Common Buckwheat: Nutritional Profiling of Grains

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ABSTRACT

Buckwheat is economically important smaller millet grown primarily for carbohydrates and protein content. In this study, biochemical composition of 14 promising genotypes of buckwheat grown in Sangla region of Himachal Pradesh were analysed. The grain weight, moisture content, crude protein, total soluble protein, crude fat (ether extract), ash, crude fibre, carbohydrates, methionine, tryptophan, in vitro protein digestibility and oxalate in genotypes ranged from 18.8 to 26.8g, 10.2 to 10.9%, 10.4 to 15.1%, 9.4 to 13.3%, 1.7 to 2.8%, 1.49 to 2.45%, 6.1 to 9.2 %, 62.0 to 67.9%, 57.9 to 103.4 mg/gN, 62.2 to 79.2 mg/gN, 66.7 to 79.5% and 98 to 152mg/100g, in that order. Based on cumulative grading of nutritionally desirable qualities, the genotypes VL-27 and PRB-9001 followed by S-B

INTRODUCTION

About 1 billion people are currently suffering from chronic hunger and malnutrition, while it is predicted that world food production needs to increase by 70% by 2050 to satisfy 9.9 billion predicted population in the world, relying on a natural resource base that is reaching its limits and with climate change adding further pressures on agriculture and acting as the main driver of crop diversity loss. Besides, adoption of monoculturing practices and biased technological development and its usage is practised for a few high-energy-demanding plant species only. Consequently, world food security and economic growth are dependent on a handful of crops, which has placed future food supply and rural income at risk. Even though mankind over time has been using more than 10,000 edible species, today about 150 species only are being commercialized significantly at the global level, out of which just 12 species meet the major nutritional (80% dietary energy) requirements, and the 60% protein and calorie requirements are met by just four species: rice, wheat, maize and potato (FAO, 2005). The limited use of a few crops for maximum economic benefits has profound environmental consequences. There is a need for new approaches to ensure food and nutrition security. These should be sustainable, resilient, and practical solutions. According to the Food and Agriculture Organization (FAO), neglected, underutilized, or orphan crops (NUCs) are plant species which for social, agronomic, or biological reasons have lost their importance over the 500 years. The original function of some neglected crops or their potential uses have been marginalized along the time; others have practically been forgotten. They constitute plant species which played a fundamental role in the agriculture and food supply of indigenous peoples and local communities. These alternative crops were traditionally used for their food, fiber, fodder, oil, or medicinal properties. These crops possess immense potential in the food, health and energy sectors besides providing opportunities for employment generation.

Buckwheat (Fagopyrum sp.) is cultivated worldwide for its seeds (achenes), which are consumed and often referred to as pseudocereal. Common buckwheat (Fagopyrum esculentum Moench) is one of the traditional crops cultivated in the world. In 2013, buckwheat production worldwide was 2.3 million tons (FAOSTAT, 2013). Buckwheat is a crop originating in the southwest China. Although buckwheat production is concentrated in China, Japan and North America, it is also produced in Europe, India, Tibet, Tasmania, Australia, Argentina, Bhutan and numerous other countries (Kreft and Germ, 2008). In India, the crop is grown from Jammu and Kashmir in the west to Arunachal Pradesh in the east. It is becoming popular in the state of Himachal Pradesh, Uttarakhand and Jammu and Kashmir due to suitable climate. The hilly areas of Himachal Pradesh represent several diverse eco-geographic cultivation region which are more suitable for cultivation of hardy crops specifically related to small millets along with pseudocereals like amaranthus, buckwheat and chenopods. In the state of Himachal Pradesh, buckwheat is grown in Kinnaur, Lahul Spiti and Sirmour districts. Since, the crop is adapted to temperate climate; hence, Himachal Pradesh can play an important role in production of this crop.

