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DEVELOPMENT OF A PLANT BASED COLLAGEN AND GLUTATHIONE BOOSTER USING CITRUS PECTIN ENCAPSULATION (VEGAN VITACAPS) .

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ABSTRACT

This paper is about the formulation development of plant-based capsule formulation, namely Vegan Vitacaps, and positions it as a vegan-friendly collagen-building nutraceutical. Plant-derived collagen-stimulating components were combined with glutathione, and citrus pectin was used as the encapsulating material. Citrus pectin, extracted from waste fruit peels, is a biodegradable polymer, featuring excellent gelation and film-forming properties, which makes this polymer applicable in microencapsulation for sensitive bioactive compounds. The methodology involved the extraction, purification, and controlled microencapsulation of active ingredients through moulding techniques. Preliminary laboratory scale evaluations revealed that the pectin-based capsules showed good mechanical stability and proved to be biodegradable and proper for oral administration. Simulated digestive condition experiments and critical comparative literature review pointed out that pectin encapsulation enhances stability by protecting the bioactive compounds and enabling their gradual release in gastrointestinal conditions. Glutathione supports detoxification, skin health, and anti-aging benefits, while plant-based ingredients support collagen synthesis. This study demonstrates the feasibility of developing a sustainable vegan nutraceutical delivery system; further in vitro and in vivo studies are recommended before commercialization.

KEY WORDS

Citrus pectin, Vegan Vitacaps, Collagen builder, Glutathione, Microencapsulation, Plant-based capsules, Bioavailability, Stability enhancement, Pectin extraction, Nutraceutical formulation, Biodegradable polymer, Targeted release, Vegan-friendly delivery system, Skin and Bone health, Sustainable encapsulation.

INTRODUCTION

The nutraceutical market is increasingly shifting toward plant-based nutraceuticals due to growing demand for clean-label, sustainable health solutions that happen to be vegan-friendly. Conventional collagen supplements are widely based on bovine, porcine, or seafood origins, hence their poor acceptance among vegetarians, vegans, or religious or culturally restricted populations. Furthermore, recent science highlights that vegan collagen does not exist as a direct structural protein; instead, it works by supplying bioactive compounds that trigger endogenous collagen biosynthesis by means of amino acids, vitamin C, and Phytochemicals. Kumar et al. (2024) [4,5]. These factors have intensified the need for novel delivery systems that enhance bioavailability while preserving ethical integrity.

Another important functional ingredient in current nutraceuticals is glutathione, an antioxidant that has been well accepted

because of its potential in skincare and cell regeneration. Glutathione plays a crucial role in detoxification, melanin synthesis control, and oxidative stress defense mechanisms. The bioavailability of oral glutathione supplements is challenged by its instability in the gastrointestinal system. As such, glutathione encapsulation technology is important in preserving its biological activity during digestion and enhancing its medicinal use (Allen & Bradley, 2023) [7].

Encapsulation has been identified as a prominent trend in the current development of nutraceuticals, especially concerning the protection of bio-sensitive compounds and the controlled release of bioactive agents. Natural biopolymers like pectin have been attracting more interest because of the potential for degradation while being biodegradable and biocompatible, and more importantly, it is a GRAS material suitable for the preparation of a controlled release matrix. Citrus pectin is a valuable encapsulant material that promotes the bioeconomic cycle concept by converting citrus processing waste into a valuable biomedical and nutraceutical material. Moreover, capsules made of hydroxypropyl methylcellulose (HPMC) show superior patient compliance and flexibility.

In this regard, the current research work is based on the formulation of Vegan Vitacaps, which is a plant-based encapsulated formulation with collagen-stimulating vitamins and glutathione with the help of citrus pectin as the encapsulating agent. The formulation has been made with the aim of improving stability, bioavailability, and controlled release properties in a manner that is earth-friendly and acceptable to the consumer. Thus, the current work has a discernible departure in terms of its ethical nutraceutical formulations.

MATERIALS AND METHODS

The procedure encompasses top-level steps such as the choice of raw materials as well as controlled extraction.purification, encapsulation, and capsule formation. Because of confidentiality restrictions on the details of the technology, the current discussion will Proportions are suppressed for intellectual property protection purposes. The encapsulation strategy takes advantage of biopolymer-based shells (Pectin with biodegradable agents) so as to indicate a slow and increased bioavailability.

Materials Required:

- *Fresh citron peels*
- *Guava peels*
- *Citric acid or dilute HCL*
- *95% Ethanol*
- *Filter paper or muslin cloth*
- *Beakers, thermometer, hot plate*
- *Blender or grinder*
- *Pectin*
- *Carrageenan*
- *Glycerol*
- *Veld grape*
- *Turmeric*
- *Beetroot*
- *Glassware*
- *Distilled water*
- *Rice flour*
- *Corn flour*
- *Hot plate with magnetic stirrer*
- *pH meter*
- *Oven (40–50°C)*
- *Analytical balance.*

Methodology :

The preparation of Vegan Vitacaps involved five major stages: raw material processing, pectin extraction, encapsulation, capsule formulation, and evaluation. Each step was performed under controlled laboratory conditions to ensure reproducibility and quality of the final product.

