CONSUMER EXPERIENCE WITH TEMPEH LABEL INFORMATION: A LONGITUDINAL STUDY OF NON-GMO VS. UNLABELED PRODUCT CHARACTERISTICS AND TECHNOLOGICAL IMPLICATIONS

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ABSTRAK

Kemasan produk pangan berperan sebagai sumber informasi utama, menyajikan detail esensial seperti status Organisme Termodifikasi Genetik (GMO), harga, dan tanggal kedaluwarsa, yang secara signifikan memengaruhi pengalaman dan kepercayaan konsumen. Penelitian ini bertujuan menyelidiki korelasi antara informasi yang tersedia pada kemasan pangan dengan atribut produk yang diobservasi konsumen, dengan membandingkan tempe berlabel non-GMO dan tidak berlabel (diasumsikan GMO). Menggunakan metodologi studi kasus observasional longitudinal kualitatif, seorang peneliti sekaligus konsumen melakukan evaluasi harian sistematis selama 120 hari. Data yang dikumpulkan mencakup informasi label, harga beli, dan karakteristik produk yang dialami (masa simpan aktual, perubahan tekstur seperti kelembapan dan kekencangan, serta profil aroma) pada kondisi penyimpanan rumah tangga yang konsisten. Hasil utama memperlihatkan tempe tidak berlabel (harga lebih rendah) memiliki masa simpan aktual lebih lama dan integritas tekstur lebih superior dibandingkan tempe non-GMO premium. Tempe non-GMO mengalami degradasi tekstur lebih awal (lembab), meskipun kedua produk umumnya sesuai dengan tanggal kedaluwarsa masing-masing yang berbeda. Penandaan "non-GMO" dan harga premiumnya menciptakan ekspektasi konsumen terhadap durabilitas produk secara keseluruhan yang tidak sepenuhnya terpenuhi oleh kinerja aktual tempe non-GMO. Penelitian ini menyimpulkan bahwa informasi pada kemasan saat ini, meski menyajikan detail spesifik, mungkin belum memadai mengomunikasikan keseluruhan nuansa kinerja produk akibat teknologi produksi pangan yang beragam, yang berpotensi memengaruhi kepercayaan konsumen. Sistem informasi yang lebih canggih (misalnya, pelabelan cerdas, platform transparansi) berpotensi meningkatkan penyampaian informasi, mengelola ekspektasi konsumen lebih efektif, dan memperkaya pengalaman konsumen dengan menjembatani kesenjangan antara informasi yang disajikan dan atribut produk aktual.

Kata Kunci: Masa simpan; Pelabelan GMO; Pengalaman konsumen; Teknologi pangan; Tempe.

ABSTRACT

Food product packaging serves as a primary source of information, conveying essential details such as Genetically Modified Organism (GMO) status, price, and expiration dates, which significantly shape consumer experience and trust. This study aimed to investigate the correlation between information provided on food packaging and the consumer's observed product attributes, specifically comparing labeled non-GMO tempeh with unlabeled (presumed GMO) tempeh. Adopting a qualitative, longitudinal observational case study methodology, a single consumer-researcher conducted systematic daily evaluations over 120 days. Data collection involved logging label information, purchase price, and meticulously recording experienced product characteristics such as practical shelf-life, textural changes (e.g., moisture development, firmness), and aroma profiles under consistent household storage conditions. Key findings revealed that the lower-priced, unlabeled tempeh demonstrated a significantly longer practical shelf-life and maintained superior textural integrity compared to the premium-priced labeled non-GMO tempeh. The latter exhibited earlier textural degradation, primarily through moisture development, even though both product types generally adhered to their respective, differing stated expiration dates. The "non-GMO" designation and its associated premium pricing fostered consumer expectations regarding overall product durability that were not holistically met by the non-GMO tempeh's tangible performance. This research concludes that current information on packaging, while offering

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specific details, may not adequately communicate the full spectrum of product performance nuances arising from diverse food production technologies, potentially impacting consumer trust. There is considerable potential for advanced information systems, such as intelligent labeling or enhanced transparency platforms, to improve information delivery, thereby managing consumer expectations more effectively and enriching the overall consumer experience by bridging the gap between presented information and actual product attributes.

