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RETENTION OF NUTRIENTS OF DIFFERENT CEREALS USING, CONVENTIONAL, MICROWAVE AND SOLAR COOKING

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Abstract

Comparative estimation of nutrients of different cereals viz. wheat, maize and barley were studied by adopting three methods of cooking i.e. conventional cooking on LPG stove, microwave cooking and solar cooking. In wheat 75.0 %, 70.98 % and 85.00 % starch was retained in, conventional cooking (LPG stove), microwave cooking and solar cooking respectively, 32.14 %, 29.87 % and 35.06 % TSC was retained in, conventional cooking (LPG stove), microwave cooking and solar cooking respectively, 97.15 %, 95.82 % and 98.58 % protein was retained in, conventional cooking (LPG stove), microwave cooking and solar cooking respectively, 78.01 %, 76.60 % and 81.98 % calcium was retained in, conventional cooking (LPG stove), microwave cooking and solar cooking respectively, 95.69 %, 95.10 % and 98.63 % iron was retained in, conventional cooking (LPG stove), microwave cooking and solar cooking respectively. Similar results were obtained in maize and barley as well. Therefore, it can be concluded that the retention of different nutrients in cereals were more in solar cooking as compared to conventional cooking and least in microwave cooking.

Key words: *Nutrition, cereals, solar, microwave, conventional cooking.*

INTRODUCTION

Health depends to a large extent on nutrition, and nutrition on food. Food in fact, is the most important single factor in connection with the attainment and maintenance of health. Every drop of the blood in the body is conditioned by the food we eat and it is on the blood that every tissue, every organ, every gland, and indeed every function of the body fundamentally depends. Some of the vegetables like tomato, cucumber, carrot etc. can best be eaten raw. But others like cereals, pulses and some vegetables must be cooked before they are eaten. Many nutrients are present like carbohydrates, proteins, vitamins, minerals, fat etc. in raw foods. In order to retain most of the nutrients in cooked foods and to maintain good health, it is essential to know and follow right method of cooking.

The different methods of cooking of food are boiling, frying, roasting, and baking etc. For boiling of rice, lentil, etc. the temperature of food being cooked is about 100° C while for other methods, higher temperatures are required. Heat is supplied at the bottom of the vessel for frying and boiling purposes in conventional cooking. Roasting and baking is generally performed on open fire or in ovens, where in food is surrounded by hot surface and heat is transferred to food by radiation and convection. Cooking renders foods more digestible. For instance, the hard grains, such as wheat, and the dried vegetables, such as beans, cannot be readily digested unless they are softened by cooking.

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 to 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 than compared to microwave oven (Eswaran and Kalpana,1998). Study was conducted by Chandrasekhar and Kowsalya (1998) on nutrient retention of cooked food, taking two methods (conventional cooking and solar cooking) when compared to the raw amaranths, the % 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 when compared to that of the cooked sample by absorption method. Srivastava and Aakanksha Nahar (2009) measured retention of nutrient in moth been 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 in the study revealed that solar cooking is better than conventional cooking because more nutrients are retained in solar cooking than conventional cooking. The objective of the study was to find out proximate analysis of nutrients in wheat, maize and barley commonly used as a staple food in India, compare different nutrients found using three different methods of cooking (Conventional, solar, and microwave cooking), and determine which method of cooking is best for nutrient retention, safe cooking, time saving and fuel saving. In this paper retention of nutrient viz, starch, total soluble carbohydrates, protein, calcium and iron in wheat, maize and barley has been studied using, conventional, solar and microwave cooking and reported.

MATERIALS AND METHODS

Conventional cooking

Wheat, maize, and barley were broken and 100 g of sample (three replications) were cooked with 200 ml distilled water in stainless steel sauce pan. LPG stove was used for cooking. Fresh samples as well as cooked samples were dried at 48^{o} C in an infrared oven. Dried samples were grounded to powdered form and sealed in a polythene bag

Microwave cooking

Wheat, maize, and barley were broken and 100 gram of samples (three replications) were cooked with 200 ml distilled water in microwave plastic container. The BPL microwave cooking system was used for cooking. A microwave oven is a metal-lined box with a magnetron in it. A glass turntable made of special heat-resistant glass is fixed in the base of this box-shaped oven. The food to be cooked is put in a non-metallic container and placed on the turntable. Microwaves of very high frequency emitted by the magnetron are carried into the oven cavity by wave guide and these waves are evenly distributed by a stirrer or diffuser which is a small fan. These waves are absorbed by the food placed inside the microwave oven. Microwaves scattered around, other than those that are directly absorbed by the food, are reflected back to the food by the metal walls of the oven and absorbed fully by the food. When absorbed by the food, microwaves of high frequency cause the water molecules in the food to vibrate with great intensity and heat is produced. This heat is used to cook the food very fast. No external heat is supplied for cooking as is done in other conventional methods. 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

Wheat, maize, and barley were broken and 100 g of sample (three replications) were cooked with 200 ml distilled water in stainless steel cooking utensil. Hot box solar cooker with double reflector (Nahar, 2001) 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 have been fixed over it with a wooden frame, which can be opened. Two 4 mm thick plane mirror reflectors were fixed over it. Four cooking utensils of 200 mm diameter can be kept inside it for cooking four dishes simultaneously. 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.