There is large pool of promising germplasm available in the country in general and in different parts of Himachal Pradesh with special reference to Sangla region of the State, which can be utilized to much extent for nutritional security of the vulnerable population groups. To achieve this objective, an organized biochemical approach is essential to select nutritionally superior genotypes to serve as parents or to isolate and identify well established crop varieties with higher protein content and quality. Therefore,
the screening of buckwheat genotypes to harness quality protein potential of germplasm seems to be essential. Since the quality of dietary protein is predominantly governed by the content of the essential amino acids in appropriate quantity and proportion, digestibility and status of anti-nutritional factors, it would be worthwhile to evaluate the amino acids status particularly methionine and tryptophan of buckwheat grains. For more reliable indexing of the protein quality, besides essential amino acid make up, evaluation of grain protein digestibility (in vitro) of buckwheat genotypes would also be desirable.

MATERIALS AND METHODS

Fourteen different genotypes of common buckwheat (*Fagopyrum esculentum* Moench) for two years were selected for this investigation: S-B-201, S-B-212, S-B-214, VHC-27, VL-27, Kullu gangetri, IC-323731, Hassoska, Emka, PRB-9001, USDA-1, VL-7, PRB-1 and OC-2 collected from different places of sangla region of Distt. Kinnaur (Himachal Pradesh) were used in the present study. The seeds of these genotypes were collected from Mountain Agriculture Research and Extension Centre (MAREC), Sangla, CSK HPKV, Palampur. The present study was carried out in the Dept. of Chemistry and Biochemistry, College of Basic Sciences, CSK HPKV, Palampur. The finely ground grain samples of these genotypes were analyzed in triplicate for seed coat colour, grain weight, moisture, crude protein, total soluble protein, fat, ash, crude fibre, carbohydrates, methionine, tryptophan, *in vitro* protein digestibility and anti-nutritional factor oxalate. The grain coat colour of each of buckwheat genotypes / varieties was noted visually. One thousand grains from each genotype were taken at random and weighed in triplicate separately. The average weight was recorded, which represented the 1000-grain weight in grams. The finely ground grain samples of these genotypes were analyzed in triplicate for moisture, crude protein, ash and crude fibre by AOAC method (1970); fat (ether extract) by AOAC (1965); total soluble protein by Bradford, 1976; methionine content by Horn *et al.* , 1946; tryptophan content by Mertz *et al.*, 1975; *In vitro* protein digestibility by Akeson and Stahman, 1964 and Oxalate by Abaza *et al.*, 1968. Data was analyzed statistically by using analysis of variance (Panse and Sukhatme 1984).

RESULTS AND DISCUSSION

Grain coat is the overall reflection of the visual acceptability of the food grains. The grain coat colour of buckwheat genotypes varied from dark brown to blackish brown (Table 1).

The grain weight is an important yield contributing trait and therefore, the variations in grain weight of buckwheat genotypes was recorded (Table 1). Significant variation in 1000-grain weight was observed to vary from 17.7 to 26.0 g during the first year. The genotype IC-323731 exhibited the highest value for this parameter. The variety OC-2, Emka, PRB-9001, Hassoska and USDA-1 (being statistically at par) recorded the next higher values. However, the lowest value for 1000-grain weight was recorded in the genotype PRB-1. During the second year, the variation was observed from 20.10 to 26.80 g. The highest value was exhibited by IC-323731 and VL-27 (being statistically at par), whereas the lowest value was shown by PRB-1 and S-B-214. Overall performance taken together during the two consecutive years showed the range of variation from 18.8 to 26.80 g. The genotype IC-323731 exhibited consistently the highest value followed by Emka. Varieties PRB-9001, USDA-1, VL-7, PRB-1 and OC-2 exhibited 25, 24.7, 22.7, 18.8 and 25.6 g, respectively.

Bonafaccia *et al.* (1994) reported variation in the 1000-grain weight from 25.40 to 28.70 g in five buckwheat samples selected from different geographical areas of Italy. Joshi and Paroda (1991) reported 100-seed weight range from 1.2 to 5.0 g among different collections and findings of the present work on this aspect are in accordance with variability pattern reported by these researchers.