Keywords: Consumer Experience; Food Technology; GMO Labeling; Shelf-life; Tempeh.

1. INTRODUCTION

Tempeh, a fermented soybean product, is a significant food source globally, valued for its nutritional content (Shurtleff & Aoyagi, 2001). The technology of food production, including genetic modification, has introduced distinctions such as GMO and non-GMO products into the market, influencing consumer choice (Park et al., 2023). Product packaging serves as a primary interface for information technology, conveying crucial data like GMO status, expiration dates, and price, which consumers use to infer quality and make purchasing decisions (Müller & Schneider, 2020; Zhang & Wang, 2021). This study views product labels not merely as static text but as outputs of a basic information system designed to communicate product attributes shaped by underlying food production technologies.

Figure 1. Tempeh: A Traditional fermented food of Indonesia

This research was initiated by a four-month longitudinal, personal observation comparing unlabeled (presumed conventional/GMO) tempeh with tempeh explicitly labeled "non-GMO." While no differences in digestive impact were noted, significant variations in shelf-life, textural integrity, and aroma development were observed under consistent storage. The premium-priced, non-GMO labeled tempeh, despite its advanced labeling technology (explicit non-GMO claim), exhibited a shorter practical shelf-life – aligning with its stated expiration date – compared to the unlabeled tempeh. This suggests a potential disconnect where the information technology on labels may not fully capture the experiential nuances stemming from different food production technologies.
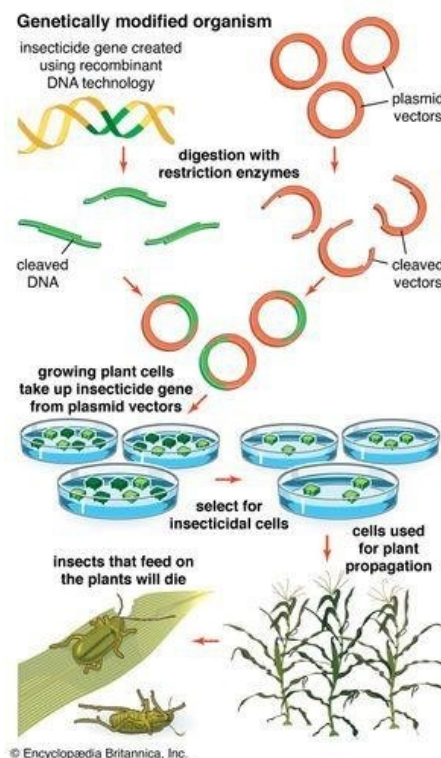
Figure 2. Genetically modified organisms (GMOs) (Fridovich & Diaz, 2025)

This study explores the consumer experience at the nexus of packaging information technology and tangible product attributes. It aims to investigate how effectively current labeling technologies communicate product characteristics and manage consumer expectations (RQ1). Furthermore, it seeks to understand the implications of any experiential discrepancies for consumer trust and to identify potential roles for more advanced information system technologies in enhancing the communication of food product information (RQ2), thereby bridging the gap between label information and actual product performance influenced by food production technology.

Research Questions (RQ)
RQ1: How does the information technology embedded in tempeh packaging (i.e., GMO labeling, expiration dates, price cues) correlate with the consumer's observed experience of product shelf-life and sensory characteristics for labeled non-GMO versus unlabeled tempeh?

RQ2: What are the implications of observed discrepancies between label-based information (as an output of information technology) and tangible product experience for consumer trust, and what is the potential for future technological enhancements in food information systems?