Raw, LPG, microwave and solar cooked samples of wheat. Maize, and barley are shown in Figure 1.

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 minutes 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^{o}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 minutes. 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

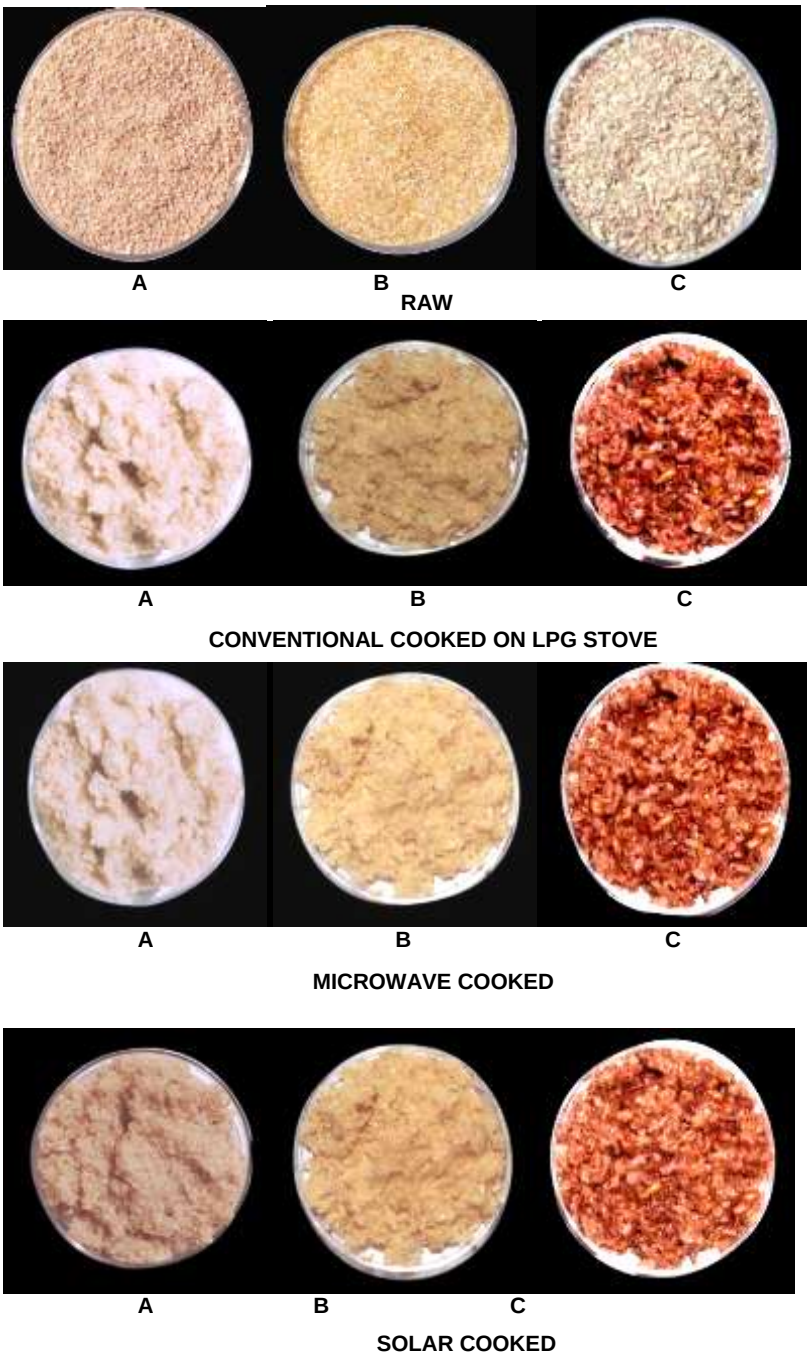

Figure 1: Food samples of broken wheat, maize, barley respectively, as raw, conventional, microwave, and solar cooked

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 of (Clegg, 1955). 4 ml 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 minutes. 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

