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*Research Article*

# Formulation of vegan nutritional gummy supplements and their textural-organoleptic analysis

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**Abstract**
Gummy supplements are an exceptional medium for delivering pharmaceuticals and nutritional bioactives, especially for children. Interestingly, they are increasingly finding favor among adults as effective bioactive delivery systems. This study aimed to identify and select natural vegan components for creating and developing gummy prototypes. The gelling agent was agar-agar, sourced from red algae, and combined with carrageenan to enhance compressibility. Phycocyanin from Spirulina and anthocyanin from purple cabbage were used as colorants to provide a range of natural hues. The study resulted in five distinct formulations: Blueberry Anthocyanin Vitamin D (BAD), Blueberry Anthocyanin Vitamin C (BAC), Mango Antacid Anthocyanin (MAA), Mango Flavored Phycocyanin (MFP), and Kiwi Flavored *Spirulina* (KFS) gummies. Notably, the MAA gummy exhibited suboptimal texture quality during preliminary assessments and was consequently excluded from further analysis.Across the formulations, no visible color changes were noted upon room temperature storage for a week. The BAD gummy displayed heightened adhesiveness and springiness in texture, while the KFS gummy demonstrated superior cohesiveness, chewiness, and gumminess in its fresh state.Interestingly, the BAD gummy exhibited the highest adhesion even in the one-week-old samples.The outcome of the 9-point hedonic sensory evaluation unveiled that the cyan shade, derived from the phycocyanin pigment of *Spirulina*, was the most preferred color among the gummies. Regarding overall likability, the MFP and BAC formulations garnered the highest responses for being 'liked extremely'. The uniqueness of the present work lies in its meticulous exploration and selection of natural vegan ingredients to craft gummy formulations with diverse bioactive and sensory attributes.

**Keywords**: Nutritional supplement, Vegan gummy, *Spirulina* gummy phycocyanin, Anthocyanin, Textural analysis, Sensory evaluation

## INTRODUCTION

Gummy bears have been a great way of delivering the active constituents for consumption by children. Their use for adults has gained acceptance as well. They offer a great variety and a sense of palatable exhilaration among those who take it as compared to the usual method of tablets or syrups. The gummy bear industry is expected to reach 4.17 million US dollars by 2025 (Davydova, 2018). Gelatin has been the favored gelling agent for these kinds of preparation. Due to its being derived from an animal source, other vegetarian options are considered its substitute. Algae could prove to be a good vegan alternative for it. In our biodiversity study of Bhuigaon coast we have reported the presence of such important macroalgae like *Gracilaria*, *Gelidium* and *Agardhiella* (Pandey and Kejariwal, 2021a). Seaweeds possess a great diversity of components for many industries including pharmaceutical and nutraceutical and are being used for the commercial production of agar-agar in many countries (Pandey and Kejariwal, 2021b). Agar-agar is used as vegan substitute for gummies. Attempts have been made to deploy gummies in medicine delivery systems (Dille *et al*., 2018).

Nutritional-Gummies with specific bioactive and nutritional doses have been reportedly made keeping kids in mind. Vitamins, Antioxidants, Iron, Calcium, and other nutritional supplements have been synthesized (Grétarsdóttir, 2019). Many natural food colorants have been tried to give the desired color but the need for more such colorants is still there and needs to be re-

searched. Plant-based food colorants are usually preferred as natural colors (Zaki and Jai,2020). Fruit seed, skin extracts, and floral pigment colors are used to give gummies various colours (Čižauskaitė*et a*l., 2019).

Phycocyanin of algal origin is a natural pigment that is accepted as a food colorant. It is major phytopigment of blue-green algae. In the microalgae biodiversity of Vasai lakes *Arthrospira*(*Spirulina*)has been reported which is a very important source of Phycocyanin (Pandey andKejariwal, 2019) can be used for preparation of ice-creams and yogurt (Mohammadi-Gouraji*et al*., 2019). In a stability testing of heat and light compared to two other plant-based dyes (Indigo and Gardenia Blue), phycocyanin was found to be a more versatile food colorant (Jespersen *et al*., 2005). In another heat stability testing, adding phycocyanin in an aqueous sucrose solution of 40-70 % increases the stability of the colorant (Faieta *et al*., 2020). Therefore, the present investigation preferred phycocyanin as a natural colorant source for gummies.

