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# Variability for protein content and determination of other physical seed Quality characteristics in Released sorghum varieties of Ethiopia

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**Sixteen sorghum varieties were grown in a randomized complete block design with three replications at Sirinka Agricultural Research Center and Kobo sub-center with the objectives of determining variability for protein content among released sorghum varieties and evaluating other physical seed quality characteristics of the varieties. The varieties used in the study are released by Sirinka Agricultural Research Center and Melkassa Agricultural Research Center in various years. The seeds for laboratory works were taken from the two central rows of the plots. Determination of grain protein content, tannin detection, grain color classification, endosperm texture classification and determination of germinative energy of each variety were undertaken at Haramaya University, Food Science and Technology Department Laboratory and protein content was subjected to analysis of variance. Analysis of variance for protein content revealed no statistically significant difference among the varieties at both locations. In terms of mean value performance, the varieties showed variable mean values at the two locations which ranged from 7.99-12.48 % and 11.29-14.71 % at Sirinka and Kobo respectively. With these ranges, the varieties showed higher grand mean value at Kobo (12.71 %) than at Sirinka (9.88 %). The highest value of protein content was obtained from Gedo followed by Abshire, Redswazi and Birhan and from Misikr followed by Birhan, 76T1#23 and Abshir at Sirinka and Kobo, respectively. Protein content also showed low genotypic variance and genotypic coefficient of variation than their corresponding environmental variance and environmental coefficient of variation with medium phenotypic coefficient of variation both at Sirinka and Kobo. Similarly, it resulted low (< 40 %) estimated value of heritability with low genetic advance expressed as percent of mean at both locations. From the bleach test, condensed tannin was obtained only from Red Swazi which was indicated by its black color over its entire surface and the rest 15 varieties are tannin free. Most (11 in number) of the varieties also showed corneous, the rest 5 intermediate endosperm texture and no variety showed floury texture. Except Tegemeo, all the other varieties have high (> 90%) enough germinative energy which enable them to be malted. Excluding Red Swazi and Birhan, all other varieties are also white in color which enables them to provide acceptable non colored food products**.

**Key words:** Protein, GCV, Heritability, Genetic advance, Tannin, Endosperm Texture, Germinative Energy

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## INTRODUCTION

Sorghum (*Sorghum bicolor* (L) Moench) is an important cereal crop belonging to the grass family Poaceae. It is one of the most important crops in Africa, Asia and Latin America (Anglani, 1998). Ethiopia is the third largest sorghum producer in Africa next to Nigeria and Sudan (CAC, 2011). In Ethiopia, it is among the top four cereal crops (teff, wheat, maize) in terms of area coverage and volume of production (CSA, 2005). The grain of sorghum is used for human consumption and beverages such as Injera, porridge, "Nefro", infant food, syrup, "Tella", and "Arekie". Some genotypes of sorghum can be "malted" to produce a nutritious foodstuff for infants and for use in bakery products. Sorghum grain is as nutritious as other cereal grains; contains about 11% moisture, 11.6% protein, 73% carbohydrate and 3% fat by weight (Hiebsch and O' Hair, 1986). The crop is a principal source of energy and protein for millions of the world's poorest (Wong *et al*., 2009). However, a well-identified and important problem with sorghum is its comparably poor nutritional quality in that the protein of cooked sorghum is significantly less digestible than that of other cooked cereals (Axtell *et al*., 1981; Maclean *et al*., 1981; Hamaker *et al*., 1987; Mertz *et al*., 1984 and Rom *et al*., 1992) presumably through the formation of strong protein cross-links that occur during cooking of the sorghum. A major scientific Axtell's finding was the discovery and identification of factors responsible for the reduced protein availability or digestibility in grain sorghum (Axtell *et al*. 1979). The presence of tannins conferred to the sorghum grain resistance to both bird damage and weathering. Certain genotypes of sorghum contain condensed tannins in the seed coat layer beneath the pericarp of the grain (Taylor and Taylor, 2008). The grain has variable levels of protein content of 11.6% (Hiebsch and O'Hair, 1986), 7-15% (FAO, 1995; Beta *et al*., 1995) and 6.8-13.6% (Sauberlich *et al*., 1953). Factors such as environment and cultivar are known to cause variations in protein content of sorghum grains (Miller *et al*., 1964). With the expanding use of irrigation, fertilization and hybrid seed in farming practices, the protein content of sorghum grain may vary more than formerly. Wide variability has been observed in the essential amino acid composition of sorghum protein, probably because the crop is grown under diverse agro climatic conditions which affect the grain composition (FAO, 1995). The presence of variation in the germplasm for the trait of interest is, therefore, very important. Estimation of the magnitude of variation within germplasm collections for important plant attributes will enable breeders to exploit genetic diversity more efficiently. Therefore, the present study was conducted to determine variability for protein content among released sorghum varieties and to evaluate other physical seed quality characteristics of the varieties.