The status of moisture content roughly indicates the degree of maturity and accumulation of different nutrients in food crops. It is an important criterion contributing towards

### Table 1: Variation in Grain coat colour, grain weight (g), moisture Content (%) of buckwheat genotypes.

| Genotypes  | Source     | Grain colour | 1000-grain weight | Moisture Content |
|------------|------------|--------------|-------------------|-----------------|
|            |            |              | I\(^{1}\) year | II\(^{1}\) year | Mean | I\(^{1}\) year | II\(^{1}\) year | Mean |
| S-B-201    | Sangla     | Dark Brown   | 23.2            | 22.1            | 22.7 | 10.2          | 10.1          | 10.2 |
| S-B-212    | Sangla     | Dark Brown   | 19.9            | 23.1            | 21.5 | 10.3          | 10.6          | 10.5 |
| S-B-214    | Sangla     | Dark Brown   | 22.1            | 20.5            | 21.3 | 10.9          | 10.6          | 10.8 |
| VHC-27     | Almora     | Dark Brown   | 24.4            | 24.1            | 24.3 | 10.8          | 10.4          | 10.6 |
| VL-27      | Almora     | Dark Brown   | 23.6            | 26.1            | 24.9 | 10.4          | 10.1          | 10.3 |
| Kullu gangetri | Sangla | Dark Brown   | 23.0            | 22.6            | 22.8 | 10.7          | 10.2          | 10.5 |
| IC-323731  | Sangla     | Dark Brown   | 26.0            | 26.8            | 26.4 | 10.4          | 10.6          | 10.5 |
| Hassoska   | Sangla     | Dark Brown   | 24.7            | 24.7            | 24.7 | 10.7          | 11.2          | 10.9 |
| Emka       | Sangla     | Dark Brown   | 25.6            | 25.9            | 25.8 | 10.6          | 10.7          | 10.7 |
| PRB-9001   | Ranichauri | Dark Brown   | 25.0            | 25.0            | 25.0 | 10.4          | 10.6          | 10.5 |
| USDA-1     | Kukumseri  | Dark Brown   | 24.6            | 24.7            | 24.7 | 10.3          | 11.4          | 10.9 |
| VL-7       | Almora     | Blackish Brown | 23.1           | 22.2            | 22.7 | 10.3          | 10.4          | 10.4 |
| PRB-1      | Ranichauri | Dark Brown   | 17.7            | 20.1            | 18.8 | 10.9          | 10.6          | 10.8 |
| OC-2       | Sangla     | Dark Brown   | 26.0            | 25.1            | 25.6 | 10.7          | 10.2          | 10.5 |
| SE (+m)    |            |              | 0.07            | 0.04            | 0.02 | 0.08          | 0.11          | 0.02 |
| CD (5%)    |            |              | 1.5             | 0.8             | 0.49 | 0.16          | 0.24          | 0.04 |
acceptable of the crop harvest. Values in respect of moisture content in grains of buckwheat genotypes presented in Table 1 were observed to range from 10.2 to 10.9 per cent in first year and 10.1 to 11.4 per cent in second year. The genotype S-B-214 and USDA-1 showed the highest moisture content in the first and second year, respectively. The genotype S-B-201 showed the lowest value for moisture content during both years of study. Based on performance of genotypes during the two years of experimentation, the range of variation was found from 10.2 to 10.9 per cent. It is notable that Hassoska and USDA-1 ranked first in order of merit. The values obtained in the present investigation in the released varieties viz., PRB-9001, VL-7, PRB-1 and OC-2 were found as 10.5, 10.4, 10.8 and 10.5 per cent, accordingly.

Considering the importance of dietary protein in human nutrition, the status of crude protein content among various buckwheat genotypes was evaluated. The performance of different buckwheat genotypes in respect of protein content obtained from grains during the Ist year is presented in Table 2. It is evident that protein content varied significantly from 10.1 to 15.2 per cent and genotype Hassoska showed the highest value for crude protein content followed by the genotype OC-2, which were statistically at par with each other. However, the lowest value was exhibited by PRB-9001 and VL-27. A perusal of data presented in Table 2 on crude protein percentage in the second year revealed that protein content in different buckwheat genotypes differed significantly ranged from 10.1 to 14.9 per cent. The protein content was consistently higher in genotype Hassoska followed by OC-2 and PRB-1 (both were statistically at par with each other). The lowest value was showed by PRB-9001.