Anthocyanin changes its color in different pH solutions due to its ionic structure (Roy and Rhim,2020), (Khoo *et al*., 2017). This study explores this phenomenon to produce different color variations in the gummy candies prepared using the vegan gelling agent agar-agar and carrageenan.The study focuses on replacing the animal product gelatin witha suitable gelling substance of natural vegan origin. Agar-agar, combined with other plant-origin substances like pectin, xanthan gum and carrageenan, are screened to give a desired gummy texture. The study's main objectivewas to design different formulations for the gummies and to be studied to get thedesired gummy texture for our product. In addition, it was also intended to achieve a natural color using anthocyanins and phycocyanin to provide different shades to the product.

## MATERIALS AND METHODS

The experimentation was designed in two stages:the preliminary screening and the main formulation and product analysis research. The gummies were prepared using agar-agar as gelling agent derived from red seaweed (*Gracilariacorticata, Gelidium and Kappaphycussps.)* to be acceptable to vegetarians also. The selection of the best ingredients for gummies followed subsequent testing and elimination processes. The process protocol flow is shown in Fig. 1.

The final gummies were prepared in two phases. First the antioxidant with colorant and second, the sugar based gelling solution. At the end, the bioactive component was added. Table 1 enlists the ingredients and their role in the gummy formation.

### Phase I- Flavored colorant with bioactive

Different color solutions were prepared using phycocyanin and anthocyanin as an aqueous extract from *Spirulina* (microalgae) and purple cabbage. The flavor and citric acid to be used was weighed and dissolved in 2 ml deionized water. This phase was kept ready to be added later in Phase II. Just before adding to phase II, the bioactive ingredients were added in Phase I and dis-

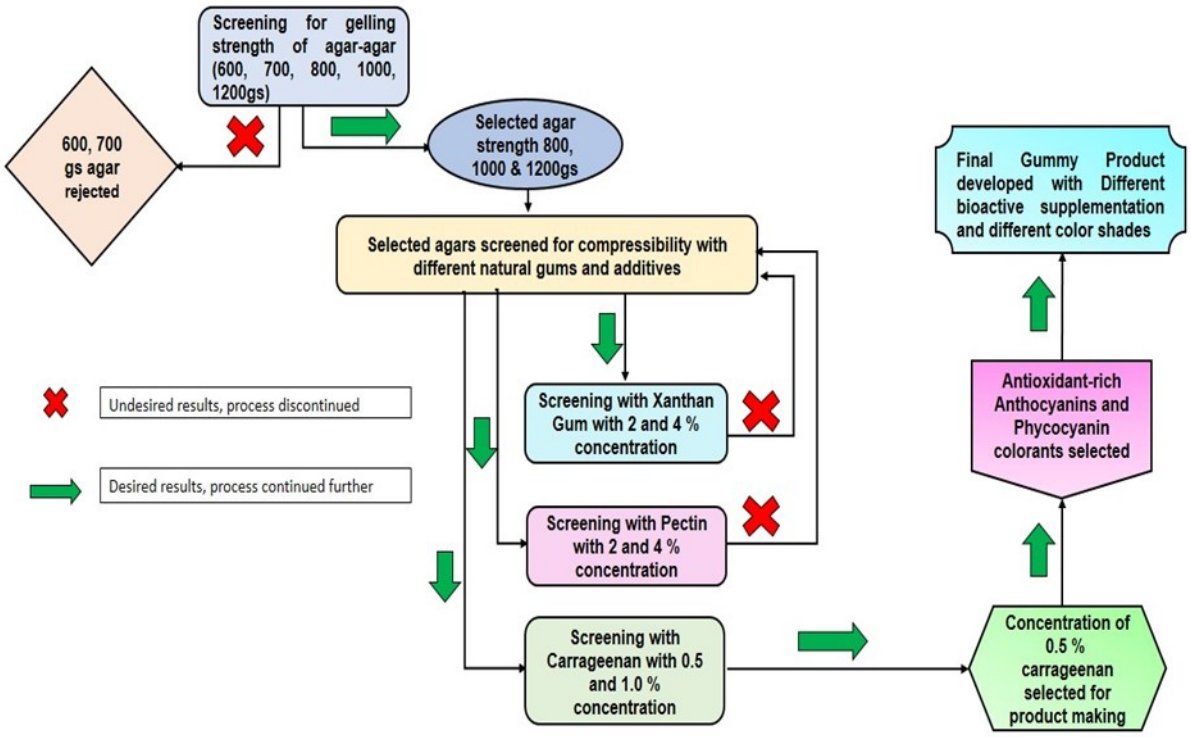


**Fig. 1.** *Flow chart for the process of selection and product formulation of base ingredients for nutritional gummy preparation*

solved.