## MATERIALS AND METHODS

Sixteen released sorghum varieties (Table 1) were grown in a randomized complete block design (RCBD) with three replications during the 2010 main season at Sirinka Agricultural Research Center (altitude 1850 meter above sea level, average annual rainfall 1023 mm and average maximum and minimum temperature is 26 °C and 13 °C) and Kobo sub center (altitude 1468 meter above sea level, average annual rainfall 310.5 mm and average maximum and minimum temperature is 14.86 °C and 29.30 °C). The data for rainfall and temperature of the locations are obtained from their respective meteorological stations. The experimental unit was a four-row plot of 3 m long, spaced at 0.75 m apart and plant-to-plant distance of 0.15 m. Urea (50kg/ha) and phosphorus (100 kg/ha) were applied to the entire plot. The seeds for laboratory works were taken from the two central rows of the plot and determination of grain protein content, tannin detection, grain color classification, endosperm texture classification and determination of germinative energy were undertaken at Haramaya University, Food Science and Technology Department Laboratory.

Grain protein content (%) was determined by micro Kjeldahl method of nitrogen analysis. The method consists of digestion, distillation and titration processes which is used as standard and universal method for crude protein analysis in food samples. The sorghum flour sample was weighed (ca. 0.5 g) on analytical balance into the digestion flask. The sample was digested by addition of 5 ml of concentrated $H_2SO_4$ as an oxidizing agent and 1g mixture of catalyst $K_2SO_4$ mixed with hydrous $CuSO_4$ in the ratio of 10:1. Digestion converts any nitrogen in flour to ammonia and other organic matter to $CO_2$ and $H_2O$. After digestion was completed, NaOH (40 %) was added to neutralize and to make the solution slightly alkaline. The ammonia was then distilled in to receiving flask that consists of a solution of 4% boric acid for reaction with ammonia. Finally, the amount of borate ion released by the reaction with ammonia distilled out was indirectly titrated with standardized HCl (ca. 0.1 M) solution. Urea was used as a control in the analysis and percentage of nitrogen was estimated as: Nitrogen % $= \frac{\text{V HCl in L X M HCl (Ca.0.1) X 14.00}}{\text{Sample weight on dry matter basis}} \text{X } 100$ Where V is volume of HCl in L consumed to the end point of titration, M is molarity of HCl and 14.00 is the molecular weight of nitrogen. Finally, percentage protein (obtained as % Protein = % N X 6.25 where 6.25 is a conversion factor) was subjected to analysis of variance (ANOVA) for each individual locations and Duncan's Multiple Range Test was used for mean comparison.

The phenotypic and genotypic variance of protein content was estimated according to the methods suggested by Burton and de Vane (1953) and these components of variance ($\sigma^2p$, $\sigma^2e$, $\sigma^2g$) were used for the estimation of coefficients of variation (PCV, GCV) as described by Singh and Chaudhary (1977) as: PCV= $\frac{\sqrt{\delta^2 P}}{x} x\ 100$ and GCV= $\frac{\sqrt{\delta^2 g}}{x}$ X100.

Heritability and expected genetic advance (K=2.06 at 5% selection intensity) of protein content were computed based on the formula developed by Allard (1960).

