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Sensory Acceptance of Malted and Un-Malted Barley Pretzels in South Punjab Sector of Pakistan

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ABSTRACT

Barley (*Hordeum vulgare*) is a cereal crop, that belongs to the grass family. It is used as a food source in some cultures as well. The current research was planned to check the sensory acceptance of malted barley confection "pretzels", which are not native to Pakistan. Purposely, the barley was procured from the local market of Multan, Pakistan by considering quality traits account i.e., colour, length, width, and thousand kernel weight. The cleaned barley was subjected to malting till seed germination for up to 4 days. After the process of germination, the seed was fried in the drier at 65 °C for 16 hours followed by flour development. The colour value of un-malted barley for l, a, and b were 54.23, 1.91, and 11.21 whilst malted barley presented 53.52, 0.86, and 11.03, respectively for the same traits. Afterwards, the pretzels were prepared by following the standard recipe by planning various treatments i.e., T0 (100% wheat flour), T1 (80% wheat flour, 20% malted flour), T2 (60% wheat flour, 40% malted flour), T3 (40% wheat flour, 60% malted flour), T4 (80% wheat flour, 20% un-malted flour), T5 (60% wheat flour, 40% un-malted flour) and T6 (40% wheat flour, 60% un-malted flour). The prepared products were subjected to sensory evaluation by a trained judges panel at different intervals during storage (0, 7th, and 14th day) by following a 9-point hedonic scale for aroma, texture, and overall acceptability. The malted barley-based pretzels 5.64±0.19 (T3) showed maximum value for aroma whereas, T5 presented 5.87±0.11 (T5) for the un-malted treatment plan on the 14th day. In the case of texture, T1 was appreciated at 0day of storage by securing 6.49±0.16. As far as overall acceptability was concerned, T6 presented 7.57±0.36 on the 0th day with a slight decline of 5.42±0.29 for the same treatment.

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INTRODUCTION

Barley (*Hordeum vulgere*) is considered the fourth cereal crop followed by wheat, corn, and rice (Marwat *et al.,* 2012), and belongs to the grass family Poaceae. Barley is the most adaptive and versatile cereal in the world and most of the barley produce well in other regions where rice and maize grow especially in the arctic and subarctic regions. Most of the Hordeum species have resistance ability against heat and they allow near desert areas such as North Africa (Zhou, 2009). Most research suggests that

the Fertile Crescent was considered the only location of domestication of barley (*Hordeum Spontaneum*) however, its centre of origin is not confirmed yet Zohary *et al.,* 2012). Some researchers showed that barley for cultivation purposes originates from South to East Asia while some evidence indicates the domestication of barley in Central Asia at the Eastern Edge (Jones *et al.,* 2008).

Barley verities are different from one another on basis of phenotypically and also variate based on genetics. First, we differentiate based on hulled barley or hulless and then differentiate on 2 or 6-row barley cultivars. These variations are due based on a seasonal basis (winter-type barley or spring-type barley). They are also differing based on their composition *e.g* lysien, β- gluten (Baik and Ullrich, 2008). In barley, the pollination process is carried out by itself in which both pollen and ovary mature at the same time for the fertilization process. In spring cultivar florets are not open during the fertilization process (cleistogamy), but in the case of winter crops, they open their floret during fertilization (chasmogamous). Barley is a short-season crop that is tolerant to drought conditions and alkali and alkaline soil. Different varieties are approved by the government in which some are sown in the summer season while others are sown in the spring season. Crops require a germination period from 5 to 7 days if they require an optimum temperature of 12 – 24 ˚C. The crop will mature in 60-90 days after germination and other biotic and abiotic factors are according to the plant requirement (Shewry and Ullrich, 2014).

In process of malting, there are various fermented products are obtained through growth and germination which are used for various purposes (Including beer, whisky, soft drinks and other bakery products). When the grain arrives at the malt house, the moisture of the grain must not exceed 12%. At this level of moisture, it helps in the prevention of the growth of mould and another mycotoxin that grows in the stored grain. Before malting, the grain passes through various tests such as its viability and germination rate (98%). These parameters will ensure that germination and grain modification remain the same throughout the batch. Protein content and nitrogen are also important parameters for the assessment of grain quality. The acceptance level of nitrogen and protein for the malting in row six-row barley varies from 1.8 to 2.0% and 11.3 to 12.5%. If the value of nitrogen content is low then the yeast requirement is not fulfilled in a fermentation process while if protein content is high then it will decrease the volume of starch in the endosperm cavity. The grains are also free from post-harvest sprout damage, insect damage, disease, and chemical damage. If the grain is quality and another parameter is fulfilled under the required condition then the maltster allows through the future process (Shewry and Ullrich, 2014).

