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CULTIVATED MEAT QUALITY: INSIGHTS FROM A SYSTEMATIC REVIEW ON TEXTURE PROPERTIES

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I. INTRODUCTION

Cultivated meat presents a sustainable alternative to conventional meat, aligning with the UN's Sustainable Development Goals. Produced by culturing animal cells under controlled conditions, it mimics the structure and composition of traditional meat. However, challenges remain in ensuring cell viability, scalability, and consumer acceptance. Key physicochemical properties, such as color, texture, and nutritional content, are critical for product quality. Advances in bioengineering and fermentation have enhanced sensory attributes, but quality control remains essential. Sensory factors like taste and mouthfeel influence acceptance, with research focusing on optimizing culture conditions to replicate conventional meat's characteristics. Systematic reviews play a crucial role in evaluating the current state of research, minimizing bias, and identifying knowledge gaps. While previous studies have explored environmental and technological aspects, few have focused on physicochemical, technological and sensory quality. This review aims to consolidate existing research on texture profile and guide future advancements in cultivated meat production.

II. MATERIALS AND METHODS

This review systematically analyzed studies that assessed the texture and sensory profiles of cultured meat, following the PRISMA guidelines. A comprehensive search was conducted in Science Direct, Web of Science, and Scopus using Boolean operators and multiple synonyms for cultivated meat, ensuring the inclusion of all possible terminologies: "cultured meat", "cultivated meat", "clean meat", "cell-based meat", "synthetic meat", "in vitro meat", "lab-grown meat" and "artificial meat" paired with "muscle tissue". The search covered articles from January 2012 to May 2024. Strict inclusion criteria ensured that only experimental studies measuring technological and sensory attributes with established methods were included. Non-English publications, reviews, conference abstracts, and studies lacking relevant analyses were excluded. From an initial 714 articles, filtering and screening narrowed the selection to 16 eligible studies. The findings were synthesized to identify trends and gaps in research, offering insights into how different cultivation methods and cell types influence cultivated meat quality.

III. RESULTS AND DISCUSSION

The texture of cultivated meat was assessed by Texture Profile Analysis (TPA), focusing on key parameters such as hardness, chewiness, springiness, cohesiveness, gumminess, and adhesiveness. Comparing these results across studies is challenging due to differences in culture duration, scaffold materials, cultivation methods, sample sizes, and test configurations. The ranges presented here aim to highlight reported values in the literature rather than define absolute benchmarks. Hardness generally ranges from 20 N to 150 N in conventional meat, varying based on the cut and preparation method. In cultivated meat, hardness values ranged from 1 N to 479.9 N. The reviewed studies indicated that various scaffolds significantly impacted the hardness of cultivated meat. The highest value (479.9 N) was reported by Zheng et al. [1] using a smooth muscle tissue-based, which promoted a dense extracellular matrix rich in collagen. Gellan gum-gelatin-based cultivated meat crosslinked with calcium ions also exhibited high hardness, enhancing structural integrity [2]. Conversely, hydrogel-based with topographic microstructures resulted in a softer texture (4 N), demonstrating the influence of scaffold type on mechanical properties [3]. Chewiness, representing the energy required for mastication, varied from 1 N to 172 N. In conventional meat, chewiness values typically range from 30 N to 150 N. The highest values were again linked to smooth tissue-based muscle scaffolds due to their compact structure and collagen content. Yeast protein-based cultivated meat produced lower chewiness (4 N), while hydrogel-based scaffolds [3] yielded softer textures (2 N), aligning with their lower hardness. Springiness values ranged from 0.55 to 1.0, with conventional meat typically within 0.6 to 0.85. Higher springiness values (1.0) were observed in elastic biopolymer-based [4, 5], whereas yeast protein-based scaffolds provided moderate elasticity (0.6). Hydrogel-based cultivated meat [3] maintained a balance between softness and resilience (0.9), making them suitable for diverse applications. Cohesiveness,

indicating structural integrity, varied from 0.35 to 0.8. Alginate-based cultivated meat [6, 7] achieved the highest cohesiveness (0.8), enhancing cell-matrix interactions, while hydrogel-based [3] (0.5) and decellularized plant scaffolds (0.35) resulted in crumbly textures [8], suitable for ground or processed meat. Gumminess ranged from 150 N to 700 N, with yeast protein-based scaffolds exhibiting the highest values [9], creating a dense structure. Hydrogel-based [3] had lower gumminess (150 N), producing softer textures desirable in certain applications. Adhesiveness was assessed in one study [10], reporting 2.78 Nmm, within the range of conventional meat (2–5 Nmm). While adhesiveness influences mouthfeel, further research is needed to understand its impact on consumer perception. TPA is a popular method for assessing meat's textural attributes, closely mimicking the human eating experience. It allows evaluation of various textural properties in a single test, making it ideal for cultivated meat studies. However, TPA's sensitivity to sample preparation and testing conditions, such as size, shape, and temperature, can lead to inconsistencies, complicating comparisons across studies. Additionally, TPA measures bulk properties, which may overlook microstructural variations and the specific contributions of scaffold material and cell-matrix interactions to texture. The findings highlight the crucial role of scaffold materials in shaping the texture of cultivated meat, emphasizing the need for standardized methodologies to improve comparability across studies.

IV. CONCLUSION

This systematic review underscores the significant influence of scaffold composition on the textural properties of cultivated meat. Variations in hardness, chewiness, springiness, cohesiveness, gumminess, and adhesiveness highlight the complexity of replicating conventional meat textures. While certain scaffold materials, such as yeast protein-based scaffolds, contribute to firmer and denser textures, hydrogel-based scaffolds provide softer alternatives. Future research should focus on optimizing scaffold formulations and standardizing TPA methodologies to enhance the reproducibility and comparability of results.

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