**Table 1:** Description of the test materials.

| S.N | Variety | Pedigree | Year of release | Breeder/maintainer |
|---|---|---|---|---|
| 1 | Gedo | Gambella1107X p-9403 | 2007 | SRARC |
| 2 | Red Swazi | NA | 2007 | MARC |
| 3 | Macia | NA | 2007 | MARC |
| 4 | Raya | PGRC/EX222878 XKAT369-1 | 2007 | SRARC |
| 5 | Misikir | PGRC/E#69441 X P-9401 | 2007 | SRARC |
| 6 | Girana-1 | CR: 35XDJ 1195 X N-13 | 2007 | SRARC |
| 7 | Hormat | ICSV 1112 BF | 2005 | SRARC |
| 8 | Abshir | P-9403 | 2000 | SRARC |
| 9 | Gobye | P-9401 | 2000 | SRARC |
| 10 | Meko | M-36121 | 1997 | MARC |
| 11 | 76T#23 | NA | 1979 | MARC |
| 12 | Birhan | Key # 8566 | 2002 | SRARC/ |
| 13 | Teshale | 3443-2-op | 2002 | MARC/SRARC |
| 14 | Yeju | ICSV 111Inc | 2002 | SRARC |
| 15 | Abuare | 90 MW 5353 | 2003 | SRARC |
| 16 | Tegemeo | NA | NA | MARC |

Source: MoARD (2007, 2008). NA=not available, SRARC= Sirinka Regional Agricultural Research Center; MARC= Melkassa Agricultural Research Center

The grain tannin of sorghum varieties was detected by bleach test. To do so, sorghum grain was immersed in a beaker containing alkaline commercial bleach solution (5g NaOH dissolved in 100ml of 3.5% sodium hypochlorite solution) and incubated at room temperature (25 °C) for 20 minutes. Finally, the bleaching reagent was discarded and the grain was dried on sheets of paper. Tannin bearing grain sorghum varieties were identified as black pigmented testa layer and the non-tannin sorghums as the absence of black pigmented testa layer as described by Waniska *et al*., 1992. For classification of grain color, grain was viewed by naked eye and classified as white or colored. In order to classify endosperm texture, sorghum grains were cut into halves longitudinally and one half was viewed with the naked eye. On the basis of the relative proportion of corneous to floury endosperm texture (scored on a 1-5 scale where 1 represented completely corneous), sorghum grain endosperm was classified as corneous, Intermediate and floury. Germinative energy was estimated by taking 100 intact sorghum grains in duplicate and allowed to germinate on a moist filter paper (4 ml) placed in a closed petridish incubated at 25 $^{o}$C and about 100% relative humidity (EBC, 1987). After 24, 48 and 72 hours, the grains were examined and at each time interval, the germinated grains, grains where the root has penetrated the pericarp, were counted and removed from the petridish. Finally, percentage of germinated grains was calculated at each time interval and germinative energy was taken as the mean of the duplicate determinations, expressed as a whole number (%).

## RESULTS AND DISCUSSION

### 1. Grain Protein content

The results of analysis of variance are presented in Table 2. The trait protein content showed non-significant difference (P=0.05) among the sixteen sorghum varieties both at Sirinka and Kobo. Ng'uni *et al*, 2012 also reported that their ANOVA revealed no significant differences for protein content of fourteen sorghum accessions, six from Malawi, four from Tanzania and four from Zambia. This indicated the existence of narrow genetic variability for protein content among the sorghum germplasm and low probability of improvement of this trait through selection. Our ability to improve the nutritional quality (defined as the content of essential amino acids) of sorghum grain protein by classical plant breeding is limited by the low level of variation in the gene pool available for crossing. Therefore, genetic engineering offers an opportunity to overcome this limitation by introducing wild type or mutant genes from other organisms.