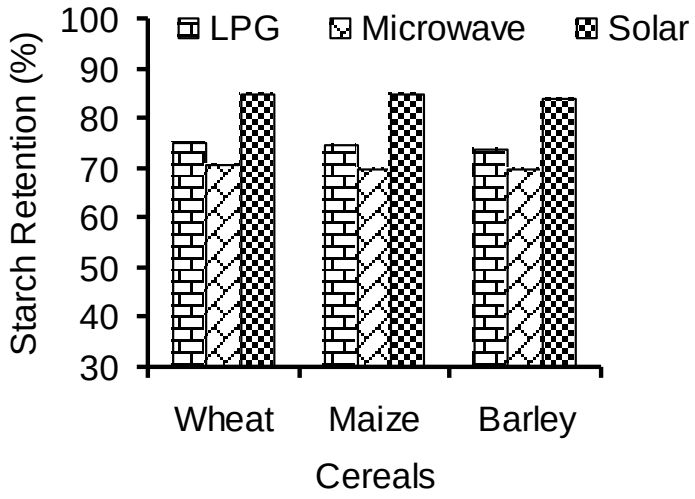

Figure 2: Retention of starch in cereals in LPG microwave and solar cooking

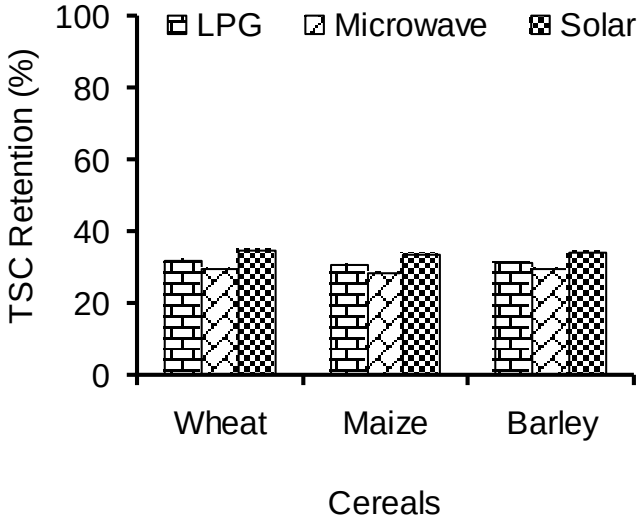

Figure 3: Retention of TSC in cereals in LPG microwave and solar cooking

minutes, 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 are 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 H2SO4 = 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

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

Where,

A = volume (ml) of 0.1 N sulphuric acid consumed

B = weight of sample taken for analysis (i.e. 0.5 g)

Determination of minerals

Preparation of ash for calcium and iron

Wet ash method was used for 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 et al, 1975).

The calcium content was calculated by using the following formula

Meq./litre of Ca^{++} = ml versanate solution (EDTA) required x Normality of versanate solution

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 sample and checked for 0 setting. Calibration curve was prepared from readings of standards The concentration of samples were determined from the standard graph.

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

RESULTS AND DISCUSSION

Time taken for cooking broken wheat, maize and barley each 100 gm by conventional cooking, microwave cooking and solar cooking is shown in Table 1.

The average time (three replications) taken for cooking by LPG stove was between 20 to 25 minutes, cooking by microwave oven was between 5 to 6 minutes and 75 to 90 minutes for solar cooking.

Temperature Variation while Cooking in Solar Cooker

The average temperature (three replications) at the time of loading in solar cooker was 115^{o} C, which was reduced to 90^{o} C after loading and again increased to 105^{o} C when cooking, was complete.

Biochemical Analysis of cereals for Nutrient values

Carbohydrates

Carbohydrates are a class of energy yielding substances by the process of respiration and include starch, glucose, sucrose, lactose etc. Roots and tubers 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 source of energy in the body. Carbohydrates

Tables 1: Duration of cooking time in selected foods

	Time taken (minutes)		
Type of Food	Conventional cooking	Microwave cooking	Solar cooking
Broken wheat	20	5	75
Broken maize	22	5	75
Broken barley	25	6	90

Table 2: Mean starch content in different cereals in raw, conventional, microwave and solar cooked

	Starch (g/100g)			
Type of food	Raw	Conventional cooked	Microwave cooked	Solar cooked
Broken Wheat	41.52	31.14 (75.00)	29.47 (70.98)	35.29 (85.00)
Broken Maize	38.43	28.74 (74.79)	26.90 (70.00)	32.64 (84.93)
Broken Barley	43.44	32.15 (74.01)	30.39 (69.96)	36.49 (84.00)
Mean	41.13	30.67 (74.6)	28.92 (70.31)	34.81 (84.63)
CD 5% for treatment		0.21		
CD 1% for treatment		0.28		
CD 5% for interaction		0.36		
CD 1% for interaction		0.49		

*Values in parenthesis indicate per cent retention

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 being no difference between starches derived from different sources.

Starch

The samples were analysed thrice and mean value of starch estimated in the broken wheat, maize and barley are shown in Table 2.

The mean value of starch content and % retention value of starch in conventional cooking, microwave and solar cooking in broken wheat, broken maize and broken barley are shown in Table 2, and Figure. 2. From the Table 2 and Figure. 2, the retention of starch was more in solar cooking as compared to conventional cooking and least in microwave cooking. In wheat 75.0%, 70.98 % and 85.00% starch was retained in, conventional cooking (LPG stove), microwave cooking and solar cooking respectively. For maize 74.79%, 70.00%, and 84.93% starch was retained in conventional cooking, microwave cooking and solar cooking respectively. Similarly in barley 74.01%, 69.96% and 84.00% starch was retained in conventional cooking, microwave cooking and solar cooking respectively.