**Phase II – Sugar gelling solution**

Gelling solution was prepared by food grade agar-agar of 1200gs, table sugar sucrose and carrageenan. The deionized water as per the formulation was weighed and kept ready before weighing and mixing these ingredients, as agar-agar and carrageenan are very hygroscopic and may form lumps if kept open for a longer time. All the ingredients were weighed according to the formulation and mixed in dry form (Achumiand Peter, 2018). All other required ingredients were weighed and kept ready before starting the Phase II solution preparation. Deionized water was added to the pan and induction was on at low temperature. The Phase II powder mix was added and the mixture was continuously stirred to avoid lumping. The heating was put on medium while continuously mixing the solution. The initial hazy solution begins to turn transparent, and within 5-8 minutes of heating, it thickens.

**Preparation of gummies**

Phase II solution turned transparent and started thickening at the end of Phase II. The induction was put off while continuing the stirring. Each Phase I Flavored bioactive colorant prepared as per formulation was individually added to the Phase II solution when it cools to approximately 600C while mixing all the ingredients. After thorough mixing, the gummies were poured onto the silicon mold for setting. After cooling for 30 minutes, the gummies were removed from the mold, air-dried for 8 –10 hours and stored at 15-25 $^{0}$C at Room Temperature. Five different formulations viz. Blueberry Anthocyanin Vitamin D (BAD), Blueberry Anthocyanin Vitamin C (BAC), Mango Antacid Anthocyanin (MAA), Mango Flavored Phycocyanin (MFP), Kiwi Flavored *Spirulina* (KFS) gummies were prepared using unique constituents and bioactive.

**Texture profile analysis (TPA)**

TPA of all four gummy samples wascarried out on fresh samples and after one week's storage at room temperature in an airtight glass jar. The Texture Pro CT V1.8 Build 31 from Brookfield Engineering Labs. Inc. was used for analysis. The gummy samples were 15 mm in length, 7 mm in breadth and 8 mm in depth. The mean average weight of each gummy sample was 1.3 g.

**9-pointer Hedonic sensory evaluation**

The assessment of textural profile analysis and 9-point hedonic sensory evaluation aregood evaluators for analyzing the final texture properties and their acceptance by the probable consumer (Romo-Zamarrón*et al.*, 2019). The sensory evaluation of the prepared gummies was done using randomly selected 48 panellistsbetween 07-70 years of age. Panelists were given the gummies to assessfor the sensory evaluation. The panelists were untrained or probable general consumers. The exact composition of the gummies was not disclosed to them so as not to influence their responses to liking or aversion to certain ingredients.

## RESULTS AND DISCUSSION

The extensive screening and elimination of gelling components and ingredients for compressibility were selected based on the desired outcome. Xanthan gum, and pectin were rejected on preliminary examinations. The concentration of agar and carrageenan were evaluated using the organoleptic test of 1 cm isosceles of agar strip. The process was established, and formulations were prepared as described in Table 2. The unique combination of agar and carrageenan reduced the actual agar concentration required for the gummies' hardening. The use of carrageenan gave a good lustre to the product. The gummy products showed no visible discoloration or changes in the structure or texture in a week of storage time in glass airtight jars. Fig. 2 shows the final product formed with the formulations.

**Texture profile analysis (TPA)**

Adhesiveness is the measure of the negative force area for the first bite, representing the work required to separate the holder away from the gummies (Rao *et al*., 2018). It is seen maximum in Blueberry Anthocyanin Vitamin D gummy (BAD). All the tested gummies showed an adhesiveness value in the 0.00-0.20 Ns-1 range (Fig. 3). The commercial gelatin shows this value at 0.2 Ns-1(Yusof *et al*., 2019). Cohesiveness is a measure of the internal strength of the product. Kiwi flavored *Spirulina* (KFS) gummies showed the maximum cohesiveness (1.94). The least cohesiveness is seen in Mango Flavored Phycocyanin (MFP) Gummies (0.00). It is reported that jelly candies show cohesiveness in the range of 0.54 to0.82 (Mutlu *et al.*, 2018). The elasticity is an important parameter in appreciation by the consumer (Guiné*et al*., 2020). Different ingredient concentrations also playan important role in determining its springiness (Banjongsinsiri *et al.*, 2020). The gummies prepared in the present study showed springiness in the range of 3.17 to 8.86. KFS gummy showed the maximum gumminess value of 980.00. The least was observed with MFP. Gumminess is a combined attribute of hardness and cohesiveness(Wang and Hartel, 2022). It is observed that the gumminess increases with increases in hardness. The literature reports gelatin to give gumminess 12.20 N (Yusof *et al.*, 2019).