Steeping is the initial step of malting in which the grains are submerged in the water to increase the moisture content of the grain which stimulates or encourages the activity of the enzyme. At the industrial level, the grain is soaked in water into a slurry at temp ranging from 11- 16 ℃. Then it is transferred to the flat bottom steeping vessel with a perforated floor. The steeping water changed two to three times within 24-40 hours. During the steeping, air is applied through the air pump to aerate the mixture. The air pump is applied in the mixture because it is also due to respiration, and oxygen and reduces the carbon dioxide concentration (Schwarz and Li, 2011). The time duration during the immersion of seed and air resting varies among the industries, seasonal changes, and malt varieties but it estimated time varies between 4-12 hours. In barley grain, the starch is packed in the protein matrix which is loosely enclosed in the endosperm in which water can easily diffuse. This can hydrate the grain more than the grain has more tightly enclosed in the endosperm. When the protein matrix are loosely packed that will help more quickly increase the hydration of the seed and that turn decrease the steeping period. During the first immersion in water, the outer layer of the grain takes up water and starts the metabolic activity (Kunze *et al.,* 2004).

Maltsters inspect the grain to check whether they attain enough moisture content by the emergence of coleorhizae, known as “chit” (Shewry and Ullrich, 2014). Once the grains attain the chit condition, it is removed from the bottom vessel containing water and placed on the bed for germination. In this condition, the grains are placed on the bed where the grain is in a moist condition and also provides air circulation to promote the germination process. Some latest techniques are also used in which the germination chamber or Saladin box are used where temperature, moisture, and air circulation are maintained to seed germination. Both Saladin box and germination are constructed from stainless steel chamber and perforated floor, providing humid air through the bed and temperature ranges from 16-20˚C. Whole grain cereals are high in antioxidants, minerals, vitamins, and dietary fibre all of which are beneficial to one's health. Germination affects a wide

variety of these substances. Although certain substances such as an increase in the vitamins and degradation of β-glucans by malting. As a result, germination and malting of cereals can be used to prepare recipes enriched with nutritional and functional compounds that help to promote human health. Malt extracts are used as a suitable substrate for probiotic bacteria growth and application (Hübner and Arendt, 2013).

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MATERIALS AND METHODS

This study was performed in the research laboratory of the Department of Food Science and Technology, MNS-University of Agriculture, Multan. This study was conducted by comparing the unmalted barley and malted barley based on acceptance among the population of South Punjab. The barley seed and other raw materials were procured from the local grain market, Multan.

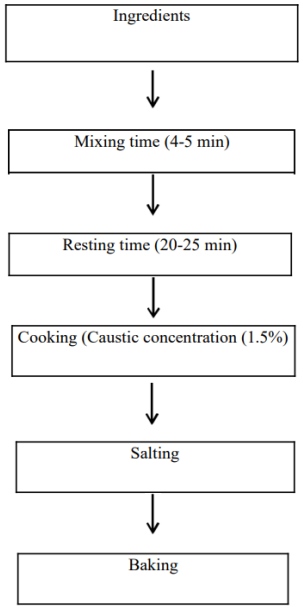

Figure 1. Pretzels development flow chart.

Grain physical parameter

Colour, Length, and width

Grain colour was determined by visual examination. The length and width of the kernel were measured with Vernier calliper having 0.01 values least count (Kasraei *et al.,* 2015).

Thousand kernel weight

Thousand kernel weight can be determined by counting the 1000 healthy seeds and weighing them on the weighing balance. Thousand kernel weight was determined according to AACC (2000). Take 100-grain seeds that should be free from broken, damaged, or insect attacks. After that, the grains weigh on the electric weighing balance with an accuracy of 0.01g. Then multiply with 10 to obtain 1000 kernel weight.

Process of malting

The first step is to clean the barley seed from the unwanted material and then steep the barley seed in water for 48 hours to attain a moisture content of up to 40 to 45% followed by steeping for 8 hours. After the steeping process, the seed was placed on a sack in stainless steel and waited for germination. It requires 2 to 4 days for maximum seed germination. After the process of germination, the seed was dried in the drier at 65°C for 16 hours. Once the seed was dried the roots that are elongated from the seed were manually de-rooted. For further analysis, the malted barley was grounded in a milling grinder to convert it into flour.