2. METHODOLOGY
This study utilized a qualitative, longitudinal observational case study approach over 120 days, with the researcher as the sole consumer to ensure consistency in interaction with product information technology and subsequent product handling.

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a) Product Selection & Timeline: Storage Protocol: Both tempeh types were stored in a domestic refrigerator (2-8°C). Products remained in their original packaging—the primary vehicle for their information technology—until opening, then in a sealed, dry container.

Table 1. Product Selection and Timeline

No	Phase	Duration (days)	Label	Presumed food technology origin	Price range (IDR)
1	Phase 1	1-60	Unlabeled tempeh	Conventional food technology (presumed GMO)	18,000 - 20,000
2	Phase 2	61-120	Tempeh with "non-GMO" label	Specific non-GMO food technology stream	26,000 - 28,800

b) Preparation for Consumption: Tempeh was fried using new, premium palm oil (stated processing technology: 2 filtrations, 3 purifications; price IDR 36,000-39,000) for each frying, standardizing this variable.

c) Data Collection & Parameters: Daily logs captured data on:
- Packaging Information Technology: GMO label presence/absence, stated expiration date (a time-sensitive data point), price.
- Observed Product Attributes (influenced by food production technology): Texture (firmness, moisture), aroma, perceived freshness, and any deviation from expectations set by the packaging's information technology.
- Experiential Notes: Observations on how the interplay between the information technology on the label and the experienced product quality influenced perceptions of value and trust.

d) Data Analysis: A thematic analysis of observations focused on:
- The correlation between information delivered via packaging technology and the experienced product reality shaped by food production technology (RQ1).
- Identifying implications of any observed discrepancies for consumer trust and outlining potential for enhanced food information systems (RQ2), drawing on principles of information clarity and reliability (Yet Huat Sam et al., 2023; Felicetti et al., 2023).

3. RESULTS AND DISCUSSION

The 120-day observation revealed a distinct consumer experience arising from the interaction between the information technology on tempeh packaging and the tangible product characteristics resulting from differing food production technologies.

a) **Correlation between Packaging Information Technology and Experienced Product Attributes (RQ1):**
- Unlabeled Tempeh (Conventional Production Technology): The information technology of its packaging (lack of non-GMO label, longer stated expiry of 10-14 days) generally correlated with a robust experience. It maintained a dry texture

longer. A sour aroma, a sensory marker of aging, typically developed around days 7-9. The experience was that of a durable product where aging was signaled by aroma before significant textural loss.

- Labeled Non-GMO Tempeh (Specific Non-GMO Production Technology): The packaging's information technology (explicit "non-GMO" label, higher price, shorter expiry of 4-6 days) correlated with a shorter practical shelf-life. Textural degradation (moisture) by day 4 was a prominent experiential factor. While the "non-GMO" information was clear, the rapid decline in textural quality was a dominant aspect of the product experience, despite its premium positioning suggested by labeling technology.

b) **Price as an Information Cue:** The higher price point for non-GMO tempeh, itself a piece of information conveyed at purchase, created an expectation. When the experienced shelf-life (a function of its specific food production technology and inherent material properties – Astuti et al., 2015) was shorter, it led to a re-evaluation of the value proposition conveyed by the combination of price and "non-GMO" information technology.

c) **Expiration Dates as Information Technology Output:** These dates were generally reliable predictors of relative lifespan. However, the nature of degradation differed significantly, which is a nuance current expiration date technology does not capture. The moist texture in non-GMO tempeh was a more definitive negative signal than the gradual souring of the unlabeled tempeh, impacting usability perceptions.

Discussion:
This study underscores that consumer experience is significantly shaped by how well the information technology of product packaging aligns with the tangible realities of products derived from different food production technologies (RQ1). Discrepancies can impact trust and perceived value (RQ2).