The textural attributes did not change considerably during the one-week gummies storage at room temper-


**Fig. 2.** *A) Blueberry Anthocyanin Vitamin D Gummy (BAD); B) Blueberry Anthocyanin Vitamin C Gummy (BAC); C) Mango Antacid Anthocyanin Gummy (MAA); D) Mango Flavored Phycocyanin Gummy (MFP); E) Kiwi Flavored Spirulina Gummy (KFS)*

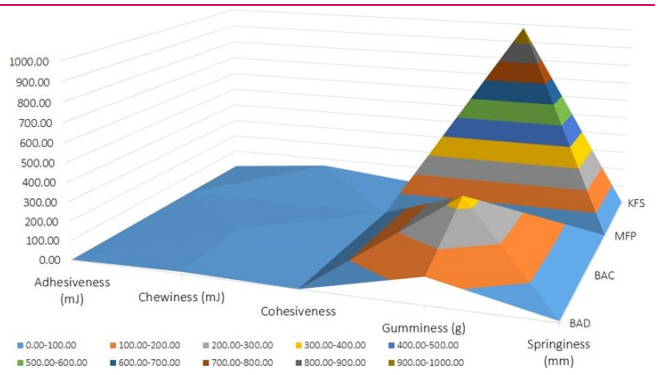


**Fig. 3.** *Texture rofile analysis of gummies BAD, BAC, MFP and KFS in fresh samples*

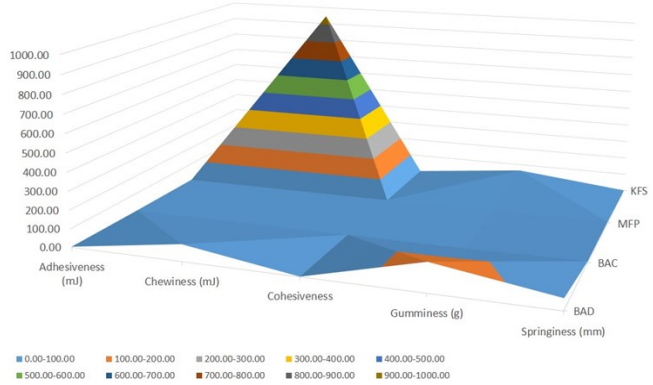


**Fig. 4.** *Texture profile analysis of gummies BAD, BAC, MFP and KFS in one week stored samples.*

ature in airtight glass jars (Fig. 4). The adhesiveness attribute of BAD gummy increased and with maximum adhesiveness. In other characteristics except chewiness BAD gummy showed maximum value. The KFS gummy had shown the maximum chewiness attributes. There was a difference in textural properties of gummies upon storage, which may be due to their different pH and bioactive constituent. Carboxymethyl cellulose was found to improve flexibility and to some extent decrease carrageenan gummy candies' fragility, with decreased water seepage during storage. The research provided evidence for utilizing hydrocolloids to adjust texture and control water migration in gummy candies (Song *et al*., 2022). Utilizing different additives for the texture and hardness of gummies contributes to their texture and stability (Tireki*et al*., 2023). Cassava starch thinned with acid wasused in an experiment to replace corn starch; 16% cassava starch showed better hardness of gummy candies, indicating different additives can influence the textural properties of gummy (Pereira *et al*., 2022).

**9-pointer Hedonic sensory evaluation**

Color can be regarded as one of those sensory attributes that can modulate the consumer's psychology in liking or disliking any product. It has been demonstrated that changing the color intensity or hue may have a very pronounced effect on consumer behavior (Spence, 2015). In the attempt to utilize many algal products, it was also seen that color variationswereobserved in the product. The four different shades of colors were chosen and expected to give some interesting sensory facts. It was observed that color indeed greatly impacted the behavior of the panellists. The sensory report showed that the most favored color for the gummies was cyan color derived from *Spirulina* pigment phycocyanin with 16 panelists saying that they extremely liked it (Fig. 5). The next color appreciated after phycocyanin was the natural purple color from anthocyanin pigment, with 14 panelists voting for like extremely. The least accepted color was the bright pink anthocyanin in acidic pH; only 7 participants liked it extremely.

