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# Evaluation of relative sweetness and sensory characteristics of tagatose

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**Abstract**
Tagatose is emerging as a very promising sugar substitute. In this study relative sweetness and sweetness characteristics of tagatose were evaluated and effect of concentration on these characteristics was also tested. The quality of sweetness was judged in terms of overall temporal profile of sweetener, any objectionable taste (bitterness, astringency, chemical-like sensations, etc.) and cooling effect. The relative sweetness and sweetness characteristics were tested through sensory evaluation by panel of experienced judges. The relative sweetness of tagatose was found 0.91. Sweetness characteristics of tagatose were found almost similar to that of the sucrose. The relative sweetness and sweetness characteristics of tagatose were not affected by change in its concentration in the range of 3.3 to 22.0%.

**Keywords:** tagatose, relative sweetness, sweetness profile, sugar substitute

## Introduction
Among the sweeteners, humans are most accustomed to disaccharide sucrose. Though sucrose elicits a sweet taste, but energy dense diets high in sucrose contribute to excess calorie intake, which in turn leads to obesity with concomitant health problems. Therefore, reduction in consumption of sugar has become an important goal. Substitution of sucrose and other nutritive sweeteners with alternative non-calorie/low-calorie and high-intensity sweeteners is practical approach to achieve this goal. However, the substitution of sucrose poses unique challenges in different types of food products [1]. Fortunately, now D- tagatose is emerging as a potential alternative low calorie full bulk sweetener.
Sugar (sucrose) is viewed as the gold standard for sweetness in terms of (1) time required for onset of sweetness, (2) peak height (intensity) of sweetness and (3) ) time required in drop-off of sweetness (WHO, 2017). In selection of any alternative sweetener for replacement of sucrose, knowledge of its sensory characteristics is very important. Generally, three things are taken into consideration while evaluating sensory characteristics of the sweetener. The first is the relative sweetness of the sweetener, the second is quality of its sweetness and the third is change in relative sweetness with change concentration [2].
From literature it appears that only study is reported on relative sweetness and sweetness characteristics of tagatose. Therefore, the present study was undertaken to evaluate relative sweetness and sweetness characteristics of tagatose.

## Materials and Methods
All solutions of tagatose and that of the sucrose were prepared in distilled water on weigh by volume basis (*i.e.* % w/v) and were kept refrigerated (6±1°C) in airtight glass containers for at least 24 hours prior to judging. Before offering both the solutions for evaluation, the solutions were removed from the refrigerator at least an hour prior to testing and were allowed to come to room temperature (~30°C).
While evaluation of relative sweetness, a test panel comprising ten experienced judges between 25 and 60 years of age was given the 10 per cent sucrose solution as known solution, whereas, 9, 10, 11, 12 and 13% tagatose solutions were coded and offered as unknown solutions. The judges were asked to compare sweetness of the tagatose solutions with that of the sucrose solution.
In evaluation of sweetness characteristics, before offering samples of 11% tagatose solution and 10% sucrose solution, for evaluating quality of their sweetness judges of the test panel were briefed about the criterions of sweetness quality including overall temporal profile, objectionable taste and cooling effect.

Both the solutions were coded and offered as unknown solutions and the judges were asked to report their comments on difference in sweetness quality of both the solution.

For comparing relative sweetness and sweetness characteristics of tagatose at different concentrations, sucrose solutions of 3, 6, 10, 15 and 20% were prepared. Expected amount of tagatose, required to give sweetness equivalent to each sucrose solution, was calculated from relative sweetness of tagatose as 0.91 (i.e. 91%). Accordingly, 3.3, 6.6, 11.0, 16.5 and 22.0% of tagatose solutions were prepared to give sweetness equivalent to 3, 6, 10, 15 and 20 per cent sucrose solutions respectively. The respective samples of sucrose and tagatose solutions were arranged in pair and coded respectively.