The mean values of both the years for crude protein content were observed to vary from 10.4 to 15.1 per cent in dry mature grains of buckwheat. The lowest value was exhibited by IC-323731 and variety PRB-9001. However, Hassoska contained highest protein content followed by varieties OC-2 and PRB-1. The rest of the genotypes differed significantly between each other. Varieties USDA-1 and VL-7 showed 13.8 and 12.1 per cent crude protein content, respectively.

The true protein in any food stuff reflects the sum total of exclusively amino acids content of the respective proteins. The total soluble protein content of buckwheat genotypes for two years of experimentation are presented in Table 2. During the first year, protein content varied from 9.5 to 13.4 per cent and it was notable that genotypes PRB-1 and Hassoska ranked first in this parameter. During the second year, the soluble protein content ranged from 9.2 to 13.2 per cent. The lowest value was exhibited by IC-323731, whereas the highest value was given by the genotype PRB-1. Genotypes PRB-1 and Hassoska maintained their same rank during both the years in order of excellence.

Average performance taken together during two consecutive years showed significant range of variation from 9.4 to 13.3 per cent. The released varieties PRB-1 and Hassoska (statistically at par) secured first rank and appeared to be promising in this character. The released varieties OC-2 and USDA-1 stood second position in order of merit which was statistically at par when compared with each other. The genotypes IC-323731 and VL-27 scored the lowest value in that order. The released varieties PRB-9001 and VL-7 exhibited 9.6 and 11.3 per cent soluble protein.

Values for fat (ether extract) of different buckwheat genotypes for the two consecutive years of experimentation are depicted in Table 2. It is evident that the genotype S-B-201 showed the highest value (2.9%) followed by VL-27 and Hassoska (statistically at par) during the first year. During the second year, fat content varied from 1.63 (VL-27) to 2.8 (S-B-201) per cent.

Average performance of the genotypes for this parameter during the two consecutive years revealed the range of variation from 1.7 to 2.8 per cent. The genotype S-B-201 exhibited the highest value followed by VL-27, the latter being statistically at par with Hassoska. Variety VL-7

### Table 2: Variation in Crude Protein, total soluble Protein, Fat and Ash content (%) of buckwheat genotypes.

| Genotypes      | Crude Protein | Total Soluble Protein | Fat (ether extract) | Ash |
|----------------|---------------|-----------------------|---------------------|-----|
|                | 1st year      | 2nd year  | Mean | 1st year | 2nd year | Mean | 1st year | 2nd year | Mean | 1st year | 2nd year | Mean |
| S-B-201        | 10.7          | 11.7      | 11.2  | 9.5       | 10.5      | 9.9  | 2.9       | 2.8       | 2.8  | 2.4       | 2.4       | 2.4  |
| S-B-212        | 14.3          | 13.9      | 14.1  | 12.4      | 12.0      | 12.2 | 1.6       | 2.0       | 1.8  | 2.2       | 2.2       | 2.2  |
| S-B-214        | 13.5          | 12.9      | 13.2  | 11.9      | 11.5      | 11.8 | 2.0       | 2.2       | 2.1  | 2.2       | 2.2       | 2.2  |
| VHC-27         | 13.0          | 13.5      | 13.3  | 11.5      | 11.0      | 11.3 | 2.1       | 2.0       | 2.1  | 2.3       | 2.3       | 2.3  |
| VL-27          | 10.7          | 10.9      | 10.8  | 9.6       | 9.3       | 9.4  | 2.5       | 2.4       | 2.5  | 2.3       | 2.3       | 2.3  |
| Kullu gangetri | 11.9          | 11.6      | 11.7  | 10.1      | 10.6      | 10.3 | 1.8       | 2.1       | 1.9  | 2.5       | 2.4       | 2.5  |
| IC -323731     | 10.8          | 10.1      | 10.4  | 9.5       | 9.2       | 9.4  | 2.0       | 1.9       | 1.9  | 1.4       | 1.7       | 1.5  |
| Hassoska       | 15.2          | 14.9      | 15.1  | 13.4      | 13.1      | 13.2 | 2.5       | 2.3       | 2.4  | 1.5       | 1.9       | 1.7  |
| Emka           | 14.5          | 13.9      | 14.2  | 12.1      | 12.2      | 12.1 | 1.9       | 2.0       | 1.9  | 1.8       | 1.8       | 1.8  |
| PRB-9001       | 10.1          | 11.0      | 10.5  | 9.5       | 9.7       | 9.6  | 2.1       | 2.0       | 2.1  | 2.3       | 2.5       | 2.4  |
| USDA-1         | 14.2          | 13.5      | 13.8  | 12.9      | 12.0      | 12.5 | 2.2       | 2.2       | 2.2  | 1.6       | 1.3       | 1.5  |
| VL-7           | 12.1          | 12.0      | 12.1  | 11.3      | 11.2      | 11.3 | 1.7       | 1.6       | 1.7  | 2.3       | 2.2       | 2.3  |
| PRB-1          | 14.6          | 14.1      | 14.4  | 13.4      | 13.2      | 13.3 | 2.0       | 1.9       | 1.9  | 2.1       | 2.1       | 2.1  |
| OC-2           | 14.8          | 14.3      | 14.6  | 12.8      | 12.3      | 12.6 | 2.1       | 2.0       | 2.1  | 1.9       | 1.9       | 1.9  |
| SE (±m)        | 0.29          | 0.09      | 0.05  | 0.35      | 0.08      | 0.06 | 0.33      | 0.10      | 0.05 | 0.26      | 0.05      | 0.04 |
| CD (5%)        | 0.6           | 0.19      | 0.11  | 0.71      | 0.17      | 0.12 | 0.69      | 0.22      | 0.11 | 0.54      | 0.11      | 0.08 |
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contained lowest fat content. The remaining released varieties viz. PRB-9001, USDA-1, PRB-1 and OC-2 showed 2.1%, 2.2%, 1.9% and 2.1% per cent fat content, respectively.