The texture properties of any food material can be assessed by sensory evaluation and instrumental analysis. Though they should be correlated to each other, experimentation finds otherwise. Hence the, texture analysis in sensory evaluation has more importance (Meullenet *et al*., 1998). Maximum panelists likedblueberry-flavoured (BAD) gummy. (Fig. 6). The Spirulina gummy, which received 10 votes for "extremely liked" from the panelists, ranked as the second most favored gummy.The higher solid content in the *Spirulina* gummy could have improved its texture.

Odor is a result of a mixture of light and small mole-

**Table 1.** Phase I and Phase II ingredient and their function.

| Phase | Ingredient | Function |
|---|---|---|
| Phase I Flavored colorant with bioactive | Phycocyanin or Anthocyanin | Colorant and natural antioxidant |
| | Fruit flavor (Mango, Blueberry, Mixed Berry, Kiwi), Citric Acid | Flavoring agent |
| | Bioactive (Vitamin C, Vitamin D, *Spirulina* powder, Phycocyanin) | Nutrient Value |
| Phase II Sugar gelling solution | Agar-agar | Gelling Agent |
| | Carrageenan | Glistening and compressibility agent |
| | Table Sugar | Sweetener |
| | Deionized water | Solvent |

**Table 2.** Formulation for Blueberry Anthocyanin Vitamin D (BAD), Blueberry Anthocyanin Vitamin C (BAC), Mango Antacid Anthocyanin (MAA), Mango Flavored Phycocyanin (MFP), Kiwi Flavored *Spirulina* (KFS)

| Ingredient (g) | BAD | | BAC | | MAA | | MFP | | KFS | |
|---|---|---|---|---|---|---|---|---|---|---|
| | g | % | g | % | G | % | g | % | g | % |
| Water | 176 | 66.67 | 176 | 66.92 | 176 | 66.92 | 166 | 63.12 | 176 | 68.22 |
| Sucrose | 72 | 27.27 | 72 | 27.38 | 72 | 27.38 | 72 | 27.38 | 72 | 27.90 |
| Agar-agar | 02 | 0.76 | 02 | 0.76 | 02 | 0.76 | 02 | 0.76 | 02 | 0.78 |
| Carrageenan | 01 | 0.38 | 01 | 0.38 | 01 | 0.38 | 01 | 0.38 | 01 | 0.39 |
| Anthocyanin Extract | 10 | 3.79 | 10 | 3.80 | 10 | 3.80 | - | - | - | - |
| Phycocyanin Extract | - | - | - | - | - | - | 20 | 7.60 | - | - |
| Blueberry Dry mix | 01 | 0.38 | 01 | 0.38 | - | - | - | - | - | - |
| *Spirulina*powder | - | - | - | - | - | - | - | - | 04 | 1.55 |
| Mango Drymix | - | - | - | - | 01 | 0.38 | 01 | 0.38 | - | - |
| Kiwi Drymix | - | - | - | - | - | - | - | - | 02 | 0.77 |
| Cholecalciferol | 02 | 0.75 | - | - | - | - | - | - | - | - |
| L-Ascorbic Acid | - | - | 01 | 0.38 | - | - | - | - | - | - |
| Sodium Bicarbonate | - | - | - | - | 01 | 0.38 | - | - | - | - |
| Citric Acid | - | - | - | - | - | - | 01 | 0.38 | 01 | 0.39 |
| Total | 264 | 100 | 263 | 100 | 263 | 100 | 263 | 100 | 258 | 100 |

cules of the compound that come in contact with various human sensory systems and, when inhaled, have an impact on the stimulation of anatomical response to it, which is perceived as the odor. The sensory assessment of food productsis very importantinthe perception of odor. In consumer preference, it plays a vital role along with the attribute of color (Brattoli*et al*., 2011). In this study, it was seen that Blueberry flavor was liked extremely by panelists of BAD Gummy (Fig. 7). It was also interestingly that though two gummies had Blueberry flavoring agent, one was preferred and the other one had the least number of participants liking it extremely. Research involved presenting participants with compatible and contrasting colors and odors for identification. It was reported that the greater the discordance between colors and odors, the more challenging it became for participants to make identifications, consequently impacting their preferences (Ahmed *et al*., 2022).

