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Effect of Roasting and Germination on Carbohydrates and Anti-nutritional Constituents of Indigenous and Exotic Cultivars of Pseudo-cereal *(Chenopodium)*

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ABSTRACT Effect of two domestic processing techniques of roasting and germination was seen on the carbohydrates and anti-nutritional constituents of two indigenous and two exotic cultivars of bathua seeds (*Chenopodium album*) (a pseudo cereal).The parameters studied were reducing sugars, non-reducing sugars, total sugars starch, energy, phytic acid, total phenol, simple phenol, tannins, Trypsin Inhibitor Activity (TIA) and flavonoid content. Results revealed that roasting and germination resulted in an increase in reducing sugars and total sugar content whereas a decrease was there in non-reducing sugars and starch content. The decrease in energy value was more in the roasted samples. The analysis of anti-nutrients revealed that total phenol and simple phenol content increased significantly with the germination whereas slight reduction was there in tannin content. The roasting of Chenopodium showed higher reduction in total phenol, simple phenol and tannin content when compared with raw and germinated seeds. The TIA and saponin was slightly reduced during germination and roasting. The phytic acid content was significantly (pd"0.05) reduced during roasting and germination of *Chenopodium* cultivars. The flavonoid content increased during germination thus increasing its anti-oxidative potential whereas roasting resulted in decrease in flavonoid content. The changes in these parameters were more in exotic varieties as compared to indigenous counterparts. Germination improved the nutritional quality of *Chenopodium*.

INTRODUCTION

Malnutrition, a major nutritional problem in India and other developing countries is responsible for about forty to fifty percent of the infant deaths all over the world (Singh et al. 2007). The major reason for this is an increasing gap between food supply and population growth. It is expected that world population will reach 9.3 billion by 2050, so food production increase is essential (Pritchard and Amthor 2005). In the present scenario it is important for diversification towards traditional crops because the current dependence on a few major crops may result in food scarcity. The new crops may provide reasonable productivity and reliability as well as nutritional and medicinal benefits. The current day need is to look upon novel high quality but inexpensive food sources and less familiar crops, which can play a vital role in this regard as their economic value is beyond dispute. These food resources include underutilized cereals, legumes, fruits and vegetables. The negligence of such lesser familiar crops is not due to their any inferior nutritional quality but due to lack of research resources in the place of origin and thus often scorned as "poor people's plants". But recently a resurgence of interest has developed in wild species because of their immense nutritional and medicinal values in diet.

These underutilized crops are also referred by other terms such as orphan, under-exploited, underdeveloped, new, novel, promising, neglected, alternative, pseudocrops or local crops. Some of these crops include *Chenopodium, amaranth*, *oca*, *kalazeera* and buckwheat, which are resistant to adverse climatic conditions and can be used to improve food supply as well as income. The one among such underutilized crop is genus *Chenopodium* (family Amaranthaceae and subfamily Chenopodiaceae) that has worldwide distribution and comprises of about 250 species. Some of the members of this genus are quinoa (*Chenopodiumquinoa*), *kaniwa* (*Chenopodium pallidicaule)*, fat hen (*Chenopodium album***)** also called as white goose foot, pigweed, dung weed, lamb's quarter, *bathua*), epa-

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zote (*Chenopodium ambrosides)*, and good king henry (*Chenopodium bonus-henricus*). It originated in the Andean region of Bolivia and Peru and is now grown and cultivated in various countries like America, Japan, Chile, Africa, India, Sri Lanka and Pakistan. The *Chenopodium* are tolerant to cold, drought and salinity and have potential for cultivation in marginal lands. In comparison to other cereals, *Chenopodium* has high nutritive value (Matiacevich et al. 2006). The grains of *Chenopodium* have abundance of essential amino acids, vitamins, minerals and high quality protein. *Chenopodium* also contains appreciable amount of lysine, which is generally deficient in cereals. Apart from its nutritive value, *Chenopodium* also has pharmaceutical properties. Its oil is effective against many intestinal parasites, abdominal pains and eye diseases and is also anti-helmintic, laxative and diuretic. The seeds are known to be hypocholestrolemic and hypoglycemic. Despite being such an important crop and having such a tremendous nutritional value, the *Chenopodium* is still under the category of underutilized crops. Two cultivars of *Chenopodium* that is indigenous and exotic are cultivated but much work has not been done on their analysis.