Preparation of pretzels

Water, bread flour, wheat gluten, yeast, and salt were used to make a sponge. In a blender with the beater attachment, the dry ingredients were combined with water for 7-10 minutes, or until pale white and easily separated from the mixing cup. For 30 minutes, the sponge was allowed to ferment. Water, flour, milk, sugar, lipid, yeast, salt, and dough conditioner were used to make the dough. The sponge was applied to the dough before mixing. The dough was mixed for 7-10 minutes with the hook attachment, until the ingredients were homogeneous and the dough stayed together. On a baking sheet, the dough was divided into pretzel sticks and proofed at 105°F for 15 minutes. Pretzel dough is typically dipped in a lye bath or boiled water before being proofed. Since this move induces a colour change in the pretzels that hides the colour change caused by the

safflower and soy ingredients, it was omitted from these experimental methods. In a convection oven at 325°F, the pretzels were baked for 10 minutes (Costantini, 2015). Various treatment plans are given in Table 1.

Table 1. Treatment plan for pretzels development.

Sample	Wheat flour (%)	Malted barley (%)	Un-malt barley (%)
T_0	100	-	-
T_1	80	20	-
T_2	60	40	-
T_3	40	60	-
T_4	80	-	20
T_5	60	-	40
T_6	40	-	60

Sensory evaluation

The trained panellists were invited to assess pretzels. The aroma, texture, and overall acceptability of pretzels were assessed. The ratings were given on a 1–9-point hedonic scale, with 9 being the most like and 1 being the least like (dislike extremely) by Lawless and Heymann (2010).

Statistical analysis

All samples were analyzed in triplicate for statistical purposes to ensure the highest level of data reliability. The term "mean" was used to describe the raw material, and it was calculated using Microsoft Excel 2016. One-way ANOVA under CRD and the Tuckey test (beyond ANOVA) were used to determine differences between treatments. Statistics 8.1 program was used for ANOVA and Tuckey test. The thresholds for statistical standard significance were set at highly significant (p: 0.05), respectively.

Results and discussion

Barley (*Hordeum valgure*) belongs to the grass family and is ranked 4th among cereals as a rich source of nutrients such as niacin, dietary fibre, and dietary minerals and manganese and they are consumed as a staple food grain in many regions. They are divided into two types barley 2-row and 6-row barley 2-row barley are major protein content than 6-row barley. It is used in barley products, beverages (alcoholic as well as non-alcoholic content), and other uses such as animal feed. Barley crops are adaptive and also very popular in the temperate area where barley is grown as a tropical, summer as well as winter crop. Barley crops are also more tolerant to drought conditions and also tolerant to soil salinity than wheat crops.

Physical parameter of barley grain

Color (Visual examination)

The color range is light yellow to tan color (Table 2).

Thickness, length, and width

The thickness, length, and width are 3.44cm, 8.94 mm, and 4.37mm.

Thousand kernel weight (TKW)

TKW of grain is measured and recorded as 44.15g by following the protocols of Ahmad et al. (2017).

Flour color

The color of the malted and unmalted flour is obtained from the color meter. The color value of barley (l; 54.23, a; 1.91, b; 11.21) and malted barley (l; 53.52, a; 0.86, b; 11.03) as given in Table 3.

Table 2. Physical parameters of barley seed.

Physical parameter	Observation
Color	Tan
Shape	Horsehoe
Length (mm)	8.94
Width (mm)	4.37
Thickness (cm)	3.44
Weight of thousand seed (g)	44.15

Table 3. Color parameter of malted and un-malted barley flour.