**Table 2:** Analysis of variance for protein content of the varieties grown at Sirinka and Kobo.

| | Mean squares at Sirinka | | | | Mean squares at Kobo | | | |
|---|---|---|---|---|---|---|---|---|
| | MSr | MSv | MSe | CV (%) | MSr | MSv | MSe | CV (%) |
| Df | 2 | 15 | 30 | | 2 | 15 | 30 | |
| | 5.46 | 3.40$^{NS}$ | 1.92 | 14.05 | 24.26 | 2.30$^{NS}$ | 1.52 | 9.69 |

NS- non-significant at 5 % probability; df- degree of freedom, MSr- mean square due to replication, MSv-mean square due to variety, MSe- mean square due to error.

Range and mean values of the traits are shown in Table 3 for both locations. Even if the result is statistically non significant, the varieties studied showed wide range of variability for the trait protein content. It ranged from 7.99-12.48 with a mean value of 9.88 at Sirinka and 11.29-14.71 with a mean of 12.71 at Kobo. At Sirinka, the highest value of protein content was obtained from Gedo followed by Abshire, Redswazi, Birhan and Teshale with a mean value of 12.48 %, 11.02 %, 10.72 %, 10.48% and 10.47 % respectively. Whereas at Kobo, the highest value of protein content was obtained from Misikr, Birhan, 76T1#23, Abshir and Gedo with a mean value of 14.71 %, 14 %, 13.67 %, 13.37 % and 12.86 % respectively (Table 4).

Variable levels of protein content of the grain is also reported by Hiebsch and O'Hair, 1986 (11.6%), FAO, 1995; Beta *et al*., 1995 (7-15%), Sauberlich *et al*., 1953 (6.8-13.6%) and Ng'uni *et al*, 2012 (9.7-16.3 %). As Miller *et al*., 1964 stated, in addition to genetic factors, environment is also known to cause variations in protein content of sorghum grains. It is confirmed from this study that, irrespective of their rank, 100 % of the varieties showed protein content increment at Kobo and the grand mean at Sirinka is lower than at Kobo which indicated the influence of the environment to cause variation in protein content of the germplasms. But, the varieties which gave high protein content are inconsistent and unstable across the locations indicating that these varieties perform differently due to environmental variations.

**Table 3:** Range, Mean, Components of Variance and Coefficients of Variation of protein content for the varieties.

| Location | Range | Mean | $\sigma^2$p | $\sigma^2$g | $\sigma^2$e | PCV (%) | GCV (%) | ECV (%) |
|---|---|---|---|---|---|---|---|---|
| Sirinka | 7.99-12.48 | 9.88 | 2.41 | 0.49 | 1.92 | 15.72 | 7.11 | 14.02 |
| Kobo | 11.29-14.71 | 12.71 | 1.78 | 0.26 | 1.52 | 10.50 | 4.01 | 9.70 |

$\sigma^2$p= phenotypic variance, $\sigma^2$g = genotypic variance, $\sigma^2$e= environmental variance
PCV and GCV = phenotypic and genotypic coefficient of variation, ECV= environmental coefficient of variation.

**Table 4:** Mean performance of the varieties for protein content (%)

| Variety Name | Teshale | Yeju | Abuare | Hormat | Grana-1 | Misikr | Raya | Gedo | Birhan |
|---|---|---|---|---|---|---|---|---|---|
| Sirinka | 10.47 | 8.93 | 9.75 | 7.99 | 8.87 | 10.06 | 9.84 | 12.48 | 10.48 |
| Kobo | 12.05 | 12.42 | 12.86 | 12.51 | 12.59 | 14.71 | 12.6 | 12.97 | 14.00 |

Table 4 continued

| Variety Name | Gobiye | Abshir | 76T1#23 | Meko | Redswazi | Macia | Tegemeo | Mean (%) | CV (%) |
|---|---|---|---|---|---|---|---|---|---|
| Sirinka | 10.36 | 11.02 | 9.49 | 9.27 | 10.72 | 9.31 | 8.96 | 9.88 | 14.05 |
| Kobo | 12.04 | 13.37 | 13.67 | 11.91 | 11.94 | 12.36 | 11.29 | 12.71 | 9.69 |

As compared to its corresponding environmental variance, lower value of genotypic variance is observed both at Sirinka and Kobo. This indicates that there is high environmental influence for the phenotypic expression of the trait protein content and the phenotypic variation of the trait is highly influenced by environmental variations since majority of the phenotypic variance component is contributed by the environmental variance.