Objectives

Keeping in view its importance of *Chenopodium*, the present study was planned to see the effect of domestic processing techniques like roasting and germination on the carbohydrates and antinutritional constituents of indigenous and exotic cultivars pseudo-cereal *(Chenopodium).*

MATERIAL AND METHODS

Procurement of Material

Four cultivars of the *Chenopodium album*(two indigenous and two exotic) namely, IC 415477 (Ic_1), IC 107299 (Ic_2), EC 507742 (Ec_1) and EC 507733 (Ec_2) were procured from the National Bureau of Plant Genetic Resources (NBPGR), Regional Station, located at Shimla and were multiplied in the farms of CSKHPKV Krishi Vigayan Kendra Bajaura, Kullu Himachal Pradesh. The seeds were harvested after maturity and then brought to the laboratory Department of Food Science, Nutrition and Technology of College of Home Science of CSKHPKV, Palampur.

Preparation of Samples

The procured seed samples were then cleaned manually to remove adhering dirt, dust and foreign particles. The seeds of all four cultivars were ground in to a fine powder separately with the help of a stainless steel mixer grinder and were stored in airtight glass containers so as to prevent changes till further analysis. All the analysis was carried out in triplicate. The seeds were divided in to two lots. One lot was roasted and other was germinated.

Roasting

For roasting, *Chenopodoium* seeds were dropped in a preheated cauldron. The seeds were pressed and moved with the help of molded cloth until these were light brown in colour.

Germination

The *Chenopodium* seeds were steeped in potable tap water for 12 hours and the grain to water ratio (1:3) was such as to dip the seeds completely. The containers were then covered over with filter paper sheets. After 12 hours, the water was drained off and the grains were ready for subsequent germination. The soaked *Chenopodium* samples were kept in trays lined with wet sand beds of 2 cm thickness, covered with filter paper sheets and allowed to germinate. Grains took 72 hours for germination. Regular sprinkling of water at equal intervals was carried out to keep grains moist. After germination the grains were dried in a dryer and were ground to fine powder and stored.

Chemical Analysis

Starch in seeds of *Chenopodium* cultivars was determined by the method of Clegg (1956). The sugars (including total reducing and non reducing sugars) in seeds were estimated by standard method of AOAC (1990). Phytic acid was determined by the method of Haugh and Lantzch (1983). The oxalates in the seeds were analyzed by the method following Abaza et al. (1968). The saponin content in samples was analyzed according to the method given by Obadoni and Ochuko (2001). The flavonoid in the sample of various *Chenopodium* cultivars was determined by the method given by Boham and

Kocipia (1994). Alkaloids were determined by the method given by Harborne (1973) with little modification by Obadoni and Ochuko (2001). Tannins were determined by the method of Makkar et al. (1993). Trypsin inhibitor activity was estimated by the modified method of Ray and Rao (1971). One unit of trypsin was defined as amount of enzyme, which converted 1mg casein to TCA soluble component at 37^0C for 20 minutes at 7.6 pH. One unit of inhibitory activity is that which reduces the activity of trypsin by one unit under assay condition. Energy in the sample was determined by chromic oxide method of O'Shea and Maguire (1962).

Statistical Analysis

The experiments were carried out in triplicate and the data so obtained was subjected to Analysis of Variance (ANOVA) using statistical package WINDOWSTAT 8.0 available in the Department of Physical Sciences and Languages, College of Basic Sciences CSKHPKV Palampur. The obtained data was interpreted following Sendecor and Cochran (1994) and compared at a five percent level of significance ($P \leq 0.05$).

RESULTS AND DISCUSSION

Total Phenols

Phenols exhibit antioxidant potential due to their redox properties, which allow them to act as reducing agents, hydrogen donators and single oxygen quenchers. It is clear from Table 1 that the total phenol content was significantly ($P \leq 0.05$) higher in germinated *Chenopodium* cultivars when compared to roasted and untreated *Chenopodium* cultivars. The decrease in total phenol content during roasting might have been due to thermal degradation and binding of total phenols with other compounds (proteins) or the alteration in the chemical structure of phenols, which cannot be extracted and determined by the available methods (Miranda et al. 2010). However, the increase in total phenol content during germination might have been due to many metabolic activities and changes such as an increase in the activity of the endogenous hydrolytic enzymes may occur in the seeds during germination process. Similar results of an increase in total phenol content during germination in quinoa seeds have been reported by Jubete et al. (2010).

