INNOVATIVE DAIRY-BASED SOLUTION FOR DEPRESSION: DEVELOPMENT OF FUNCTIONAL YOGURT WITH GABA-ENRICHED ANTHOCYANIN-COFFEE HUSK PECTIN GUMMIES

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Introduction:

This project aims to develop a fortified yogurt with enhanced health benefits by incorporating grape seed anthocyanins, coffee husk pectin (CHP), and gamma-aminobutyric acid (GABA). Functional foods are gaining popularity due to their role in promoting physical and mental well-being.

Yogurt, a widely accepted dairy product, serves as an ideal base for fortification. The project emphasizes sustainability by utilizing coffee husks, an agro-industrial waste, to extract pectin using an eco-friendly microwave-assisted extraction (MAE) method.

Coffee husk pectin has demonstrated antibacterial activity and prebiotic potential. It also serves as a stabilizing agent for anthocyanins, which are otherwise sensitive to environmental and digestive conditions.

Grape seed anthocyanins provide antioxidant and anti-inflammatory benefits, while GABA supports neuroprotection by reducing anxiety and oxidative stress. These bioactive compounds are first used to prepare edible gummies, which are later integrated into yogurt.

The yogurt is further enriched with an indigenous probiotic strain isolated from human breast milk, enhancing its digestive and immune-boosting properties.

Cell line studies using neuronal models will assess the yogurt's neuroprotective potential. Parameters such as cell viability, oxidative stress, inflammation, and apoptosis will be measured.

The project contributes to waste valorization, improved nutrition, and cognitive health. It holds promise for industrial application, consumer acceptance, and potential patentability in the functional food sector.

Objectives:

- To prepare and standardize edible gummies enriched with GABA, grape seed anthocyanins, and coffee husk pectin (CHP).
- To formulate and optimize functional yogurt by incorporating the gummies and utilizing an indigenous probiotic strain.
- To evaluate the neuroprotective effects of the developed yogurt in a cell line model.

Methodology:

The study was divided into three phases: (1) formulation of encapsulated edible gummies, (2) preparation of fortified functional yogurt, and (3) in vitro evaluation of neuroprotective potential.

Preparation of Encapsulated Edible Gummies:

A pectin blend was prepared using 4% total pectin, consisting of 20% coffee husk pectin (CHP) and 80% standard pectin. To this, 2% grape seed anthocyanin extract, 300 mg GABA, and 1% fructooligosaccharides (FOS) were added. The ingredients were dissolved and homogenized to ensure uniform mixing. The mixture was then carefully dropped using a syringe into 0.2 M calcium chloride solution to form calcium-induced gel beads (encapsulated gummies) via ionic crosslinking. The formed gummies were allowed to stabilize in the calcium chloride bath, then washed and stored for further use.

Preparation of Functional Yogurt:

High-quality milk was pasteurized at 85–90 °C, then cooled to 40–45 °C. An indigenous probiotic strain isolated from breast milk samples was used as the starter culture. The prepared encapsulated gummies were incorporated into the milk before fermentation. Fermentation was carried out at 37–42 °C for 4–6 hours until the desired consistency and pH were achieved. Yogurt was stored at 4 °C and analyzed for physicochemical properties and probiotic viability.

Neuroprotective Evaluation (In Vitro):

SH-SY5Y neuroblastoma cells were cultured under standard conditions. Cells were treated with varying concentrations of the fortified yogurt extract. MTT assay was conducted to assess cell viability. ROS levels were measured to determine oxidative stress.

Results and conclusion:

The first objective was successfully achieved with the formation of stable, uniform gummies enriched with GABA, grape seed anthocyanins, and coffee husk pectin. Using ionic gelation in chilled $CaCl_2$, spherical gummies were obtained (Figures 1 and 2), with an **average diameter of 2.552 mm**. This confirms effective encapsulation, supporting further integration into functional yogurt formulations.