Color parameter	Men value	
	Un-malted barley grain	Malted barley grain
I	54.23±1.95	53.52±1.69
a	1.91±0.24	0.86±0.06
b	11.21±0.89	11.03±0.44

Color analysis

The "l" parameter indicates the whiteness and darkness of the sample. In the case of parameter "b" the result also shows a highly significant and it indicates the redness in the sample. In this case color "b" value shows a significant value and 'b" indicate the yellowness in color. Mean value for color "a", "b" and "c" are mentioned in Table 8. The color "l" value of pretzel sample result is observed which are T_0 56.13, T_1 46.80, T_2 57.94, T_3 41.25, T_4 51.56, T_5 57.29 and T_6 43.12. The maximum value of pretzel color of parameter "l" is 57.94 and minimum 43.12. In case of color parameter "a" T_0 4.30, T_1 7.02, T_2 5.14, T_3 7.99, T_4 5.58, T_5 5.52 and T_6 7.62. The maximum value of pretzel color parameter of "a" is 7.99 whereas minimum value is 4.30. In the case of parameter "b" T_0 17.66, T_1 16.44, T_2 17.57, T_3 17.52, T_4 17.22, T_5 17.97 and T_6 17.28. The maximum value of "b" is 17.97 whereas minimum value "b" is 16.44 (Figure 2).

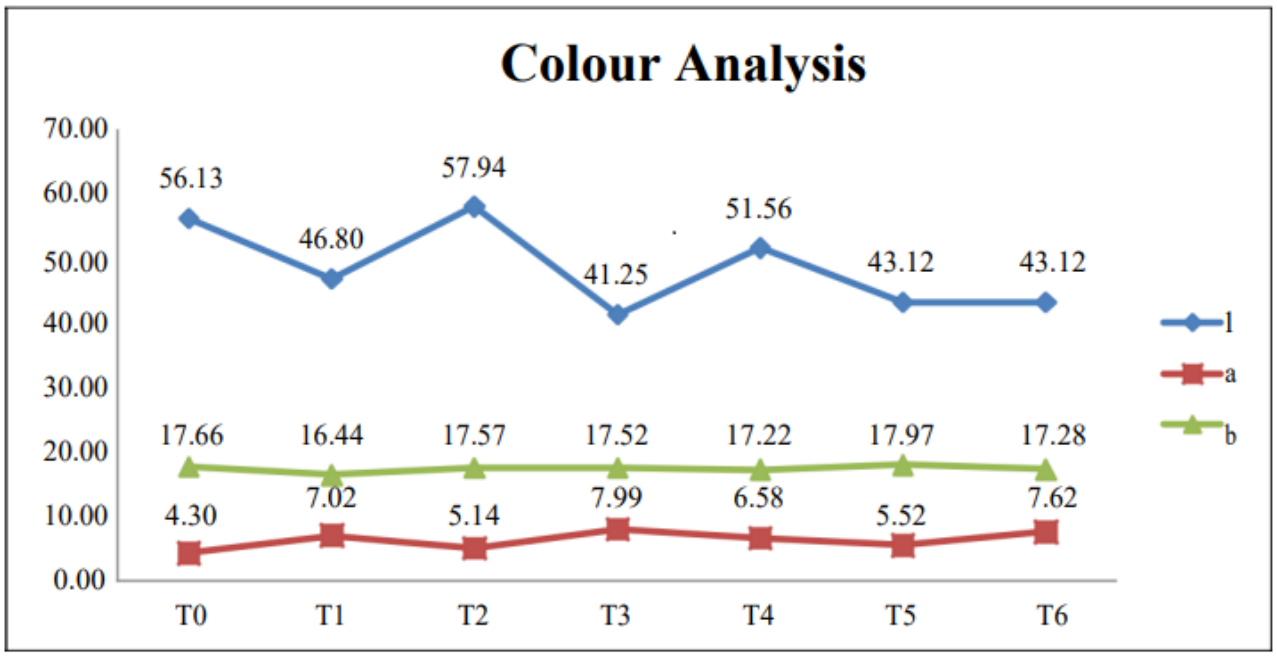

Figure 2. Comparative assessment of pretzel color.

Storage studies

Aroma

Aroma is also crucial sensory property for any food product which ultimately affect the customer acceptance of the product and it also causes changes in the flavor of the food product. The mean value for the aroma of the pretzel (storage study at 0 days) of the pretzel is mentioned in Table 4.

According to the mean, the result ranges from T_0 7.59, T_1 6.49, T_2 6.59, T_3 7.59, T_4 5.70, T_5 6.47, and T_6 7.51. T_0 is the maximum range is 7.59 and the minimum range from T_4 is 5.70 (80% wheat flour and 20% un-malted flour). These results are identical to El-Gohery (2020). In Figure 3, The result shows that the pretzels prepared from the treatments T0 (100% wheat flour), T_3 (40% wheat flour, 60% malted flour) and T_6 (40% wheat flour, 60% un-malted flour) shows high aroma on storage of 0 days,7 days and 14 days as compared to other treatment that shows T_1 (80% wheat flour, 20% malted flour) and T_4 (80% wheat flour, 20% un-malted flour) are considered to lower aroma value. The difference in the aroma is due

to environmental factor such as temperature, storage medium, and moisture content.