Ash content of a foodstuff represents inorganic residue remaining after destruction of organic matter. The data for ash content of buckwheat genotypes for two years are presented in Table 2. In the first year, genotype Kullu gangetri gave the highest ash content while the lowest value was observed in IC-323731 with the overall range of variation from 1.4 to 2.5 per cent. During the second year, the ash content of various genotypes ranged from 1.3 to 2.5 per cent. It is remarkable that genotype Kullu gangetri gave the highest and maintained first position during both the years of investigation.

The average values for both the years of experimentation, showed significant variation in ash content to range from 1.49 to 2.45 per cent in the grains of buckwheat genotypes. The genotypes Kullu gangetri, PRB-9001 and S-B-201 emerged promising genotypes for this parameter. However, the lowest value was exhibited by USDA-1, which was statistically at par with IC-323731. The study indicated that varieties VL-7, PRB-1 and OC-2 showed 2.3, 2.1 and 1.9 per cent, ash content on this aspect.

Crude fibre content of various buckwheat genotypes is depicted in Table 3. In the first year, the crude fibre content varied from 6.0 to 9.3 per cent and S-B-214 gave the highest value, while the lowest was showed by S-B-212, which had statistically at par value with S-B-201. The next highest value was given by VHC-27.

During the second year, the data differed significantly for this parameter and the range of variation was observed from 6.2 to 9.0 per cent. The highest crude fibre was recorded in case of genotype S-B-214. The next highest value was given by VHC-27 and OC-2, values of which were statistically at par with each other. The lowest value was exhibited by S-B-212 and S-B-201. The average performance of various genotypes taken together during the two consecutive years showed the range of variation from 6.1 to 9.2 per cent in dry mature grains of buckwheat. It is remarkable that genotype S-B-214 possessed the highest value in both the years. The second position was occupied by VHC-27, which was statistically at par with variety OC-2 and the third position was maintained by the genotype Emka. It was further observed that the genotypes PRB-1, IC-323731, PRB-9001 and Hassoska were statistically at par when compared with each other.

The lowest content of crude fibre was exhibited by S-B-212 and S-B-201. The values obtained in the present investigation in the released varieties PRB-9001, USDA-1, VL-7 and PRB-1 were found 7.7, 7.2, 7.4 and 7.8 per cent, accordingly for this quality parameter.