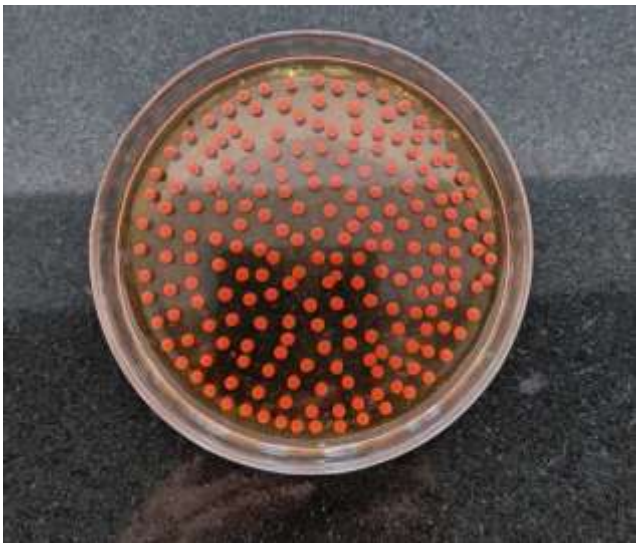

Figure 1: Spherical gummies obtained using ionic gelation in chilled $CaCl_2$

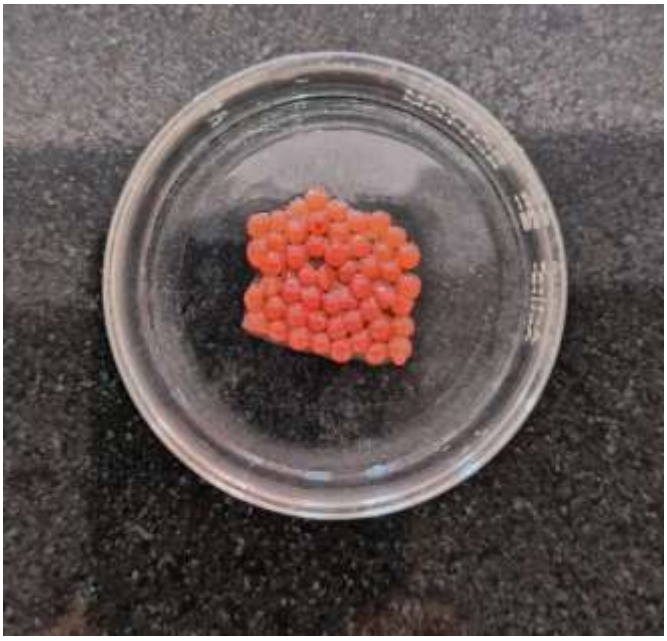

Figure 2: The gummies obtained

Project Outcome & Industry Relevance:

The project successfully develops a fortified yogurt product enriched with grape seed anthocyanins, GABA, and coffee husk pectin (CHP), offering both physical and mental health benefits. By utilizing CHP extracted from coffee production waste, the project exemplifies sustainable food innovation through effective waste valorization. The inclusion of GABA supports cognitive well-being, such as stress reduction and improved sleep, while grape seed anthocyanins provide antioxidant and cardiovascular benefits. Additionally, the use of an indigenous probiotic strain enhances the yogurt's digestive health potential. This functional food product shows promise in improving stability, shelf life, and bioavailability of key nutrients. With comprehensive lab evaluations and market potential studies, the project aligns with current industry trends in health-oriented and eco-friendly food solutions. Its relevance is significant for the food industry, particularly in functional foods and sustainable food processing, and holds patentable novelty.

Working Model vs. Simulation/Study:

This project involved the development of a physical working model. The formulation of encapsulated gummies and their incorporation into probiotic yogurt were carried out in a laboratory setting, resulting in a tangible functional food product. Each stage—from encapsulation using calcium-induced ionic gelation to fermentation with an

indigenous probiotic strain—was experimentally executed. While certain advanced analytical assays such as HPLC, and in vitro neuroprotective evaluations are planned, the core formulation and product development aspects were practically implemented, making this a hands-on, application-driven study rather than a theoretical or simulation-based project.

Project Outcomes and Learnings:

This project led to the development of a fortified functional yogurt incorporating encapsulated gummies enriched with grape seed anthocyanins, GABA, and coffee husk pectin (CHP). The encapsulation technique, using calcium-induced ionic gelation, is expected to enhance the bioavailability and stability of the bioactive compounds while protecting them through processing and digestion. Integration of these gummies into probiotic yogurt fermented with an indigenous strain resulted in a formulation with promising cognitive and gut health potential. The neuroprotective efficacy of the product will be confirmed through planned in vitro assays, including MTT for cell viability and ROS analysis for oxidative stress. The use of CHP, derived from agro-industrial coffee waste, exemplifies sustainable food innovation and adds industry relevance in the context of eco-conscious functional food development.

Throughout the project, our team engaged in a multidisciplinary approach spanning food science, microbiology, and bioprocessing. We deepened our understanding of encapsulation strategies, functional dairy product formulation, and the design of bioactive delivery systems. Upcoming analytical techniques such as HPLC will support precise evaluation of encapsulation efficiency and bioactive retention. This work reflects the growing emphasis on sustainability-driven, health-oriented innovation and highlights the potential of research-driven, waste-valorized formulations in the evolving functional food landscape.

Future Scope:

This project lays a strong foundation for future advancements in the development of sustainable and functional food products. One major avenue for future work is the scale-up of coffee husk pectin extraction for industrial applications, which can contribute significantly to the circular economy in the food sector. Further clinical trials

and human studies can be conducted to validate the neuroprotective effects of GABA and anthocyanin-fortified yogurt, confirming their efficacy beyond in vitro models.

There is also potential for diversifying product forms, such as beverages, snack bars, or capsules, to reach a broader consumer base. The indigenous probiotic strain identified can be explored for other probiotic-based formulations, enhancing gut health research. Additionally, nanoencapsulation techniques can be employed to further improve the stability and targeted delivery of bioactive compounds like GABA and anthocyanins.

This innovation can inspire cross-sector collaborations between the food, pharmaceutical, and nutraceutical industries. With increased focus on mental health and natural health boosters, this fortified yogurt has strong potential for commercial success. Lastly, as consumer interest in plant-based diets grows, adapting the formulation to plant-based milk alternatives could enhance inclusivity and marketability.