Texture

The mean value of the pretzel texture (0 days) is mentioned in Table 5. The mean value of physical characteristics of treatment texture means lies between T_0 7.55, T_1 6.49, T_2 5.42, T_3 6.56, T_4 7.44, T_5 6.48, T_6 5.43. The maximum value of physical characteristics of pretzel treatment means T_0 (100% wheat flour) is 7.55 and the minimum value of physical characteristics of pretzel color of treatment mean are T_2 (60% wheat flour and 40% malted flour) is 5.42**.** On the 7th day of storage, the mean value of physical characteristics of treatment texture mean are lies between T_0 6.45, T_1 5.47, T_2 4.98, T_3 5.43, T_4 6.30, T_5 5.37, T_6 4.36. The maximum value of physical characteristics of pretzel treatment means T0 (100% wheat flour) is 6.45 and the minimum value of physical characteristics of pretzel color of treatment mean are T_2 (60% wheat flour and 40% malted flour) is 4.98. These results are identical to Sharif *et al.* (2003). In Figure 4, the most acceptable pretzel on the basis texture at 0,7 and 14 days are two treatments T_0 (100% wheat flour) and T_4 (80% wheat flour, 20% un-malted flour) while the least acceptable pretzel on a textural basis is T_2 (60% wheat flour, 40% malted flour) and T_6 (40% wheat flour, 60% un-malted flour). T_0 and T_4 have more textural stability because wheat flour has more gluten network that holds the structure of dough stable as compared to the other treatments.

Overall acceptability

The mean value of the pretzel's overall acceptability (0 days) is mentioned in Table 6. The mean value of physical characteristics of treatment color means is lies between T_0 7.71, T_1 6.79, T_2 5.80, T_3 6.53, T_4 7.65, T_5 6.72, T_6 7.57. The maximum value of physical characteristics of pretzel treatment means T1 (80% wheat flour and 20% malted flour) is 7.71 and the minimum value of physical characteristics of pretzel color of treatment mean is T_2 (60% wheat flour and 40 malted flour) is 5.80. These results are identical to Jan *et al*. (2021). The mean value of the pretzel overall acceptability (7 days) is mentioned in Table 6. The mean value of physical characteristics of treatment color mean lies between T_0 6.46, T_1 5.44, T_2 4.52, T_3 5.36, T_4 6.33, T_5 5.61, T_6 6.49. The maximum value of physical characteristics of pretzel treatment means T_6 (40% wheat flour and 60% un-malted flour) is 6.49 and the minimum value of physical characteristics of pretzel color of treatment mean is T_2 (60% wheat flour and 40% un-malted flour) is 4.52. These results are identical to Sharif *et al.* (2009).

The mean value of the pretzel for overall acceptability (21 days) is mentioned in Table 6. The mean value of physical characteristics of treatment color mean lies between T_0 5.67, T_1 4.37, T_2 3.32, T_3 4.73, T_4 5.52, T_5 4.45, T_6 5.42. The maximum value of physical characteristics of pretzel treatment means T0 (100% wheat flour) is 5.67 and the minimum value of physical characteristics of pretzel color of treatment mean are T2 (60% wheat flour and 40% malted flour) is 3.32. These results are identical to Pasha et al. (2002). In Figure 5, it shown that the pretzel prepared from the treatment was preferable to eat after 0, 7 and 14 days are T_0 (100% wheat flour), T_4 (80% wheat flour, 20% un-malted flour), and T_6 (40% wheat flour, 60% un-malted flour) while less attention on a pretzel with the treatment of T_2 (60% wheat flour, 40% malted flour) and T_5 (60% wheat flour, 40% un-malted flour). The impact of the storage study was also examined the bakery product that is prepared from the addition of malted barley flour and un-malted barley flour. The result shows that over time the consumer preference for product decreased when compared with freshly prepared item. Different factors are also involved in the acceptance of bakery product on the basis of storage study such as environmental factor *i.e.* moisture content.

Table 4. Mean value of pretzel for aroma during storage.