In general, the variance components for the two environments showed that the trait protein content had lower genotypic variance estimates than the environmental variance estimates suggesting that expressions of the trait was more of due to environment which cannot be exploited by classical breeding. According to Deshmukh *et al*., 1986, phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) values greater than 20 % are regarded as high, whereas values less than 10 % are considered to be low and values between 10 % and 20 % to be medium. Based on this benchmark, the trait protein content showed medium PCV value both Sirinka (15.72 %) and Kobo (10.5 %) (Table 3). The trait also revealed low GCV value (7.11 %) at Sirinka and (4.01 %) at Kobo and the environmental coefficient of variation (ECV) of the trait is greater than its corresponding genotypic coefficient of variation. This low GCV value of the character suggests that the possibility of improving this trait through selection is limited or impractical.

As a general, GCV value was generally smaller than its corresponding PCV values of the trait protein content, indicating the contribution of environmental variance for the expression of phenotypic variance of the trait. The difference between PVC and GCV values were higher at both locations indicating the greater contribution of environmental variance on the genotypic expression of the trait.

According to Singh (2001), high heritability of a trait (≥ 80 %) provides selection for such traits could be fairly easy due to a close correspondence between the variety and the phenotype due to the relative small contribution of the environment to the phenotype. In other words, if environmental variability is small in relation to genotypic differences, selection will be efficient because the selected character will be transmitted to its progeny. But selection may be considerably difficult or virtually impractical for traits with low heritability (≤ 40 %) due to the masking effect of the environment so that the greater the proportion of the total variability is due to environment. Based on this benchmark, protein content resulted low estimated value of heritability i.e. 20.44 % and 14.61 % at Sirinka and Kobo, respectively (Table 5). Low heritability of protein content coupled with its low genotypic coefficient of variation (7.11 % at Sirinka and 4.01 % at Kobo) indicating that selection among the varieties under the present study may be considerably difficult or virtually impractical at all.

**Table 5**: Heritability ($h^2$), genetic advance (GA) and genetic advance as percent of the mean (GA %) of the varieties for protein content.

| Location | $h^2$ (%) | GA | GAM (%) |
|---|---|---|---|
| Sirinka | 20.44 | 0.67 | 6.80 |
| Kobo | 14.61 | 0.50 | 3.92 |

Like heritability, protein content also resulted low estimated value of expected genetic advance expressed as percentage of mean for both locations with a value of 6.80 % and 3.92 % at Sirinka and Kobo, respectively. In order to get improvement of estimates of expected gain for a particular trait, genetic advance should be in conjunction to heritability. On the other hand, as it is indicated by Burton and de Vane (1953), the genotypic coefficient of variation together with heritability estimate gives the best picture of expected advances from selection. Therefore, high heritability with high value of genotypic coefficient of variation provides the required expected genetic advance through selection. From this study, low values of genotypic coefficient of variation (low genotypic variability) and estimated value of heritability caused protein content to have low genetic advance at individual locations. Therefore, improvement of this trait is so difficult because selection is the result of genetic variability and improvement is the result of heritability and genetic advance.

**2. Other physical seed Quality characteristics of the varieties**

**2.1. Detection of tannin by the bleach test**

After the bleach test, most of the varieties showed white color (Table 6). Red Swazi and Birhan are the colored varieties before the bleach test. According to Taylor and Taylor (2008), tannin sorghum grains are those grains that are black over the entire surface of the grain after the bleach test, with the exception of the germ which is somewhat lighter in color. A non-tannin sorghum grains are those which are either completely white, or are brown over part on the surface of

the grain. Based on this description, Red Swazi was the only variety which became black over its entire surface after the bleach test indicating the presence of condensed tannin in it. This most probably contribute to low digestibility since tannin sorghums do slow and reduce the digestibility of nutrients, especially proteins (Rooney, 2005).