Carbohydrates a readily available prominent source of biological energy and perform various structural and metabolic functions in the body. In view of the dietary significance of this important dietary component the status of carbohydrates in buckwheat genotypes were evaluated and the pertinent data are presented in Table 3. The mean values of carbohydrates during both the years of experimentation observed to vary significantly from 62.0 to 67.9 per cent in dry mature grains of buckwheat. The highest value for carbohydrates content was observed in IC-323731 and the lowest in Hassoska. The study indicated that released varieties i.e., PRB-9001, USDA-1, VL-7, PRB-1 and OC-2 exhibited carbohydrates content was 66.8, 64.6, 66.3, 62.9 and 67.2 per cent.

Kusano et al. (1983) evaluated the proximate composition and observed that moisture, protein, lipid, carbohydrates and ash content varied from 11.0 to 11.5, 15.1
to 16.3, 6.1 to 6.9, 73.3 to 74.7 and 3.5 to 3.9 per cent on dry weight basis, accordingly when the nutritive components of tetraploid buckwheat grains in comparison to those of diploid seed. The range of variation in respect of these parameters of proximate analysis have also been reported by these investigators; Bonafaccia et al.,1994; Tang, 2007; Wang et al., 1995; Bonafaccia et al., 2003; Li and Zhang, 2001; Steadman et al., 2001.

Methionine is sulfur containing essential amino acid. The genotypic performance of buckwheat in respect of methionine content for the two years of experimentation is presented in Table 3. A persual of the data revealed that significant variation in methionine content among various buckwheat genotypes. Methionine content of buckwheat genotypes evaluated during the first year showed the range of variation from 55.4 to 104.7 mg/g N. It was observed that genotypes PRB-9001 and VL-27 (statistically at par) possessed higher value of methionine over others. The lowest content of methionine was observed in variety OC-2, which was statistically at par with the Hassoska.

During the second year, methionine showed significant variation from 60.4 to 102.2 mg/g N. The variety OC-2 exhibited the lowest value, whereas the genotype PRB-9001 possessed the highest value followed by VL-27, Emka and USDA-1. The genotypes Emka and USDA-1 were statistically at par with each other.

On the basis of average performance taken together during the two years of experimentation, the range of variation was observed from 57.9 to 103.4 mg/g N and varieties OC-2 and PRB-9001 gave the lowest and highest values, respectively. Genotypes VL-27, Emka, USDA-1 and IC-323731 stood second, third, fourth and fifth in order of preference which differed significantly among themselves. The genotypes Kullu gangetri and S-B-214 were statistically at par, when compared with each other. The values obtained in the present investigation in the released varieties viz., VL-7 and PRB-1 were found 86.2 and 84.9 mg/g N, accordingly.

Tryptophan is an essential amino acid involved in various metabolic processes in the body. Evaluation of genotypes for tryptophan content revealed significant variation from 60.9 to 78.2 mg/g N and 63.5 to 80.1 mg/g N in the first and second year of investigation, accordingly (Table 3). S-B-212 and PRB-1 gave the lowest and highest tryptophan content uniformly during both the year(s) of study. The next higher value was observed as Emka and OC-2 consistently in both the year(s).

The mean values in respect of tryptophan content in grains of buckwheat genotypes for two year of investigation were observed to range from 62.2 to 79.2 mg/g N. Variety PRB-1 showed the highest value closely followed by Emka (statistically at par). The genotypes OC-2, VL-27 and USDA-1 exhibited the next higher value for tryptophan content. The genotypes USDA-1, Hassoska and VL-7 were statistically at par with each other. The genotype S-B-212 showed the lowest value of tryptophan content. S-B-201 and Kullu gangetri were statistically at par when compared with each other, while all other genotypes differed significantly among each other. The released varieties i.e., PRB-9001 and VL-7 exhibited 70.1 and 75.1 per cent tryptophan content, respectively.

Robinson (1980) reported methionine content was 0.15 per cent in grain and 0.21 per cent in groat, while tryptophan content was 0.14 per cent in grain and 0.19 per cent in buckwheat groat samples when the average amino acid concentrations in buckwheat was evaluated. The overall status of methionine and tryptophan content noticed in the present study was found very close to the range earlier reported by other investigators in this crop (Marshall and Pomeranz, 1982; Thacker et al., 1984; Bonafaccia et al., 1994; Wang et al., 1995; Karlubik et al., 1997 and Zheng et al.,1998).