Treatment	Storage study of texture		
	0 day	7 day	14 day
T_0	7.59 ± 0.28	6.45±0.09	5.62±0.34
T_1	6.46± 0.33	5.60±0.23	4.56±0.16
T_2	6.59±0.26	6.62±0.44	5.43±0.31
T_3	7.58±0.35	6.63±0.36	5.64±0.19
T_4	5.70±0.33	6.31±0.39	4.35±0.26
T_5	6.47±0.22	5.79±0.19	5.87±0.11
T_6	7.51±0.33	6.49±0.44	5.66±0.27

Table 5. Mean value of pretzel for texture during storage.

Treatment	Storage study of texture		
	0 day	7 day	14 day
T_0	7.55±0.32[a]	6.45±0.25[h]	5.34±0.25[o]
T_1	6.49±0.16b	5.47±0.16[i]	4.50±0.15[p]
T_2	5.42±0.31[c]	4.98±1.46[j]	3.84±1.40[q]
T_3	6.56±0.37[d]	5.43±0.36[k]	4.30±0.40[r]
T_4	7.44±0.19[e]	6.30±0.13[l]	5.15±0.08[s]
T_5	6.48±0.26[f]	5.37±0.25[m]	4.08±0.28[t]
T_6	5.43±0.14[g]	4.36±0.09[n]	3.25±0.16[u]

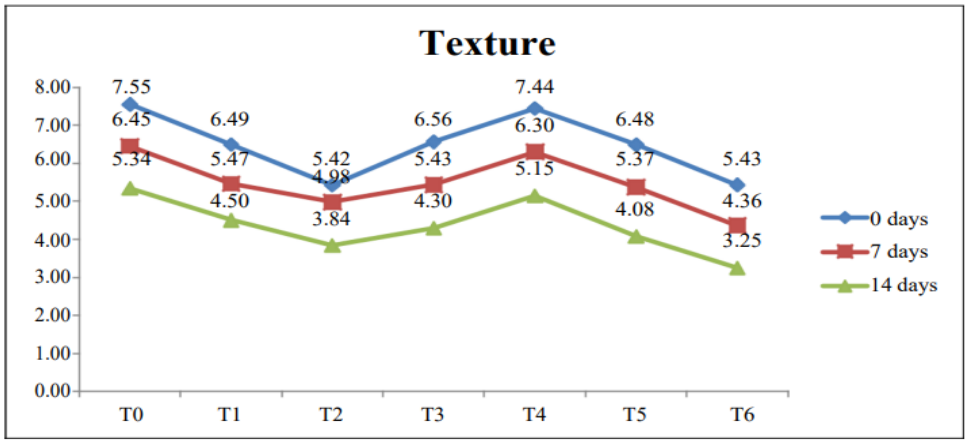

Figure 4. Combine effect of texture and storage on pretzel.

Table 6. Mean value for overall acceptability of pretzel.

Treatment	Storage study of texture		
	0 day	7 day	14 day
T_0	7.71±0.12[a]	6.46±0.32[h]	5.67±0.31[o]
T_1	6.79±0.14[b]	5.44±0.23[i]	4.37±0.20[p]
T_2	5.80±0.15[c]	4.52±0.19[j]	3.32±0.05[q]
T_3	6.53±0.20[d]	5.36±0.35[k]	4.73±0.15[r]
T_4	7.65±0.47[e]	6.33±0.17[l]	5.52±0.20[s]
T_5	6.72±0.27[f]	5.61±0.20[m]	4.45±0.28[t]
T_6	7.57±0.36[g]	6.49±0.34[n]	5.42±0.29[u]