Simple Phenols

A broad range of phenolic compounds occur in the food products especially those coming from the plant material, in which they contribute to the organoleptic properties, that is, astringency, beer hazes, specific coloration and off-flavor. The effects of the dietary phenolic compounds are of great interest due to their antioxidative, cardiovascular protective, anti-allergic, anti-inflammatory, antiviral and anti-carcinogenic activities. The highest simple phenol content was there in germinated Ic_2 cultivar (106.00 mg GAE/100g) and lowest in roasted Ec_2 cultivar (19.88 mg GAE/100g) (Table 1). It is clear from the data the simple phenol content increased significantly in germinated cultivars when compared with untreated and roasted *Chenopodium* cultivars. Roasting of *Chenopodium* cultivars led to decrease in simple phenol content when compared to raw *Chenopodium* cultivars. The increase in simple phenol content during germination may be attributed due to the metabolic changes going on inside the seeds such as hydrolysis of high molecular weight insoluble polymers in to small molecular weight soluble polymers, which might lead to the synthesis of phenols and solubilization as grain took water. Elkhalifa and Tinay (1999) also found increase in phenols during germination in sorghum cultivars. The decrease in simple phenol content during roasting might have been due to the enzymatic and thermal degradation of simple phenols leading to the conversion of simple phenols to some other form due to polymerization.

Tannins

The polyphenolic compounds such as tannins form complexes with dietary proteins and also with digestive enzymes. As is clear from the data (Table 1), highest tannin content was present in untreated cultivars when compared with roasted and germinated *Chenopodium* cultivars. Roasting of the *Chenopodium* cultivars lead to significant reduction in tannin content however during germination there was slight reduction in tannin content when compared to untreated. The maximum tannin content was present in untreated Ec_1 cultivar (378.84 mg GAE/100g) and mini-

Table 1: Effect of roasting and germination on anti-nutritional content of *Chenopodium (Bathua)* cultivars

Treatment/ Attribute	*Total Phenol (mg GAE/ 100g)*	*Simple Phenol (mg GAE/ 100g)*	*Tannins (mg GAE/ 100g)*	*TIA (TIU/mg)*	*Saponin (g/100g)*	*Phytic Acid (g/100g)*	*Flavonoid (mg/100g)*
Untreated							
Ic_1	352.21	34.68	317.54	1.18	0.27	1.32	113.33
Ic_2	387.43	36.54	350.89	1.72	0.43	1.19	93.33
Ec_1	405.0	30.82	378.84	1.0	4.07	1.03	123.33
Ec_2	205.0	28.25	176.75	1.26	0.93	1.27	133.33
Roasted							
Ic_1	255.52	25.64	229.88	1.09	0.19	1.17	97.72
Ic_2	293.51	27.67	265.83	1.64	0.38	0.96	83.70
Ec_1	311.81	21.38	290.43	0.81	3.81	0.86	111.31
Ec_2	146.38	19.88	126.49	1.19	0.90	1.05	126.95
Germinated							
Ic_1	414.64	103.39	311.25	1.06	0.07	0.93	129.57
Ic_2	447.51	106.00	341.51	1.61	0.26	0.76	103.61
Ec_1	473.10	100.65	372.46	0.86	1.17	0.65	128.49
Ec_2	267.20	99.07	168.13	1.18	0.50	0.91	147.87
LSD at 5%	3.36	1.02	3.65	0.09	0.13	0.07	2.23

mum in roasted Ec_2 cultivar (126.49 mg GAE/ 100g). The highest tannin content in untreated sample might have been due to the reason that it is one of the anti-nutritional factors present in husk portion. Since no treatment is given to raw sample therefore maximum tannins are there. The decrease in tannin content during heat treatment might have been due to thermal degradation and denaturation of the anti-nutrient as well as formation of insoluble complexes. Moreover, heat treatment also leads to the activation of polyphenol oxidase, which is responsible for the loss of tannins. While slight reduction in tannins due to germination might have been due to the reason that tannins are present in outer coat of seed, which gets ruptured during germination, moreover new complexes are also formed during germination and some losses are also due to leaching of tannins in soaking water. Joshi (2005) reported decrease in tannin content during roasting and germination of fenugreek seeds.