The judge were briefed to compare sweetness intensity and sweetness quality of solutions in each pair.

## Results and Discussion

### Relative sweetness of tagatose

The first consideration in selection of any sucrose substitute is its relative sweetness. The relative sweetness of sucrose substitute indicates its intensity or potency of sweetness as compared to that of the sucrose. Sweetness of sucrose is given a value of 1.0. Sometimes relative sweetness is represented on a scale of 100, where sucrose has a value of 100 and sweetness of the substitutes are rated in comparison with the sucrose [3]. Therefore, relative sweetness of tagatose was ascertained in water by following the procedure as describe below. Total four replications were conducted.

In most of the reports the relative sweetness of tagatose is given in comparison to 10 per cent aqueous solution of sucrose. Average results obtained from four replications are presented below in Table 1.

**Table 1:** Sweetness of tagatose solution at different concentration in comparison to 10 per cent sucrose solution

| Sr. No. | Tagatose solution (%) | Sweetness intensity of the tagatose solution compared to 10% sucrose solution |
|---|---|---|
| 1. | 9 | Lower than the sucrose solution |
| 2. | 10 | Slightly lower than sucrose solution |
| 3. | 11 | Almost comparable with the sucrose solution |
| 4. | 12 | Slightly higher than the sucrose solution |
| 5. | 13 | Higher than the sucrose solution |

Sweetness intensity of 9 and 10 per cent tagatose solutions were rated as lower and slightly lower respectively, compared to 10 per cent sucrose solutions. Similarly, sweetness intensity of 12 and 13 per cent tagatose solutions were rated as slightly higher and higher respectively, compared to 10 per cent sucrose solutions. Whereas sweetness intensity of 11 per cent tagatose solution was rated as almost similar to that of the 10 per cent sucrose solution. Therefore, it is evident from the results that sweetness of 11 per cent tagatose solution was found equivalent to the sweetness of 10 per cent sucrose solution. From these data the relative sweetness of tagatose was worked as 0.91 (*i.e.* 10/11 = 0.909 ≈ 91) and in terms of percentage expressed ads 91 per cent.

The available information from literature on relative sweetness of tagatose, most of the reports suggests that tagatose is about 0.90 to 0.92 times (90 t0 92%) as sweet as sucrose when compared in 10 per cent aqueous solutions [4–9]. Whereas, Gwak *et al.* [10] reported the relative sweetness of tagatose to be 0.85. Therefore, in the present study value of 0.91, obtained for relative sweetness tagatose, was very well in corroboration with the values reported in the literature.

### Sweetness quality of tagatose

The quality of sweetness was judged in terms of overall temporal profile of sweetener, any objectionable taste (bitterness, astringency, chemical-like sensations, etc.) and cooling effect. The overall temporal profile of sweetener is described in terms of time required for onset of sweet taste (late or early), rate at which at maximum intensity of sweetness is reached (slow or fast) and duration for which the sweet taste persists (short or long). The overall temporal profile of sucrose is unique. It generates sweet taste at a certain rate of onset, reaches to a maximum intensity and promptly fades out. The most of the alternative sweeteners are reported to be unable to match this temporal profile of sucrose [11]. As discussed in previous section, sweetness of 11 per cent tagatose solution was found equivalent to 10 .0per cent sucrose solution. Therefore, 11 per cent tagatose solution was selected for evaluating the quality of sweetness in comparison to 10 per cent sucrose solution. Total four replications were conducted. The results obtained from four replications are presented in Table 2.

**Table 2:** Comparison of sweetness quality of tagatose solution with sucrose solution

| Sr. No. | Aspect of sweetness quality | Sweetness quality of 11% tagatose solution compared to 10% sucrose solution |
|---|---|---|
| 1. | Overall temporal profile | Similar to that of the sucrose |
| 2. | Objectionable taste | No objectionable taste |
| 3. | Cooling effect | No cooling effect |

The overall temporal profile of 11 per cent tagatose solution was reported as similar to that of the10 per cent sucrose solution. No objectionable taste perceived by any of the member of the judging panel. No cooling effect was felt by any of the member of the judging panel.