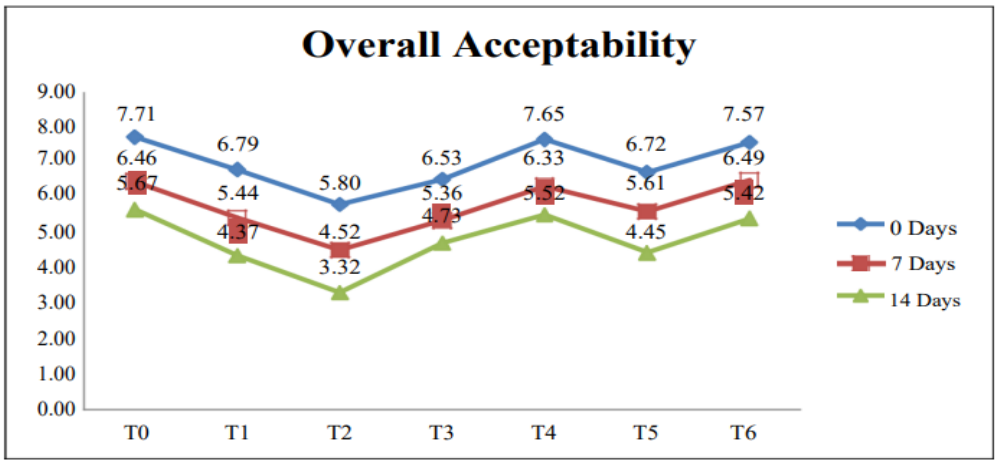

Figure 5. Combine effect of overall acceptability and storage of pretzel.

CONCLUSION

Pakistan is a developing country with continuous progress in various industry. Bakery and confections is one of the prominent entrepreneur. In this context, innovation in such fields is always encouraged. Barley pretzels is one of the novel food products introduced in South Punjab, Pakistan by the efforts of research and experimentations. It is liked by various segments of population and are likely to be popular in coming era.

References

AACC, 2000. Approved methods of the American association of cereal chemists, American Assoication of Cereal Chemists.

Baik, B. K., and S. E. Ullrich. 2008. Barley for food: Characteristics, improvement, and renewed interest. J. of Cereal. Sci. 48: 233-242.

Costantini, L. 2015. Optimizing a Functional Snack for Clinical Trials: Soy and Safflower Soft Pretzels (Doctoral dissertation, The Ohio State University).

El-Gohery, S. S. 2020. Quality Aspects for High Nutritional Value Pretzel. Current Science International, 9(4): 583-593.

Hübner, F., and E. K. Arendt. 2013. Germination of cereal grains as a way to improve the nutritional value: a review. Critical reviews in food science and nutrition, 53(8): 853-861.

Jan, N., H. R. Naik, G. Gani, O. Bashir, S. Z. Hussain, A. H. Rather and T. Amin. 2021. Optimization of process for the development of rice flour incorporated low-gluten wheat-based pretzels: Evaluation of its physicochemical, thermal and textural characteristics. J. of Saudi Soc. of Agri. Sci. 20(2): 116-127.

Jones, H., F. J. Leigh, I. Mackay, M. A. Bower, L. M. Smith, M. P. Charles, and W. Powell. 2008. Population-based resequencing reveals that the flowering time adaptation of cultivated barley originated east of the Fertile Crescent. Molecular biology and evolution. 25(10): 2211-2219.

Kasraei, M., J. Nejadi, and S. Shafiei. 2015. Relationships between grain physicochemical and mechanical properties of some Iranian wheat cultivars. J. of Agri. Sci. and Tech. 17(3): 635-647.

Kunze, W., T. Wainwright, and H. Mieth. 2004. Technology brewing and malting, vol. 3. Vlb Berlin.

Lawless, H. T. and H. Heymann 2010. Sensory evaluation of food: principles and practices, Springer Science & Business Media.

Marwat, S. K., M. Hashimi, K. U. Khan, M. A. Khan, M. Shoaib, and Fazal-ur-Rehman. 2012. Barley A Prophetic Food Mentioned in Ahadith and its Ethnobotanical Importance. American-Eurasian J. of Agri. and Enviro. Sci. 12: 835-841.

Schwarz, P., and Y. Li. 2011. Malting and brewing uses of barley. Barley: Production, Improvement, and Uses 478-521.

Sharif, M. K., M. S. Butt, F. M. Anjum, M. Nasir, R. A. S. H. I. D. Minhas, and M. N. Qayyum. 2003. Extension of cookies shelf life by using rice bran oil. Int. J. Agric. Biol. 5(4): 455.

Shewry, P., and S. Ullrich. 2014. Barley: Chemistry and Technology, 2nd ed. American Association of Cereal Chemists International, St. Paul, MN.

Zhou, M.X., 2009. Barley production and consumption. In Genetics and improvement of barley malt quality. p. 1-17.

Zohary, D., M. Hopf, and E. Weiss. 2012. Domestication of Plants in the Old World: The Origin and Spread of Domesticated Plants in Southwest Asia, Europe, and the Mediterranean Basin. Oxford: Oxford University Press.