Trypsin Inhibitor Activity (TIA)

TIA is an anti-nutritional factor present in plant foods, which is responsible for reduced digestibility in human system. Its activity must be destroyed to improve digestibility. The trypsin inhibitor activity in untreated seeds of Ic_2 *Chenopodium* cultivar was found to be high, that is, 1.72 TIU/mg, which reduced slightly during roasting and germination (Table1). The lowest value was found in roasted Ec_1 cultivar, that is, 0.81 TIU/mg. A significant ($P \leq 0.05$) difference was observed in trypsin inhibitor activity when untreated *Chenopodium* cultivars were compared with roasted and germinated *Chenopodium* cultivars. Roasting resulted in decrease of TIA, which might have been due to the reason that trypsin inhibitors are heat labile and during roasting heat treatment is applied thus leading to its reduction. The decrease in trypsin inhibitor during germination might have been due to leaching out of solids against concentration gradient governing diffusion. According to Saharan et al. (2002), the TIA content reduced during germination in faba bean and rice bean because they are low molecular weight protein and hence they are likely to pass out from the seed to the soaking medium easily, moreover the decrease during germination might also be due to mobilization and breakdown of chemical constituents including trypsin.

Saponins

Saponins are nitrogen free glycosides each consisting of a sapogenin and a sugar. The sapogenin may be a steroid or a triterpene and the sugar is generally glucose, galactose, pentose or methyl pentose. They impart bitter taste and tend to foam in aqueous solution. It is evident from the data in Table 1 that the maximum saponin content was present in untreated Ec_1 cultivar (4.07 g/100g) and minimum in germinated Ic_1 cultivar (0.07 g/100g). Significantly ($p \leq 0.05$) low-

er saponin content was there in germinated *Chenopodium* cultivars when compared with untreated cultivars whereas non-significant difference was observed when it was compared with roasted *Chenopodium* cultivars. The reduction in saponin content during roasting might have been due to thermal sensitivity. Anwa et al. (2007) also reported reduction in saponin content of *Albizzia lebbeck* seeds during roasting. The loss of saponin during germination might have been due to leaching of these organic compounds in soaking water and enzymatic degradation. Saharan et al. (2002) found decrease in saponin content of faba bean and rice bean during germination.

Phytic Acid

Phytic acid is one of the anti-nutritional factors present in plant foods. It affects the digestion and absorption of minerals. It is clear from the Table 1 that germination resulted in a decrease in phytic acid content. A significant ($p \leq 0.05$) difference in phytic acid content was observed when germinated *Chenopodium* counterparts were compared with untreated and roasted counterparts. Roasting and germination decreased the phytic acid content of *Chenopodium* cultivars when compared with untreated samples. The decrease in phytic acid content during roasting might have been due to the reason that they are heat labile and thus lost during roasting. The decrease in phytic acid content during germination can be attributed to leaching of phytate ions into soaking water under the influence of concentration gradient and also due to hydrolytic activity of phytase reported to be present in many plant foods. Joshi (2005) also reported decrease in phytic acid content of fenugreek seeds during germination and roasting.

Flavonoids

Flavonoids, a secondary plant metabolite,are a natural antioxidant, which helps **in** maintaining the body's health and protect it against diseases. However, nutritionally flavonoid is considered as an anti-nutrient as its polyphenol structure is a metal chelator, and therefore capable of binding iron and facilitating its removal from the body. The flavonoid content increased during germination of the grains whereas roasting of the grains led to reduction in flavonoid content when compared with untreated sample (Table 1). A significant ($p \leq 0.05$) difference was observed in untreated, roasted and germinated cultivars when were compared with each other. The decrease in the flavonoid content during roasting might have been due to the heat labiality of specific flavonoids because of some chemical characteristics. The increase in flavonoid content during germination might have been due to metabolic changes occurring inside the seed. Pasko et al. (2008) and Jubete et al. (2010) also reported increase in flavonoid content during germination of *Chenopodium quinoa* seeds and thus increasing its antioxidant potential.

Reducing Sugars

A glance at Table 2 reveals that a significant ($p \leq 0.05$) difference was there in reducing sugar content when roasted and germinated *Chenopodium* cultivars were compared with untreated cultivars. Higher reducing sugar content was present in germinated seeds in comparison to roasted and untreated seeds. This increase in reducing sugar content during germination might have been due to the reason that carbohydrates consists primarily of low molecular weight oligosaccharides particularly sucrose, raffinose and stachyose. Total sugars mostly representing the non-reducing sugars are acted upon by á galactosidases, which gets activated during germination. So, breakdown of non-reducing sugars results in increased formation of reducing sugars (Sinha et al. 2002). However, increase of reducing sugar content during roasting might have been due to the biochemical changes taking place during heating as a result complex carbohydrates are broken down in to simple sugars. Akintosotu and Akinyele (1991) reported that germination increased starch digestibility and sucrose, fructose, glucose and galactose contents while oligosaccharides content decreased.

