649 which is significantly greater than table value for 4 degrees of freedom at 1%, that is, 4.604 so difference between two means is highly significant, showing lost of calcium in cooking.

For retention of calcium when conventional cooking and solar cooking are compared from Table 4, calculated values of t was 3.220 for pearl millet which is greater than table value for 4 degrees of freedom at 5%, that is, 2.776 so difference between two means is significant, indicating solar cooking is significantly better than conventional cooking for retention of calcium.

Iron

Iron is an essential element for formation of haemoglobin of red cells of blood and plays an important role in the transport of oxygen. Tissues also require iron for various oxidation reduction reactions. Most of the iron in the body
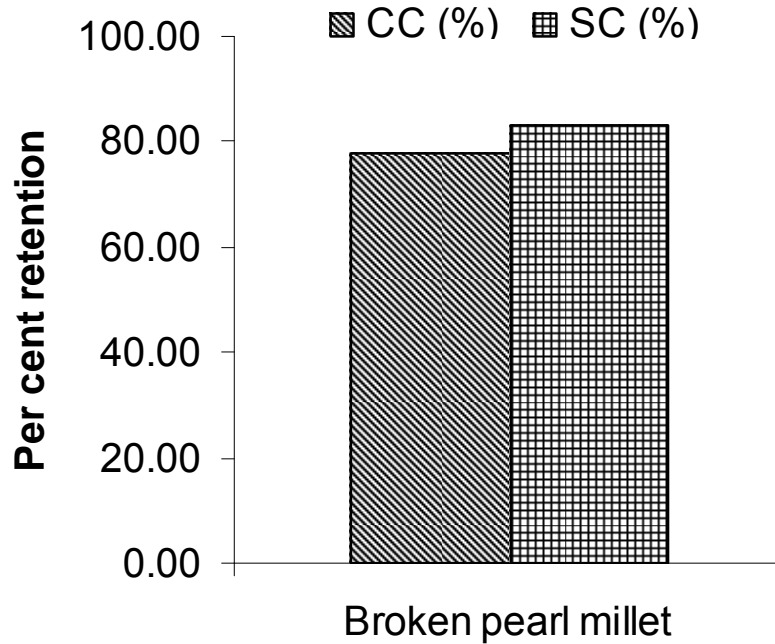
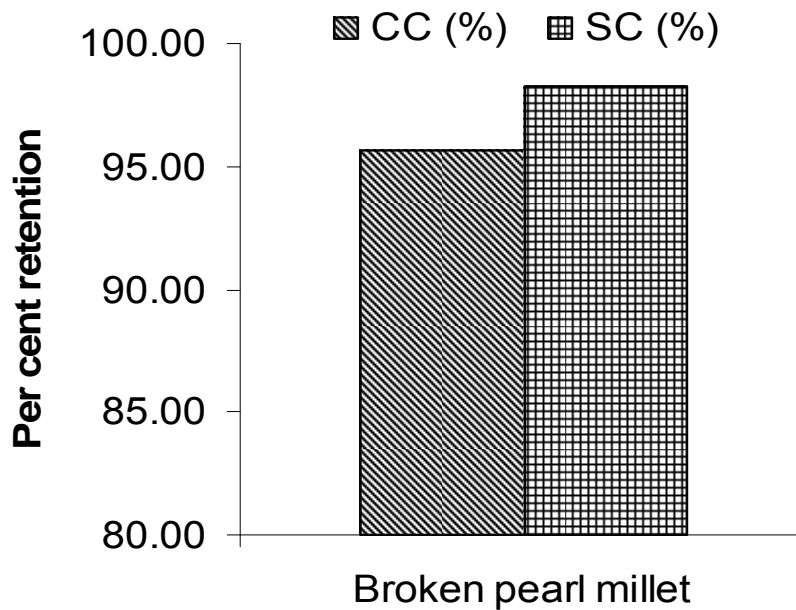**Figure 4.** Calcium retention in conventional cooked (CC) and solar cooked (SC) pearl millet.

Figure 5. Iron retention in conventional cooked (CC) and solar cooked (SC) pearl millet.

is utilised and some of the body iron is also stored in liver and spleen. The amount of iron to be absorbed from the daily diet is quite small. Since there is limited capacity to absorb dietary iron, diet should contain 10-25 fold iron required daily.

Results of analysis of iron in pearl millet in raw form, conventional cooked and solar cooked is shown in Table 5. Samples were analysed thrice and their arithmetic means of these values are shown in Table 5. The percent retention of iron in conventional and solar

cooked pearl millet is shown in Figure 5. From Table 6 and Figure 5, it is clear that retention of iron is more in solar cooked food as compared to conventional cooked food. 98.27% iron was retained in solar cooking while it was 95.66% in conventional cooking. Similar results were obtained by Chandrasekhar and Kowsalya (1998) in different vegetables viz. amaranthus, beans and cabbage.

When raw and conventional cooking is compared for retention of iron as shown in Table 5 calculated values of t was 6.669 which is significantly greater than table value for 4 degrees of freedom at 1%, that is, 4.604 so difference between two means is highly significant indicating lost of iron in cooking.

For retention of iron when conventional cooking and solar cooking are compared as shown in Table 5, calculated values of t was 4.001 which is greater than table value for 4 degrees of freedom at 5%, that is, 2.776, therefore, difference between two means is significant, showing solar cooking is significantly better than conventional cooking for retention of iron.

Conclusions

Comparative estimation of nutrients of pearl millet by two methods of cooking, that is, conventional cooking on LPG stove and solar cooking revealed that:

1. Retention of starch was 98.58% for solar cooked and 74.51% for conventional cooked pearl millet.
2. Retention of total soluble carbohydrate was 31.22% for solar cooked and 28.96% for conventional cooked pearl millet.
3. Retention of protein was 98.00% for solar cooked and 97.24% for conventional cooked pearl millet.
4. Retention of calcium was 83.3% for solar cooked and 77.8% for conventional cooked pearl millet.
5. Retention of iron was 98.27% for solar cooked and 95.66% for conventional cooked pearl millet.
6. It can be concluded that solar cooking is better than conventional cooking because more nutrients are retained in solar cooking than conventional cooking.

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Conflict of Interests

The author(s) have not declared any conflict of interests.

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