The differing shelf-lives are likely attributable to variations in soybean characteristics (GMO vs. specific non-GMO varieties) or processing technologies used for each product stream (Nout, 1994; Wijaya & Suryadi, 2022). Conventional soybeans (often GMO) might be selected or processed using technologies that result in a more stable product matrix. Non-GMO varieties, or the processes used for them to maintain that identity, might inadvertently lead to a product with a shorter window of optimal textural quality. This highlights a limitation in current labeling technology: it conveys status ("non-GMO") but not the full spectrum of associated performance characteristics (Meng Shen et al., 2018).

Implications for Trust and Potential for Technological Enhancements in Food Information Systems (RQ2):
When the information conveyed by packaging technology (e.g., premium status via "non-GMO" and price) is not fully matched by all aspects of product experience (e.g., shorter shelf-life compared to a cheaper alternative), consumer trust in the overall value proposition can be affected (Park et al., 2023). This does not necessarily mean the "non-GMO" information is false, but that its perceived benefit might be narrowly defined by the consumer if other performance aspects are subpar.

Future technological enhancements in food information systems could address these gaps:

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a) **Smarter Labeling Technologies**: Moving beyond static print, technologies like dynamic QR codes or NFC chips on packaging could link consumers to richer databases. This could provide more context on the specific soybean variety used, its typical characteristics (e.g., "delicate texture, best consumed within X days for optimal experience"), or even batch-specific processing details (Rodrigues et al., 2020). This would represent an evolution of the information technology at the consumer's disposal.

b) **Predictive Analytics for Shelf-Life:** Information systems, leveraging data from food science and supply chains, could offer more nuanced "best before" or "optimal quality window" information rather than just a single expiration date (Santos & Costa, 2023). This requires integration of food production technology data with consumer-facing information technology.

c) **Enhanced Transparency through Blockchain or Similar Technologies:** For attributes like GMO status or origin, distributed ledger technologies could provide auditable and transparent information trails, bolstering the trustworthiness of the data conveyed on labels (Zhang & Wang, 2021, on information asymmetry).

The challenge lies in designing information systems that provide comprehensive and relevant data without overwhelming the consumer (Grunert & Wills, 2007). The current technology of printed labels is simple but limited in its capacity to convey complex, multi-faceted product information.

4. CONCLUSION AND SUGGESTIONS

This longitudinal study examined the nexus of packaging information technology and consumer experience with tempeh. The study revealed that current labeling practices, while conveying specific data points like GMO status and expiration dates, may not fully align with all dimensions of the consumer's tangible product experience. The unlabeled tempeh, a product of conventional food technology, exhibited greater durability than the premium-priced, non-GMO labeled tempeh, whose specific production technology resulted in quicker textural degradation, despite both aligning with their respective stated expiration dates.

This underscores the pivotal function of advancements in information technology for the realm of food packaging and systems. Discrepancies between information provided by current label technology and the experienced product attributes, which are outcomes of specific food production technologies, have the potential to influence consumer trust and value perception. The potential for future advancements in information systems, such as smarter labels, predictive shelf-life analytics, and enhanced transparency technologies, to bridge this gap is significant. By offering more nuanced, context-rich information, technological enhancements have the potential to result in more informed consumer expectations and a more satisfactory overall product experience. The objective is to establish a seamless flow of information from food production technology to the consumer through effective and trustworthy information technology interfaces.

Limitations:

The study's observations are derived from a single consumer-researcher perspective, encompassing a limited selection of products. The GMO status of unlabeled tempeh was presumed based on its common market availability. These factors, however, impose limitations on the generalizability of the findings. Nevertheless, the study offers profound qualitative insights into the interaction between packaging information technology and lived product experience.

Future Research:
Future studies should involve diverse consumer groups and a wider range of products. Research could concentrate on the efficacy of different information technology interventions (e.g., interactive labels vs. static ones) in managing consumer expectations. A critical area for exploration is the investigation of methods to effectively translate and communicate data from food production technologies (e.g., specific processing parameters, soybean varietal effects) to consumers through new information system interfaces.

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