Thus, it was evident from the results that there was no apparent difference in overall temporal profile of both solutions of both the sweeteners. Similarly, tagatose did not elicited any objectionable taste on its consumption in form of 10 per cent solution. Moreover, tagatose did not caused cooling effect. Therefore, the results of this study suggest that the entire sweetness quality of tagatose was found almost similar to that of the sucrose.

According to Zehner [12] no apparent aftertaste or negative observations on quality of sweetness were noted. Levin [7] reported tagatose proved virtually indistinguishable in taste from sucrose (except slight) and no cooling effect was detected. Kim, [6] found the sweetness profile of D-tagatose is similar to that of sucrose. He further mentioned that no cooling effect was found, as found in case of sugar alcohol used as sucrose substitute. Oh [8] found that tagatose had sucrose-like taste with no cooling effect or aftertaste. Gwak *et al.*, [10] conducted a study to evaluate various bulk sweeteners (fructose, fructose corn syrup, xylose, tagatose, xylitol, erythritol, maltitol) and intense sweeteners (aspartame, sucralose, stevia, and rebaudioside A 97. The authors reported that only maltitol and tagatose were shown to elicit very

similar sensory characteristics to that of sucrose. Thus, sweetness quality of tagatose found in present study is in total agreement with that reported in the literature.

**Effect of concentration on relative sweetness of tagatose**

The relative sweetness of some sweeteners may vary with concentration of the sweetener under examination. Consequently, it is also necessary to examine how relative sweetness of any sucrose substitute varies with concentration, compared to that of the sucrose [13]. Hence, in present study experiment was conducted to ascertain relative sweetness of tagatose over a range of concentrations in which it was required for sweetness equivalent to sucrose. The sucrose is commonly used as sweetener in food and beverages at the rate of 3 to 20 per cent [2].

Therefore, relative sweetness of tagatose were compared at different concentrations, sucrose solutions. Total four replications were conducted. Results obtained for relative sweetness of tagatose at different concentrations are presented in Table 3.

**Table 3:** Relative sweetness of tagatose at different concentration

| Sr. No. | Concentration (%) | | Sweetness intensity of tagatose solution & respective sucrose solution when offered in pair for evaluation |
|---|---|---|---|
| | Sucrose | Tagatose | |
| 1. | 03.0 | 03.3 | Almost similar in both the samples |
| 2. | 06.0 | 06.6 | Almost similar in both the samples |
| 3. | 10.0 | 11.0 | Almost similar in both the samples |
| 4. | 15.0 | 16.5 | Almost similar in both the samples |
| 5. | 20.0 | 22.0 | Almost similar in both the samples |

The relative sweetness of 3.3, 6.6, 11.0, 16.5 and 22.0 per cent solutions of tagatose was found as almost similar to the sweetness of 3.0, 6.0, 10.0, 15.0 and 20.0 per cent solutions of sucrose respectively.

The results suggested that tagatose generated the same strength of sweetness to sucrose in the entire range of concentrations in which evaluation was carried out. Thus, sweetness of tagatose and sucrose grew at nearly identical rates with increase in their concentrations used in the testing. These results suggested that relative sweetness of tagatose same (*i.e.* 91) to sucrose, when dissolved in water at the rate required to generate sweetness equivalent to that of the sucrose. Thus, it was evident from results of this study that the relative sweetness of tagatose was not dependent on concentration ranging from 3.3 to 22.0 per cent.