Step 1: Raw Material Processing

Fresh citrus and guava peels were collected, washed thoroughly with distilled water to remove dirt , and then shade-dried for 48-72 hours. The dried materials were powdered using a grinder and stored in airtight Container until further use.

Figure 1 : sterilization of citron peel for dry and direct Extraction of pectin.

Figure 2 : Drying of citron peel to powder it pectin extraction.

Step 2: Extraction of Citrus Pectin

About 25 g of dried peel powder was boiled in acidified distilled water (pH 1.5–2.0, adjusted using dilute HCL acid) for 1–2 hours with continuous stirring. The mixture was filtered through muslin cloth, and the filtrate was treated with ethanol in a 1:1 ratio to precipitate pectin. The precipitated pectin was washed, dried at 50 °C in a hot-air oven, and stored in a desiccator.

Figure 3: Adjusting of PH in dry powdered peel to obtain pectin.

Figure 4 : Removal of water content for drying .

Step 3: Encapsulation Process

The extracted pectin was dissolved in warm distilled water to form a uniform gel solution (2–3 % w/v). Dissolve 2-4% pectin in 2ml distilled water, Additionally add 10mg of carrageenan in 1ml of warm water for strength (optional Rice flour). Mix both the prepared mixture, heat to 80 degree Celsius, stir until clear and homogenous for 2 mins, and then add plasticizer (glycerol 1-2% w/v) along with the veld grape extract about 3-4 drops and then allow to Cool to 40 degree Celsius.

Figure 5: Extraction of veld grape extract through double boiling Method.

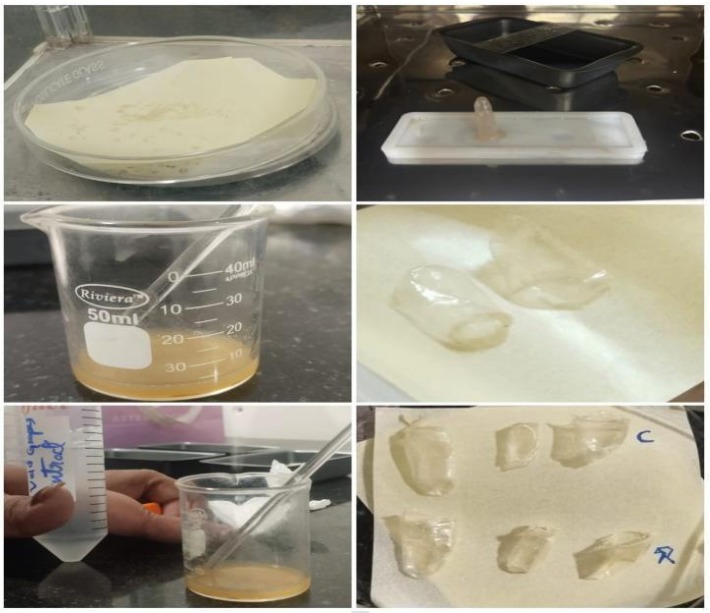

Figure 6 : Sheeting the sample in a silicon tray.

Step 4: Capsule shell Formation and Evaluation

Pour the gel into the glass slides and rod shape silicon Mold (uniformed thickness~1).Dry at 40-50 degree Celsius for 6-12 hours (Humidity<50%),Once the sheet is formed, obtainIt uses forceps and checks the stability, flexibility, and thickness.

Encapsulation process table :

3 ml Preparation	*Trial 1 2% pectin*	*Trial 2 3% pectin*	*Trial 3 4% pectin*
Pectin	*0.060 g*	*0.090 g*	*0.120 g*
Glycerol (2%)	*0.06 ml*	*0.06 ml*	*0.06 ml*
Carageenan (0.3%)	*0.009 g*	*0.009 g*	*0.009 g*

*Pectin yield = Dry pectin \ Dry pectin weight *100. Car*

RESULT & DISCUSSION

Result :