Statistical analysis was carried out by applying F test. F values for different methods of cooking, cereals and their interaction with different methods of cooking with cereals were more than table values at 3, 2, 6 degrees of freedom and 24 error degrees of freedom at 1% level of significance. The ANOVA showed that there were significant differences between cooking methods, cereals and interaction of cereals with cooking methods (Table 3).

Critical difference (CD) value at 1% for treatments (methods of cooking) was 0.28 and for interaction was 0.49. Starch content with microwave cooking was 28.92% and it was significantly lower than conventional cooking (30.67%) and solar cooking (34.81%) as these values were more than 28.92 $\pm$ 0.28. Starch content with conventional cooking was 30.67% and it was significantly lower than solar cooking (34.81%) as this value was more than 30.67 $\pm$ 0.28. The maximum starch content was 43.44% in raw broken barley. There was significant decrease in starch content in all the three methods of cooking. Maximum loss was for microwave cooking while minimum loss was for solar cooking.

Table 3: ANOVA for starch contents in cereals with different methods of cooking

Source of variation	Degree of freedom	Mean sum of square	F
Treatment	3	264.79	5791.3**
Cereals	2	48.56	1062.0**
T X C	6	0.42	9.2**
Error	24	0.046	

** $p < 0.01$

Table 4: Mean total soluble carbohydrate content in different cereals in raw, conventional, microwave and solar cooked

Total soluble carbohydrate (g/100g)				
Type of food	Raw	Conventional cooked	Microwave cooked	Solar cooked
Broken Wheat	3.08	0.99	0.92	1.08
		-32.14	-29.87	-35.06
Broken Maize	2.56	0.79	0.73	0.87
		-30.86	-28.52	-33.98
Broken Barley	2.78	0.88	0.82	0.96
		-31.65	-29.5	-34.53
Mean	2.81	0.89	0.82	0.97
		-31.67	-29.18	-34.52
CD 5% for treatment		0.06		
CD 1% for treatment		0.08		
CD 5% for interaction		0.11		
CD 1% for interaction		0.14		

*Values in parenthesis indicate per cent retention

Total soluble carbohydrate

The samples were analysed thrice and mean value of total soluble carbohydrate estimated in the broken wheat, maize and barley are shown in Table 4.

The mean value of total soluble carbohydrate (TSC) content and % retention value of TSC in conventional cooking, microwave and solar cooking in broken wheat, broken maize and broken barley are shown in Table 4, and Figure. 3. From the table 4 and Figure. 3, the retention of TSC was more in solar cooking as compared to conventional cooking and least in microwave cooking. In wheat 32.14%, 29.87% and 35.06% TSC was retained in, conventional cooking (LPG stove), microwave cooking and solar cooking respectively. For maize 30.86%, 28.52%, and 33.98% TSC was retained in conventional cooking, microwave cooking and solar cooking respectively. Similarly in barley 31.65%, 29.50% and 34.53% TSC was retained in conventional cooking, microwave cooking and solar cooking respectively.

Statistical analysis was carried out by applying F test. F values for different methods of cooking, cereals and their interaction with different methods of cooking with cereals were more than table values at 3, 2, 6 degrees of freedom and 24 error degrees of freedom at 1% level of significance. The ANOVA showed that there were significant differences between cooking methods, cereals and interaction of cereals with cooking methods (Table 5).

CD value at 1% for treatments (methods of cooking) was 0.08 and for interaction was 0.14. TSC content with microwave cooking was 0.82% and it was significantly lower than solar cooking (0.97%) as this value was more than 0.82 ± 0.08. TSC content with conventional cooking (0.89%) was significantly lower than solar cooking (0.97%) at 5% level as this value was more than 0.89 ± 0.06. The maximum TSC content was 3.08% in raw broken wheat. There was significant decrease in TSC content in all the three methods of cooking. Maximum loss was for microwave cooking while minimum loss was for solar cooking.

Protein

Protein is vital to any living organism. Protein is important constituent of tissues and cells of the body. Protein forms the important component of muscle and

Table 5: ANOVA for total soluble carbohydrate contents in cereals with different methods of cooking

Source of variation	Degree of freedom	Mean sum of square	F
Treatment	3	8.252	2001.9**
Cereals	2	0.229	55.5**
T X C	6	0.02	4.9**
Error	24	0.004	

** $p < 0.01$

Table 6: Mean protein content in different cereals in raw, conventional, microwave and solar cooked