Non-reducing Sugars

As is clear from the data in Table 2 that a significant ($p \leq 0.05$) difference was there in non-reducing sugar content of *Chenopodium* cultivars when untreated cultivars were compared with roasted and germinated cultivars. The roasting and germination of *Chenopodium* cultivars lead to decrease in non-reducing sugar content.

Table 2: Sugars, starch and energy content of roasted and germinated *Chenopodium (Bathua)* cultivars

Treatment /Attribute	*Reducing sugar (% glucose)*	*Non-reducing sugar (% Sucrose)*	*Total sugar (% Sucrose)*	*Starch (%)*	*Energy (Kcal/100g)*
Untreated					
Ic_1	1.48	1.91	3.39	55.33	386
Ic_2	1.02	2.13	3.16	58.93	385.49
Ec_1	1.24	2.12	3.36	62.67	380.09
Ec_2	1.62	2.26	3.88	52.13	386.61
Roasted					
Ic_1	2.1	1.39	3.49	53.33	377.93
Ic_2	2.27	0.95	3.23	55.11	373.9
Ec_1	2.3	1.14	3.44	60.1	375.35
Ec_2	2.4	1.53	3.93	49.09	383.53
Germinated					
Ic_1	2.22	1.55	3.93	42.55	340.26
Ic_2	2.37	1.19	3.77	45.68	338.42
Ec_1	2.47	1.48	3.95	49.78	335.52
Ec_2	2.42	1.68	4.1	40.01	341.39
LSD at 5%	0.09	0.09	0.15	1.04	5.22

The decrease in non-reducing sugar content of roasted grains might have been due to bio-chemical changes taking place during heating as a result complex carbohydrates are broken down in to simple sugars. The decrease in non-reducing sugar content of germinated grains might have been due to the result of seed respiration and hydrolysis of starch, which is converted to simpler sugars like glucose and maltose, (reducing sugars). Sinha et al. (2002) reported decrease in non-reducing sugar content of cowpea during germination due to its breakdown by enzymes in to reducing sugars.

Total Sugars

The data pertaining to total sugar content of roasted and germinated *Chenopodium* reveals that the maximum total sugar was present in germinated Ec_2 cultivar (4.10%) and minimum in roasted Ic_2 cultivar (3.23%) (Table 2). A significant ($p \leq 0.05$) difference was observed in total sugars when roasted Ic_1, Ic_2 and Ec_1 cultivar were compared with their germinated counterparts. However, a non-significant difference was observed when roasted Ec_2 cultivar was compared with germinated Ic_1 and Ec_1 cultivar but varied significantly ($p \leq 0.05$) from Ic_2 and Ec_2 cultivar. The increase in total sugar content on germination can be attributed to increased activity of á amylase and rapid depletion of starch, which may probably account for the increase of total sugar during germination. Whereas, roasting resulted in an increase in total sugars content might have been due to the biochemical changes taking place during heating as a result complex carbohydrate are broken in to simple sugars. Gupta (1995) also reported an increase in total sugar content during germination and roasting of faba beans.

Starch

It is evident from the Table 2 that the highest starch content was present in untreated samples whereas roasting and germination lead to a decrease in starch content. A significant ($P \leq 0.05$) difference was there in starch content when untreated *Chenopodium* cultivars were compared with its roasted and germinated counterparts. Reduction of starch content caused by germination may be due to activation of amylase enzyme during germination thus resulting in hydrolysis of starch. However, a decrease in starch content during roasting might have been due to the breakdown of carbohydrates because of heat therefore reduction in starch content and conversion to sugars. Sharma and Kapoor (1997) also reported reduction in starch content of pearl millet due to action of amylase enzyme on starch. Joshi (2005) also found reduction in starch content of roasted and germinated fenugreek.

CONCLUSION

The two processing methods that is roasting and germination are also beneficial in improving the nutrient scores of the *Chenopodi-*

um seeds. The wide variation among the cultivars for quality attributes has shown ample potential, which can be exploited for further quality. *Chenopodium* seeds after processing can be used for consumption and value addition.

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