Springiness and Chewiness are two important factors ingummies' material structure and composition. It was observed that different pH and extracts of natural products have an impact on these two attributes together (Charoen *et al*., 2015). It was also demonstrated that a good correlation exists between the textural profile analysis data for Hardness and Springiness andthe sensory evaluated data (Meullenet*et al*., 1998). For springiness attributes, both the BAD gummy and MFP gummies were equally liked, with 9 panelists each voting for Like extremely (Fig. 8). Chewiness was most liked in MFP gummy, with 11 panelists voting for Like extremely and 10 panelists voting for Like highly (Fig. 9). Sensory evaluation in food products isimportant as their nutritional aspects and biological functioning aregiven. In case studies, it was observed that the sensory profile may alter the acceptance or denial by the consumers. Especially when botanical subjects are chosen as a component in food product, they need to be ‘tailor-made’ concerning the senses and likeliness of the consumer (Civille and Oftedal., 2012). With re-

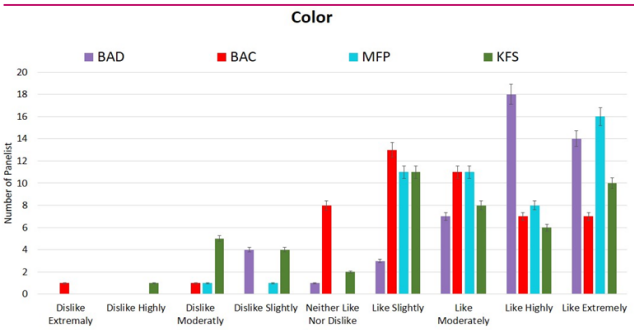


**Fig. 5.** *Results of the 9-point hedonic sensory evaluation of gummies BAD, BAC, MFP and KFS for Color.*

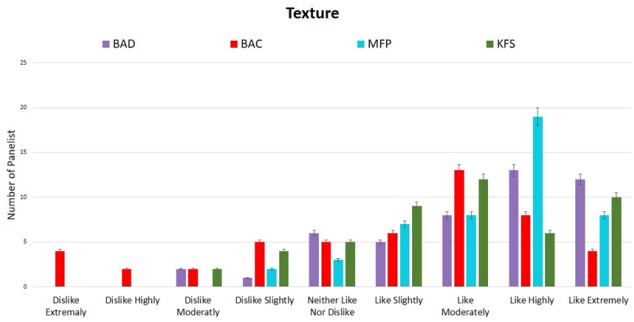


**Fig. 6.** *Results of the 9-point hedonic sensory evaluation of gummies BAD, BAC, MFP and KFS for textur.*

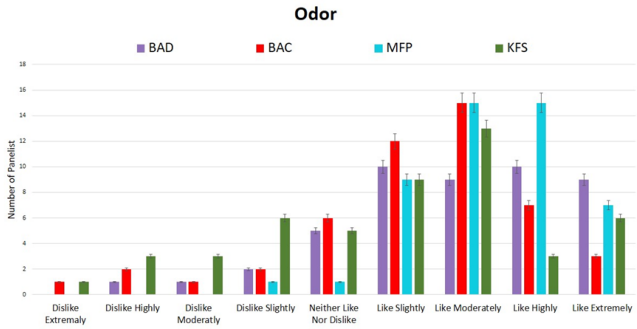


**Fig. 7.** *Results of the 9-point hedonic sensory evaluation of gummies BAD, BAC, MFP and KFS for odor*

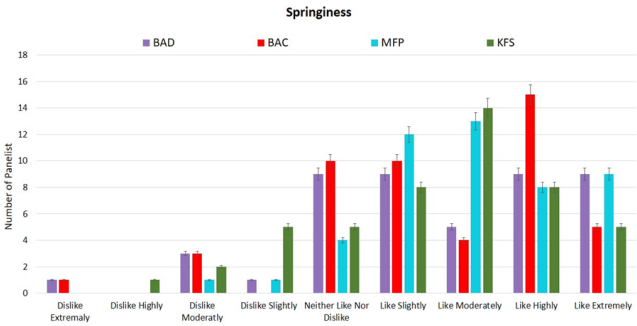


**Fig. 8.** *Results of the 9-point hedonic sensory evaluation of BAD, BAC, MFP and KFS for springines.*

spect to the taste of gummies the MFP gummy was the one which was voted maximum by 13 panelists as Like extremely (Fig. 10). A close second was BAD Gummy with 11 panelist vote for Like extremely. The BAC Gummy was the least liked, where only four panelists