Protein (g/100g)				
Type of food	Raw	Conventional cooked	Microwave cooked	Solar cooked
Broken Wheat	11.24	10.92 (97.15)	10.77 (95.82)	11.08 (98.58)
Broken Maize	10.64	10.33 (97.09)	10.29 (96.71)	10.48 (98.5)
Broken Barley	10.84	10.54 (97.23)	10.48 (96.68)	10.69 (98.62)
Mean	10.91	10.6 (97.16)	10.51 (96.53)	10.75 (98.53)
CD 5% for treatment		0.11		
CD 1% for treatment		0.14		
CD 5% for interaction		0.18		
CD 1% for interaction		0.25		

*Values in parenthesis indicate per cent retention

other tissues and vital body fluids like blood. The protein in the form of enzymes and hormones are concerned with a wide range of vital metabolic process in the body. Protein supplies the body building material and helps in repair of wear and tear in the body. Protein is antibodies that help the body to defend against infection. Thus the 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 have to be supplied through the diet we consume regularly in order to perform various function of the body. The amount of protein in the diet is an important measure of adequacy and quality of a diet.

The samples were analysed thrice and mean value of protein estimated in the broken wheat, maize and barley are shown in Table 6.

The mean value of protein content and % retention value of protein in conventional cooking, microwave and solar cooking in broken wheat, broken maize and broken barley are shown in Table 6, and Figure. 4. From the table 6 and Figure. 4, the retention of protein was more in solar cooking as compared to conventional cooking and least in microwave cooking. In wheat 97.15%, 95.82% and 98.58% protein was retained in, conventional cooking (LPG stove), microwave cooking and solar cooking respectively. For maize 97.09%, 96.71%, and 98.50% protein was retained in conventional cooking, microwave cooking and solar cooking respectively. Similarly in barley 97.23%, 96.68% and 98.62% protein was retained in conventional cooking, microwave cooking and solar cooking respectively.

Statistical analysis was carried out by applying F test. F values for different methods of cooking, cereals and their interaction with different methods of cooking with cereals were more than table values at 3, 2, 6 degrees of freedom and 24 error degrees of freedom at 1% level of significance. The ANOVA showed that there were significant differences between cooking methods and cereals (Table 7).

CD value at 1% for treatments (methods of cooking) was 0.14 and for interaction was 0.25. Protein content with microwave cooking was 10.51% and it was significantly lower than solar cooking (10.75%) as this value was more than 10.51 $\pm$ 0.14. Protein content in conventional cooking was 10.60% and it was significantly lower than solar cooking (10.75%) as this value was more than 10.60 $\pm$ 0.14. The maximum protein content was 11.24% in raw broken wheat. There was significant decrease in protein content in all the three methods of cooking. Maximum loss was for microwave cooking while minimum loss was for solar 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 Chandrasekhar and Kowsalya (1998) in beans.

Minerals

A large number of minerals and trace metals are present in the body. Some of these form part of body structural

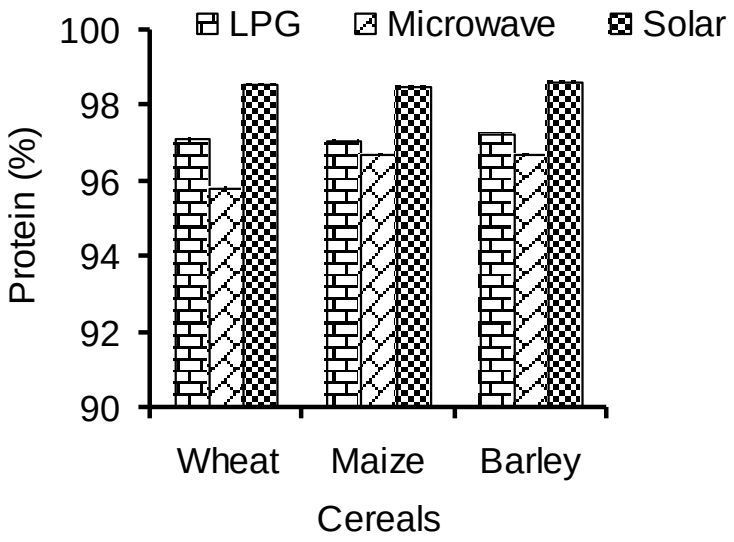

Figure 4: Retention of Protein in cereals in LPG microwave and solar cooking

Table 7: ANOVA for protein contents in cereals with different methods of cooking

Source of variation	Degree of freedom	Mean sum of square	F
Treatment	3	0.274	23.19**
Cereals	2	0.99	83.72**
T X C	6	0.003	0.27
Error	24	0.012	

** $p < 0.01$

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 and 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, for contraction of heart for its normal function, nervous activity and blood clotting. These later function are carried out by ionised calcium content in the cells. The calcium levels in the cells and plasma are well maintained. Calcium content in bones helps to maintain the calcium level in plasma in the face of dietary calcium deficiency leading to weak bones.

The samples were analysed thrice and mean value of calcium estimated in the broken wheat, maize and barley are shown in Table 8.