FINAL PRODUCT

In conclusion, the development and evaluation of Vegan Vitacaps were efficiently carried out, showing that a fully plant-based capsule could be successfully formulated by using pectin from citrus as the primary encapsulating polymer. Experimental extraction of pectin from citrus peel produced a pale-yellow-coloured polysaccharide powder that possesses good solubility and gel forming characteristics. The average yield in extraction was 22%, which increased to 18 g after purification, corresponding to 82% of recovery efficiency of the applied methodology. This shows that the adopted method of pectin extraction is effective and reproducible. The encapsulation of the active blend containing plant-derived collagen-stimulating components and L-glutathione resulted in uniform microcapsules with desirable structural stability. Encapsulation efficiency was observed visually to be high, while leakage during processing was minimal. Pectin compatibility with the active compounds was confirmed by the integrity of the microcapsules during drying and filling into capsules. A simulated digestion test confirmed that the capsules were stable under the acidic conditions simulated at the stomach pH and gradually released the active components under neutral to slightly alkaline conditions simulated at intestinal pH. Indeed, this suggested that pectin. encapsulation succeeded in providing controlled release behaviour, protecting glutathione and collagen-building compounds from early degradation.Cost evaluation showed successful feasibility at a laboratory scale. The total raw material cost for producing 10 capsules was about ₹20, wherein glutathione and collagen builder components were the costliest ingredients.

***DISCUSSION** :*

The Vegan Vitacaps formulation demonstrates a successful combination of collagen-stimulating ingredients and antioxidant protection, creating a synergistic effect that may support skin health, joint movement, and overall cellular defence. The plant-based amino acids and vitamin C act as cofactors in collagen synthesis, while glutathione helps reduce oxidative stress together offering functional benefits similar to findings reported by Kumar et al. (2024).Using citrus pectin as the capsule material adds further value, as it is biodegradable, GRAS-certified, and safe for long-term use. The encapsulation efficiency and stability results indicate that pectin effectively protects active compounds during digestion, aligning with previous studies showing its suitability for nutraceutical delivery systems.Sustainability is another advantage, as pectin is sourced from fruit waste, supporting circular bioeconomy principles and enhancing commercial potential in the growing vegan supplement market.While the formulation does not contain true collagen, it adopts a collagen-building strategy supported by early human evidence. Future clinical trials and optimization may strengthen its efficacy claims and expand its applications in both beauty and functional health sectors.

CONCLUSION:

The Vegan VitaCaps formulation successfully demonstrates a plant-based, sustainable, and effective approach to delivering collagen-building nutrients and glutathione using citrus pectin encapsulation. By combining vegan science with biodegradable technology, this study confirms that nutraceuticals can be both ethical and functional. The results highlight the potential for commercialization and future clinical validation, positioning Vegan VitaCaps as a promising innovation for modern health, wellness, and eco-conscious living.

Possible side effects and safety considerations :

Vegan Vitacaps are generally safe, but mild side effects may occur in some individuals. Citrus pectin may cause temporary bloating, gas, or loose stools, especially for those not used to dietary fibre. Rare allergic reactions may occur in people sensitive to citrus fruits. Glutathione may occasionally cause nausea, headache, or mild stomach upset, especially at higher doses. Individuals who are pregnant, breastfeeding, taking medication, or have medical conditions should consult a healthcare professional before use. When taken as recommended, the capsules are typically well tolerated and safe for long-term use.

Yield and cost efficiency of encapsulation process :

Process Step	*Raw Input (g)*	*Yield (g)*	*% Recovery*	*Unit Cost (₹)*	*Cost Per Yield (₹)*
Pectin Extraction (Citrus Peel)	*100*	*22*	*22%*	*1.00*	*0.05*
Pectin Purification	*22*	*18*	*82%*	*0.50*	*0.03*
Encapsulation Process	*18*	*16*	*89%*	*2.00*	*0.12*
Capsule Filling	*16*	*15*	*94%*	*3.00*	*0.20*
Overall Process Efficiency	–	–	*76%*	–	–

Note : All costs are approximate and represent laboratory scale estimations (₹ 1 - ₹ 5 per unit range) .

FUTURE SCOPE:

The Vegan Vita Capsules project opens a wide horizon for innovation in nutraceutical science and sustainable healthcare. With the continuous rise in demand for plant-based supplements globally, this formulation is likely to evolve into a commercially viable product with multiple health oriented versions to target immunity, skin health, or energy enhancement.

1. Advanced nutrigenomic formulations: tailor capsule compositions based on the individual's genetic and nutritional profile.

2. Integration of functional foods by converting the capsule formulation into gummies, energy bars, or powdered drink mixes for convenience to consumers.

3. Clinical validation and large-scale production will enable the product to meet pharmaceutical□grade standards for safety and efficiency.

4. Eco-friendly packaging and branding that advocate for a sustainable product life cycle, from formulation through to disposal.

5. Entry into the global nutraceutical market by offering a new-generation line of vegan supplements, targeting health-oriented and ecologically conscious consumers.

6. *Merging biotechnology with nutrition and sustainability, the Vegan Vita Capsules project pioneers a pathway toward a healthier, cruelty-free, and eco-friendly future in nutraceutical innovation.*

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