Chemical composition and amino acid profile give only an approximation of protein quality. Actual biological utilization of the protein must be determined using biological feeding trials or by enzymatic hydrolysis of proteins and evaluation of digestible nitrogen of plant proteins. Keeping this aspect in view the in vitro protein digestibility of buckwheat genotypes was evaluated and pertinent data are presented in Table 4.

Table 4: Variation in in vitro protein digestibility (%), Oxalates (mg/100g) content of buckwheat genotypes.

| Genotypes     | 1st year | 2nd year | Mean  | 1st year | 2nd year | Mean  |
|---------------|----------|----------|-------|----------|----------|-------|
| S-B-201       | 78.0     | 75.0     | 76.5  | 103.0    | 93.0     | 98.0  |
| S-B-212       | 65.0     | 68.3     | 66.7  | 100.3    | 98.0     | 99.2  |
| S-B-214       | 77.0     | 75.3     | 76.2  | 135.0    | 130.0    | 132.5 |
| VHC-27        | 78.4     | 75.4     | 76.9  | 109.0    | 110.0    | 109.5 |
| VL-27         | 78.8     | 80.1     | 79.5  | 108.0    | 105.0    | 106.5 |
| Kullu gangetri| 75.4     | 74.2     | 74.8  | 107.7    | 105.0    | 106.3 |
| IC-323731     | 78.3     | 75.2     | 76.7  | 106.0    | 100.0    | 103.0 |
| Hassoska      | 74.8     | 70.8     | 72.8  | 143.0    | 140.0    | 141.5 |
| Emka          | 73.6     | 72.6     | 73.1  | 140.0    | 150.0    | 145.0 |
| PRB-9001      | 78.5     | 80.2     | 79.4  | 103.0    | 99.0     | 101.0 |
| USDA-1        | 70.8     | 68.2     | 69.5  | 101.3    | 104.0    | 102.7 |
| VL-7          | 73.0     | 72.0     | 69.4  | 101.3    | 104.0    | 102.7 |
| PRB-1         | 68.5     | 70.2     | 69.4  | 126.0    | 117.0    | 121.5 |
| OC-2          | 71.8     | 74.7     | 73.2  | 155.0    | 149.0    | 152.0 |
| SE (±m)       | 0.82     | 0.47     | 0.21  | 0.85     | 3.38     | 1.36  |
| CD (5%)       | 1.6      | 0.9      | 0.43  | 1.7      | 6.9      | 2.74  |
In vitro protein digestibility of buckwheat genotypes during the first year varied from 65.0 to 78.8 per cent. The highest and lowest values were given by the genotype VL-27 and S-B-212, respectively. It was observed that the genotypes differed significantly. The next higher values was exhibited by genotypes PRB-9001, VHC-27, IC-323731 and S-B-201 which were statistically at par with the highest value. During the second year, genotypes showed a range of 68.2 to 80.2 per cent. USDA-1 scored the lowest value and was statistically at par with S-B-212. The genotype PRB-9001 and VL-27 (being statistically at par) showed the highest value.

On the basis of overall performance during the two years of experimentation, the significant range of variation was observed from 66.7 to 79.5 per cent. It was observed that VL-27 and PRB-9001 (statistical at par) possessed higher value of in vitro protein digestibility followed by VHC-27, IC-323731 and S-B-201 (statistically at par). The lowest value was showed by S-B-212 for this quality character. The released varieties viz., USDA-1, VL-7, PRB-1 and OC-2 exhibited 69.5, 72.5, 69.4 and 72.3 per cent protein digestibility.

Gupta and Sehgal (1991) and Guo et al. (2006), reported the trend of variation for this parameter as 80.22 to 84.43 per cent in cereals and pulses mixtures and 81.2, 79.6, 66.9 and 58.1 per cent in different protein fractions of Chinese tartary buckwheat, respectively and the results of the present study on this aspect found in close proximity with Eggum et al. (1981) and Dietryoh-szostak and Ploszynski (1986), who have observed variation on this aspect from 78.9 to 88.3 per cent.