According to Woodhead *et al*. (1980), the presence of tannin in sorghum grain protects the grain from being damaged by insects. Hoshino *et al*. (1979) and Rooney (2005) also indicated the role of tannin in sorghum to prevent it from bird damage. Therefore, Red Swazi has most probably less degree to be infested by insect and bird damaged. Birhan showed brown color over part of its surface and no grain showed completely black or white color in its entire surface. Therefore, according to Waniska *et al*. (1992) and Taylor and Taylor (2008), this variety could not be considered as tannin sorghum. Excluding Red Swazi and Birhan, all other varieties showed white color after bleach test indicating that these varieties are tannin-free, so that they most probably are susceptible to bird damage.

**2.2. Sorghum Grain Color Classification**

According to Taylor and Taylor (2008), a white grain is colored white all over its surface and a colored grain is colored yellow, pink, red, brown, or purple (or combinations of these colors) all over its surface. Therefore, with this classification, Red Swazi and Birhan have red and reddish brown grain color, respectively (Table 6). All other varieties of the present study, namely Teshale, Yeju, Abuare, Hormat, Grana-1, Misikr, Raya, Gedo, Gobye, Abshir, 76T1#23, Meko, Macia and Tegemeo have white grain color. Taylor and Taylor (2008) and Waniska (2000) also indicated that the color of sorghum grain and flour play an important role in its acceptance and is important with regard to end-use, in particular for milling to produce meal for porridge making and for malting. Therefore, if the criterion for preference of the material is non-colored food product, all the varieties of the present study with white grain color will have priority in acceptance. This is because white sorghums produce the most acceptable food product, as described by Waniska (2000). But Red Swazi and Birhan will have less preference due to their colored grain, regardless of their potential for resistance to be attacked by insects and birds.

### 2.3. Estimation of grain endosperm texture

On the basis of the relative proportion of corneous to flour endosperm, the grain of sorghum might be much corneous or >50% of the endosperm is translucent. Sorghum grain with continuous outer corneous endosperm comprising less than 50% of the total endosperm and the inner part of the endosperm being floury is intermediate. However, grains where the endosperm is totally floury or the outer, corneous endosperm is very narrow and incomplete is said to be floury (Taylor and Taylor, 2008). Based on this description, corneous endosperm texture (>50% of the grain is translucent) was obtained from 69 % of the varieties of the present study and the rest 31% of the varieties showed an intermediate texture (Table 6).

**Table 6:** Tannin detection, endosperm texture and grain color classification of the varieties.

| SN | Variety Name | Bleach Test Information On Condensed Tannins | | Endosperm Texture Information | | | Grain Color |
|---|---|---|---|---|---|---|---|
| | | Grain Color After Bleach Test | Tannin Status | Corneous % | Floury % | Texture Status | |
| 1 | Teshale | White | Tannin free | 61.3 | 38.7 | Corneous | White |
| 2 | Yeju | White | Tannin free | 74.0 | 26.0 | Corneous | White |
| 3 | Abuare | White | Tannin free | 78.5 | 21.5 | Corneous | White |
| 4 | Hormat | White | Tannin free | 74.0 | 26.0 | Corneous | White |
| 5 | Grana-1 | White | Tannin free | 69.5 | 30.5 | Corneous | White |
| 6 | Misikr | White | Tannin free | 63.3 | 36.7 | Corneous | White |
| 7 | Raya | White | Tannin free | 79.0 | 21.0 | Corneous | White |
| 8 | Gedo | White | Tannin free | 42.0 | 58.0 | Intermediate | White |
| 9 | Birhan | Partly brown | Tannin free | 48.0 | 52.0 | Intermediate | Reddish brown |
| 10 | Gobye | White | Tannin free | 47.0 | 53.0 | Intermediate | White |
| 11 | Abshir | White | Tannin free | 34.0 | 66.0 | Intermediate | White |
| 12 | 76T#23 | White | Tannin free | 69.0 | 31.0 | Corneous | White |
| 13 | Meko | White | Tannin free | 80.5 | 19.5 | Corneous | White |
| 14 | Red Swazi | Black | Tannin | 30.0 | 70.0 | Intermediate | Red |
| 15 | Macia | White | Tannin free | 62.5 | 37.5 | Corneous | White |
| 16 | Tegemeo | White | Tannin free | 69.0 | 31.0 | Corneous | White |