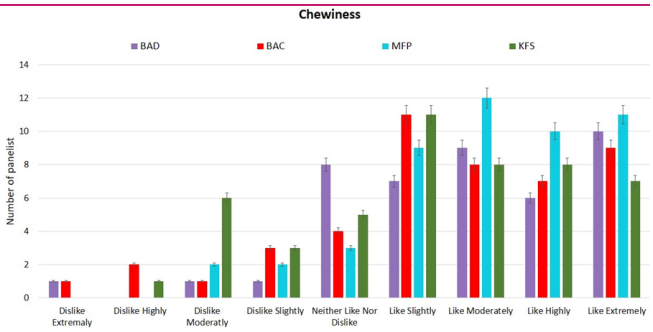


**Fig. 9.** *Results of the 9-point hedonic sensory evaluation of gummies BAD, BAC, MFP and KFS for chewiness*

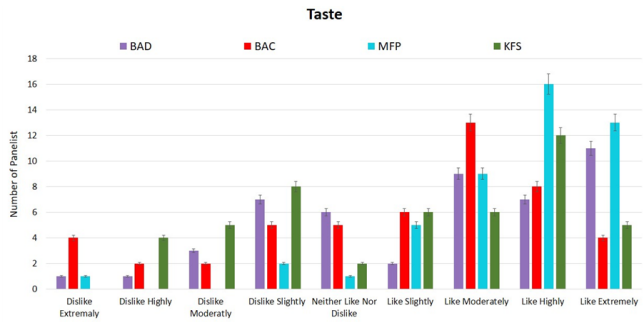


**Fig. 10.** *Results of the 9-point hedonic sensory evaluation of gummies BAD, BAC, MFP and KFS for taste*

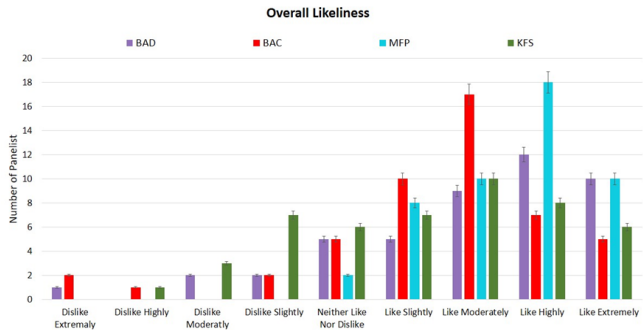


**Fig. 11.** *Results of the 9-point hedonic sensory evaluation for of gummies BAD, BAC, MFP and KFS Overall Likeliness.*

Liked extremely. As shown in Fig. 11, overall likeliness BAD and MFP were topmost liked, with 10 panelists each voting for 'Like extremely'. A close second was KFS with 6 panelists voting for 'Like extremely'.

## Conclusion

In conclusion, this study sheds light on the innovative potential of gummies as a novel vehicle for delivering nutraceuticals to adults and the younger generation. Incorporating beneficial compounds such as phycocyanin and anthocyanin, along with essential vitamins like Vitamin D and Vitamin C, offer a convenient and wholesome source of antioxidants and nutrients through Spirulina-infused gummies. Moreover, these gummies present a value-added utilization of raw materials by utilising agar-agar and carrageenan.With the growing emphasis on vegan dietary choices, these innovative and

vegan-friendly options hold promising market opportunities within the nutraceutical and health supplement sector. The study's textured analysis revealed that consumers displayed positive receptiveness toward the texture profile of the agar-carrageenan gummy as demonstrated by the sensory evaluation.In light of the present work, it is evident that these gummies provide a tangible and practical means of incorporating vital nutrients into everyday lives. The findings underscore the novel approach of merging nutrition with convenience, ultimately contributing to the broader landscape of nutraceutical offerings. As further research continues, exploring various formulations and optimizing sensory attributes could potentially refine these gummies' appeal and efficacy.

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### Conflict of interest

The authors declare that they have no conflict of interest.

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