It appears from the survey of literature that only one systematic study is reported for investigation on sensory characteristics and relative sweetness of tagatose compared to sucrose and some other alternative sweeteners. The study was conducted at Oregon State University by Fujimaru *et al.* [2] to evaluate relative sweetness and sweetness quality of tagatose at different concentration compared to other sweeteners including sucrose, sucralose, erythritol, and Rebaudioside A. The authors reported that the tagatose produced about the same relative sweetness to sucrose across the concentrations tested, while the relative sweetness of other sweeteners was highly concentration dependent. Therefore, findings obtained from the present study for relative sweetness of tagatose at in the concentration ranging from 3 to 20 per cent (w/v) were very well in accordance with those reported by Fujimaru *et al*. (2012).

**Effect of concentration on sweetness characteristics of tagatose**

The sweetness characteristics of some sweeteners may change with concentration of the sweetener under examination. Consequently, it is also necessary to examine how characteristics sweetener of any sucrose substitute is changing with concentration, compared to that of the sucrose [13]. Hence, in present study experiment was conducted to examine sweetness characteristics of tagatose over a range of concentrations in which it was required for sweetness equivalent to sucrose. Therefore, effect of concentration on relative sweetness of tagatose was studied. The results obtained on effect of concentration sweetness quality of tagatose are presented in Table 4.

**Table 4:** Sweetness quality of tagatose at different concentration

| Sr. No. | Concentration | | Sweetness quality of tagatose compare to sucrose | | |
|---|---|---|---|---|---|
| | Sucrose (%) | Tagatose (%) | Temporal profile | Objectionable taste | Cooling effect |
| 1. | 3.0 | 3.3 | Almost similar to sucrose | None | No |
| 2. | 6.0 | 6.6 | Almost similar to sucrose | None | No |
| 3. | 10.0 | 11.0 | Almost similar to sucrose | None | No |
| 4. | 15.0 | 16.5 | Almost similar to sucrose | None | No |
| 5. | 20.0 | 22.0 | Almost similar to sucrose | None | No |

The overall temporal profile of 3.3, 6.6, 11.0, 16.5 and 22.0 per cent solutions of tagatose was reported similar to 3.0, 6.0, 10.0, 15.0 and 20.0 per cent sucrose solutions respectively. Similarly, there was no objectionable taste was noticed in any of the 3.3, 6.6, 11.0, 16.5 and 22.0 per cent solutions of tagatose. Moreover, there was no cooling effect was felt in any of the 3.3, 6.6, 11.0, 16.5 and 22.0 per cent solutions of tagatose.

It was clearly evident from these results that the tagatose concentration in the range of 3.3 to 22.0 per cent had no any adverse effect on its overall temporal profile. The overall temporal of tagatose remained same as that of the sucrose in the entire range of concentration tried. Similarly, tagatose did not give bitterness, astringency, chemical-like sensations or any other objectionable taste in solutions at any concentration, ranging from 3.3 to.22.0 per cent. Moreover, tagatose did not generate cooling effect in the mouth in concentration range of 3.3 to.22.0 per cent tasted in this studied. As discussed earlier the study conducted at Oregon State University by Fujimaru *et al.* [2] to evaluate relative sweetness and sweetness quality of tagatose at different concentration compared to other sweeteners including sucrose, sucralose, erythritol, and Rebaudioside A. The authors reported that the tagatose produced a sweet taste without any undesirable qualities (bitterness, astringency, and chemical-like sensations) over a wide range of concentrations. Therefore, findings obtained

from the present study about effect of concentration on sweetness quality of tagatose in the concentration ranging from 3 to 20 per cent (w/v) were very well in accordance with those reported by these authors.

## Conclusion

Sweetness and sweetness characteristics of tagatose were compared with that of the sucrose. The relative sweetness of tagatose was found 0.91 (*i.e.* 91%). The sweetness quality of, tagatose when judged in terms of overall temporal profile of sweetener, any objectionable taste (bitterness, astringency, chemical-like sensations, etc.) and cooling effect were found almost similar to that of the sucrose. The relative sweetness and sweetness characteristics of tagatose were not affected by change in its concentration in the range of 3.3 to 22.0%.

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