The mean value of calcium content and percentage retention value of calcium in conventional cooking, microwave and solar cooking in broken wheat, broken maize and broken barley are shown in Table 8, and Figure. 5. From the table 8 and Figure. 5, the retention of calcium was more in solar cooking as compared to conventional cooking and least in microwave cooking. In wheat 78.01%, 76.60% and 81.98% calcium was retained in, conventional cooking (LPG stove), microwave cooking and solar cooking respectively. For maize 79.04%, 78.35%, and 82.93% calcium was retained in conventional cooking, microwave cooking and solar cooking respectively. Similarly in barley 77.00%, 74.99% and 81.00% calcium was retained in conventional cooking, microwave cooking and solar cooking respectively.

Statistical analysis was carried out by applying F test. F values for different methods of cooking, cereals and their interaction with different methods of cooking with cereals were more than table values at 3, 2, 6 degrees of freedom and 24 error degrees of freedom at 1% level of significance. The ANOVA showed that there were significant differences between cooking methods, cereals and interaction of cereals with cooking methods (Table 9).

Table 8: Mean calcium content in different cereals in raw, conventional, microwave and solar cooked

	Calcium (mg/100g)			
Type of food	Raw	Conventional cooked	Microwave cooked	Solar cooked
Broken Wheat	39.06	30.47 (78.01)	29.92 (76.6)	32.02 (81.98)
Broken Maize	8.73	6.9(79.04)	6.84(78.35)	7.24 (82.93)
Broken Barley	24.43	18.81 (77)	18.32 (74.99)	19.79 (81)
Mean	24.07	18.73 (77.81)	18.36 (76.28)	19.68 (81.76)
CD 5% for treatment		0.14		
CD 1% for treatment		0.2		
CD 5% for interaction		0.25		
CD 1% for interaction		0.34		

*Values in parenthesis indicate per cent retention

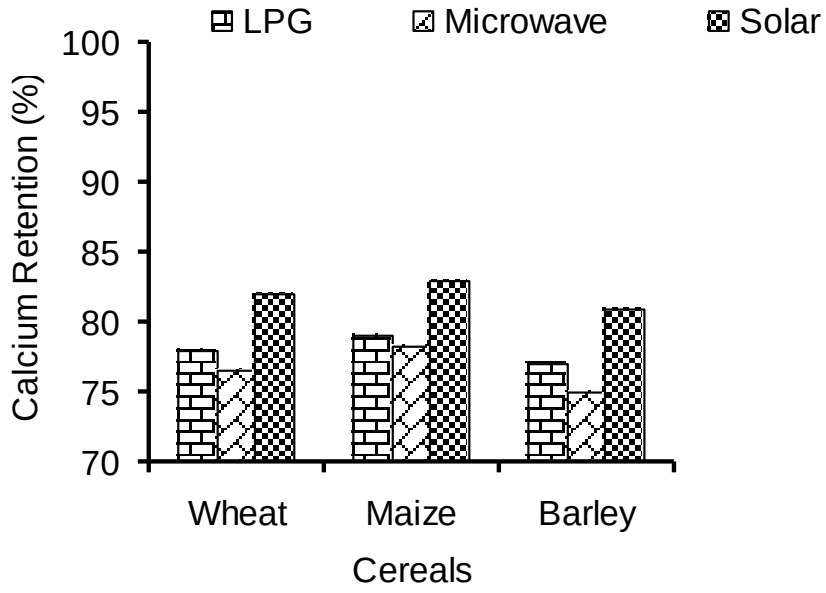

Figure 5: Retention of calcium in cereals in LPG microwave and solar cooking

Table 9: ANOVA for calcium contents in cereals with different methods of cooking

Source of variation	Degree of freedom	Mean sum of square	F
Treatment	3	62.49	27914.0**
Cereals	2	1941.98	86749.5**
T X C	6	8.41	375.5**
Error	24	0.022	

** $p < 0.01$

CD value at 1% for treatments (methods of cooking) was 0.14 and for interaction was 0.34. Calcium content with microwave cooking was 18.36 mg/100g and it was significantly lower than conventional cooking (18.73 mg/100g) and solar cooking (19.68 mg/100g) as these values were more than 18.36 $\pm$ 0.14. Calcium content with conventional cooking was 18.73 mg/100g and it was significantly lower than solar cooking (19.68 mg/100g) as this value was more than 18.73 $\pm$ 0.14. The maximum calcium content was 39.06 mg/100g in raw broken wheat. There was significant decrease in calcium content in all the three methods of cooking. Maximum loss was for

Table10: Mean iron content in different cereals in raw, conventional, microwave and solar cooked