The maximum percentage of corneous texture of the grain was obtained from Meko followed by Raya and Abuare with a value of 80.5%, 79.0% and 78.5%, respectively. The other varieties which showed corneous texture include Teshale, Yeju, Hormat, Grana-1, Misikr, 76T#23, Macia and Tegemeo. Ggrains with a high proportion of corneous endosperm tend to be more resistant to breakage during decortication (debranning) and milling than grains with a high proportion of floury endosperm. These varieties (sorghum grain with more corneous) tend to yield proportionally more clean (uncontaminated with bran) endosperm of large particle size during milling operations. As it is indicated by Bandyopadhyay *et al*. (2000) and Waniska (2000), an appropriate level of grain hardness necessary for mold resistance is required in grains without compromising on its food making properties. Therefore, the varieties with more corneous texture probably will have more resistant to insect and mould damage than grains of the rest varieties.

### 2.4. Determination of Germinative Energy

To produce sorghum malt, it is necessary that a high proportion of sorghum grains in a batch germinate. The recommended germinative energy of sorghum grain for malting is ≥ 90% (O'Rourke, 2004 and Taylor and Taylor, 2008). Macia and Red Swazi are registered as malting types and other varieties are released as food types (MoARD, 2007). Except Tegemeo, all the varieties have high enough (>90 %) germinative energy (Table 7) for malting. This means that all the varieties are suitable for malting. Similar results of grains of sorghum varieties with high enough germinative energy were reported by Nso *et al*. (2003) and Okrah (2008).

**Table 7:** Germinative energy of the varieties in 24, 48 and 72 hours interval.

| Variety | Germinative energy in | | |
|---|---|---|---|
| | 24 hrs (%) | 48 hrs (%) | 72 hrs (%) |
| Teshale | 27 | 88 | 99 |
| Yeju | 12 | 92 | 96 |
| Abuare | 10 | 88 | 93 |
| Hormat | 16 | 91 | 96 |
| Grana-1 | 16 | 91 | 98 |
| Misikr | 17 | 96 | 97 |
| Raya | 70 | 97 | 97 |
| Gedo | 14 | 91 | 95 |
| Birhan | 32 | 94 | 97 |
| Gobye | 23 | 94 | 98 |
| Abshir | 36 | 95 | 96 |
| 76T#23 | 42 | 94 | 96 |
| Meko | 22 | 99 | 99 |
| Red Swazi | 78 | 96 | 96 |
| Macia | 42 | 95 | 97 |
| Tegemeo | 16 | 82 | 89 |

## CONCLUSION

The analysis of variance for each location revealed no significant difference among the varieties for the trait protein content, indicating that improvement of this trait through selection will not be achieved easily due to the existence of narrow genetic variability among the released varieties. Due to this, the variance components for the two locations showed that protein content had lower genotypic variance estimates than the environmental variance as well as lower genotypic coefficient of variation than environmental coefficient of variation. In addition, it showed low heritability and genetic advance expressed as percent of mean. These low values of the trait indicated the more influence of environment on this trait. Due to this, improvement of the trait through classical breeding method becomes difficult or impossible which needs application of molecular techniques. From the bleach test, condensed tannin was obtained for Red Swazi which was indicated by its black color in its entire surface and it makes the variety nutritionally unsuitable. Majority of the varieties showed corneous endosperm texture and the rest showed an intermediate texture which makes them to be resistant to mechanical, insect and bird damage. Except Red Swazi and Birhan, all the varieties have white grain color that might provide preference for non-colored food products. Even if all, except Red Swazi and Macia, of the varieties are released as food types, they are suitable for malting due to their high germinative energy comparable with the recommended germinative energy.

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