Oxalate is a toxic substance and important health risk. A high dietary oxalate intake plays a key role in secondary hyperoxaluria, a major risk factor for calcium oxalate stone formation as it reduces the intestinal absorption of calcium and magnesium and impair the bioavailability of a number of trace elements due to the formation of insoluble complexes (Hesse and Siener, 1997).

The performance of buckwheat genotypes for two years of experimentation for their oxalate content is depicted in Table 4. The data of first year showed a significant variation of 100.3 to 155.0 mg/100g and the genotypes S-B-212 and OC-2 gave the lowest and highest values, respectively. Genotypes S-B-212 and USDA-1 were statistically at par with each other. The values for this parameter conducted during second year ranged from 93.0 (S-B-201) to 150.0 (Emka) mg/100g. Genotypes S-B-201, S-B-212 and PRB-9001 were statistically at par with each other.

The mean oxalate content for two years of study showed that the genotypes differed significantly among themselves. The range of variation of oxalate content was noticed from 98 to 152 mg/100g. Variety OC-2 gave the highest oxalate content followed by Emka, Hassoska and S-B-214. However, S-B-201 and S-B-212 (statistically at par) giving the lowest value and were considered as promising genotype for this anti-nutritional factor. The genotypes IC-323731, USDA-1 and PRB-9001 were statistically at par when compared with each other. The released varieties i.e., PRB-9001, USDA-1, VL-7 and PRB-1 exhibited 101, 102.7, 115.5 and 121.5 per cent oxalate content, in that order. The
findings of the present study with regard to oxalate content among the different genotypes of buckwheat in close proximity with the range (56.7 to 178 mg/100g) reported by Siener et al., 2006.

**Varietal grading in search of versatile/multipurpose genotypes**

During the course of study, it was noticed that none of the varieties/genotypes were excellent in each and every parameter. To identify overall nutritionally superior versatile varieties/genotypes, the entire genotypes under study were graded for their overall excellence to strike a balance of maximum superiority among different characters, although some of the characters had to be sacrificed. Therefore, grading of genotypes for prominent desirable quality characters viz., protein, carbohydrate, crude fibre, amino acid- methionine and tryptophan and in vitro protein digestibility as well as undesirable constituents i.e., oxalates of various buckwheat genotypes was done and the pertinent information in this aspect is presented in Table 5.

It was observed that the genotypes VL-27 and PRB-9001 occupied the first and second place, while genotypes S-B-201, Emka, VHC-27 and IC-323731 scored third, fourth and fifth position respectively in order of preference based on cumulative genotypic grading. Status of biochemical constituents of these promising varieties/genotypes is shown in Table 5. It may be expounded that the genotypic grading made it convenient to identify versatile/multipurpose genotypes suited for their direct inclusion in the human diet. The study opened an option for nutritional improvement.

In the accompanying work, genotypes / varieties showed differences of varying magnitude in respect of various biochemical parameters. Variations in biochemical constituents among various genotypes might be attributed to inherited genetic character of individual genotype / variety, soil texture, environmental factors such as nutrition, location and other agro-climatic variables altogether influencing both crop productivity and quality traits. Sinha (1977) described the different environmental factors which have a modifying effect on hereditability of varieties for certain characters and concluded that soil fertility, plant population, location, season etc. are some of the causes of alterations. As such, it would be desirable that the genotypes / varieties described in the text are evaluated further for their location specific consistent.

**CONCLUSION**

The wide variations among genotypes for quality attributes have shown ample potential which can be exploited for further quality improvement. This variability observed is due to both genetic and environmental factors which may influence the individual chemical composition of the grain and legumes. In all the study indicated wide range of variability in individual biochemical parameter(s) of nutritional significance to be useful to the plant breeders and those engaged in pseudocereals quality improvement. The information related to nutritional and anti-nutritional factors would also be of great value for the researchers in varietal selection programmes and will make the people aware of this legume for using it in their routine cuisine. This will also help in utilising underutilised crops as affordable source of nutrition.

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