	Iron (mg/100g)			
Type of food	Raw	Conventional cooked	Microwave cooked	Solar cooked
Broken Wheat	5.1	4.88 (95.69)	4.85 (95.1)	5.03 (98.63)
Broken Maize	2.12	2.01 (94.81)	1.97 (92.92)	2.07 (97.64)
Broken Barley	1.47	1.4 (95.24)	1.38 (93.88)	1.44 (97.96)
Mean	2.9	2.76 (95.17)	2.73 (94.14)	2.85 (98.28)
CD 5% for treatment		0.08		
CD 1% for treatment		0.11		
CD 5% for interaction		0.14		
CD 1% for interaction		0.19		

*Values in parenthesis indicate per cent retention

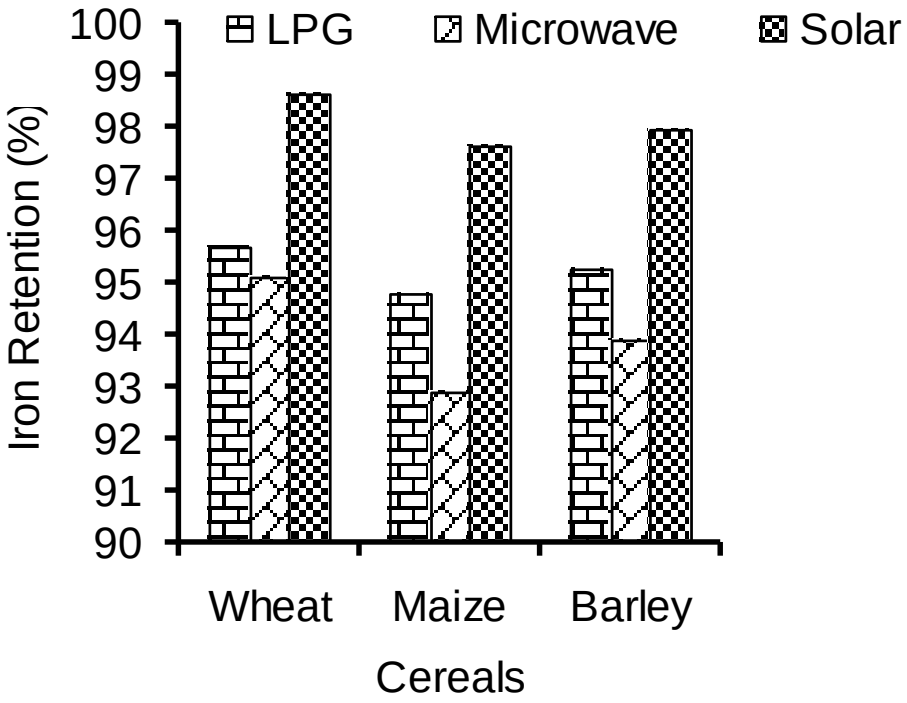

Figure 6: Retention of iron in cereals in LPG microwave and solar cooking

microwave cooking while minimum loss was for solar cooking. Similar results were obtained by Chandrasekhar and Kowsalya (1998) in carrot, beans and cabbage

Iron

Iron is an essential element for formation of haemoglobin of red blood cells 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 is utilised and some of the body iron is also stored in liver and spleen. The amount of iron to absorb 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.

The samples were analysed thrice and mean value of iron estimated in the broken wheat, maize and barley are shown in Table 10.

The mean value of iron content and percentage retention value of iron in conventional cooking, microwave and solar cooking in broken wheat, broken maize and broken barley are shown in Table 10, and Figure. 6. From the table 10 and Figure. 6, the retention of iron was more in solar cooking as compared to conventional cooking and least in microwave cooking. In wheat 95.69%, 95.10% and 98.63% iron was retained in, conventional cooking (LPG stove), microwave cooking and solar cooking respectively. For maize 94.81%,

Table 11: ANOVA for iron contents in cereals with different methods of cooking

	Mean sum of square		
Source of variation	Degree of freedom		F
Treatment	3	0.047	7.06**
Cereals	2	43.014	6428.01**
T X C	6	0.005	0.72
Error	24	0.006692	

** $p < 0.01$

92.9%, and 97.64% iron was retained in conventional cooking, microwave cooking and solar cooking respectively. Similarly in barley 95.24%, 93.88% and 97.86% iron was retained in conventional cooking, microwave cooking and solar cooking respectively.

Statistical analysis was carried out by applying F test. F values for different methods of cooking, cereals and their interaction with different methods of cooking with cereals were more than table values at 3, 2, 6 degrees of freedom and 24 error degrees of freedom at 1% level of significance. The ANOVA showed that there were significant differences between cooking methods and cereals (Table 11).

CD value at 1% for treatments (methods of cooking) was 0.11 and for interaction was 0.19. Iron content with microwave cooking was 2.73 mg/100g and it was significantly lower than solar cooking (2.85 mg/100g) as these values were more than 2.73 ± 0.11. Iron content with conventional cooking (2.76 mg/100g) was significantly lower than solar cooking (2.85 mg/100g) at 5 % level as this value was more than 2.76 ± 0.08.The maximum iron content was 5.10 mg/100g in raw broken wheat. There was significant decrease in iron content in conventional cooking and microwave cooking but there was no significant decrease in iron content in solar cooking. Maximum loss was for microwave cooking while minimum loss was for solar cooking. Similar results were obtained by Chandrasekhar and Kowsalya (1998) in different vegetables viz. amaranths, beans and cabbage.

Retention of nutrient in cereals viz. starch, total soluble carbohydrate, protein, calcium and iron were maximum in solar cooking because cooking was performed at low temperature, and were minimum in microwave cooking because cooking was performed at high temperature.

CONCLUSIONS

Comparative estimation of nutrients of different cereals by three methods of cooking i.e. conventional cooking on LPG stove, microwave cooking and solar cooking revealed that:

- The average time taken for cooking on LPG stove was between 20 to 450 minutes, cooking on microwave was between 5 to 8 minutes and it was 75 to 120 minutes for solar cooking.
- The average temperature at the time of loading in solar cooker was 115°C, which was reduced to 90° C after loading and again increased to 105° C when cooking was complete.
- Retention of starch in cereals was more in solar cooking as compared to conventional cooking and least in microwave cooking. In wheat 75.0%, 70.98% and 85.00 % starch was retained in, conventional cooking (LPG stove), microwave cooking and solar cooking respectively. For maize 74.79%, 70.00%, and 84.93% starch was retained in conventional cooking, microwave cooking and solar cooking respectively. Similarly in barley 74.01%, 69.96% and 84.00% starch was retained in conventional cooking, microwave cooking and solar cooking respectively. By applying F test it was found that there was significant decrease in starch content in all the three methods of cooking. Maximum loss was for microwave cooking while minimum loss was for solar cooking. Solar cooking is better than conventional cooking and microwave cooking for retention of starch in cereals.
- Retention of TSC was more in solar cooking as compared to conventional cooking and least in microwave cooking. In wheat 32.14%, 29.87% and 35.06% TSC was retained in, conventional cooking (LPG stove), microwave cooking and solar cooking respectively. For maize 30.86%, 28.52 %, and 33.98% TSC was retained in conventional cooking, microwave cooking and solar cooking respectively. Similarly in barley 31.65%, 29.50% and 34.53% TSC was retained in conventional cooking, microwave cooking and solar cooking respectively. By applying F test it was found that there was significant decrease in TSC content in all the three methods of cooking. Maximum loss was for microwave cooking while minimum loss was for solar cooking. Solar cooking is better than conventional cooking and microwave cooking for retention of TSC in cereals.
- Retention of protein was more in solar cooking as compared to conventional cooking and least in microwave cooking. In wheat 97.15%, 95.82% and 98.58% protein was retained in, conventional cooking (LPG stove), microwave cooking and solar cooking respectively. For maize 97.09%, 96.71%, and 98.50% protein was retained in conventional cooking, microwave cooking and solar cooking respectively. Similarly in

barley 97.23%, 96.68% and 98.62% protein was retained in conventional cooking, microwave cooking and solar cooking respectively. By applying F test it was found that there was significant decrease in protein content in all the three methods of cooking. Maximum loss was for microwave cooking while minimum loss was for solar cooking. Solar cooking is better than conventional cooking and microwave cooking for retention of protein in cereals.

- Retention of calcium was more in solar cooking as compared to conventional cooking and least in microwave cooking. In wheat 78.01%, 76.60% and 81.98% calcium was retained in, conventional cooking (LPG stove), microwave cooking and solar cooking respectively. For maize 79.04%, 78.35%, and 82.93% calcium was retained in conventional cooking, microwave cooking and solar cooking respectively. Similarly in barley 77.00%, 74.99% and 81.00% calcium was retained in conventional cooking, microwave cooking and solar cooking respectively. By applying F test it was found that there was significant decrease in calcium content in all the three methods of cooking. Maximum loss was for microwave cooking while minimum loss was for solar cooking. Solar cooking is better than conventional cooking and microwave cooking for retention of calcium in cereals.
- Retention of iron was more in solar cooking as compared to conventional cooking and least in microwave cooking. In wheat 95.69%, 95.10% and 98.63% iron was retained in, conventional cooking (LPG stove), microwave cooking and solar cooking respectively. For maize 94.81%, 92.92%, and 97.64% iron was retained in conventional cooking, microwave cooking and solar cooking respectively. Similarly in barley 95.24%, 93.88% and 97.86% iron was retained in conventional cooking, microwave cooking and solar cooking respectively. By applying F test it was found that there was significant decrease in iron content in conventional cooking and microwave cooking but there was no significant decrease in iron content in solar cooking. Maximum loss was for microwave cooking while minimum loss was for solar cooking. Solar cooking is better than conventional cooking and microwave cooking for retention of iron in cereals.

It can be concluded that the retention of different nutrients in cereals were more in solar cooking as compared to conventional cooking and least in microwave cooking.

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