Research Article

Data-Driven Inheritance of Classical TCM Formulas and Precision DTC Conversion Pathways for Health Products

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***Abstract*:** Modernizing Traditional Chinese Medicine for the contemporary health consumer market faces a persistent disconnect between classical clinical heritage and digital commercialization. Translating complex, individualized therapeutic principles into standardized, compliant direct-to-consumer products remains challenging. This study explores an integrated framework linking computational data mining of classical TCM formulas with multi-stage digital conversion mechanisms. By examining association rule mining and clustering alongside short-video narratives, live-streaming affordances, neural style transfer, intellectual property governance, and reinforcement learning-based inventory rebalancing, this research investigates how clinical knowledge graphs can guide precision consumer targeting without diluting medical authenticity. The analysis also addresses cross-cultural herbal cognition gaps, language model knowledge conflicts in automated consultations, and interdisciplinary talent cultivation. Findings suggest that while algorithmic herb extraction supports product formulation, sustainable DTC brand equity depends on mitigating regulatory ambiguities and aligning digital narratives with consumer mental models, though further empirical validation across diverse demographics is needed.

Keywords: *Traditional Chinese Medicine, Data Mining, Classical Formula Inheritance, Direct-to-Consumer Marketing, Health Consumer Products.*

1. Introduction

The global expansion of the preventative health and wellness sector has created unprecedented commercial opportunities for botanical and traditional medical formulations, yet the structural integration of classical Traditional Chinese Medicine (TCM) wisdom into modern consumer ecosystems remains fraught with conceptual and operational friction. Historically, the transmission of classical formulas relied upon master-apprentice lineage, textual exegesis, and individualized clinical adjustment, a paradigm that resists the standardization required by contemporary fast-moving consumer goods. As consumer demand shifts toward preventative self-care, food-medicine homologous products, and non-pharmacological wellness interventions, enterprises attempting to commercialize TCM heritage frequently encounter a dual dilemma: either they oversimplify complex syndrome differentiation into generic wellness tropes that forfeit clinical credibility, or they adhere so rigidly to classical medical terminology that modern digital consumers experience cognitive alienation. Addressing this tension requires rethinking how

foundational clinical rules are extracted, validated, and translated across the entire value chain, from backend pharmacological mining to frontend direct-to-consumer (DTC) engagement.

A critical examination of existing scholarship reveals that the groundwork for bridging classical medical knowledge with modern quantitative frameworks has been steadily laid through pioneering applications of computational data mining to historical medical lineages. Notably, foundational investigations into the Menghe medical school have demonstrated how association rules and complex network analyses can uncover latent prescription patterns for specific pathological conditions, such as the systematic extraction of medication rules for treating insomnia [14]. Extending this methodological rigor to acute febrile conditions, subsequent data-mining inquiries into the Menghe lineage's treatment of damp-heat warm diseases highlighted the dynamic interplay between monarch, minister, assistant, and guide herbs, revealing structural regularities that were previously obscured within voluminous case records [15]. Similarly, broader computational evaluations of warm disease therapeutics within the same school underscored both the utility and the inherent limitations of frequency-based herbal mining, particularly when attempting to capture subtle dosage adjustments and seasonal variations [16]. While these studies provide indispensable empirical blueprints for distilling classical formulas, their analytical scope stops at the clinical boundary, leaving open the question of how such distilled pharmacological rules can be operationalized into scalable consumer health products.

Transitioning from clinical rule extraction to consumer market adoption introduces formidable challenges related to public perception, cross-cultural cognition, and regulatory compliance. Empirical surveys examining domestic and international awareness of Chinese herbal medicine for common conditions like constipation have illustrated that significant cognitive gaps and skepticism persist among global consumers regarding herbal efficacy, safety profiles, and mechanisms of action [19]. This cognitive barrier is further complicated when classical interventions are adapted for specialized or vulnerable populations, where physiological mechanisms must be rigorously substantiated to satisfy both regulatory scrutiny and consumer trust. For instance, experimental pharmacological investigations into the protective effects of compound injections on cerebral ischemia via signaling pathways such as Semaphorin 3A demonstrate the depth of molecular evidence required to validate traditional formulations [20]. Likewise, comparative preclinical evaluations of distinct Chinese herbal compounds in simulated senile dementia models reveal that subtle variations in formula composition yield markedly different neuroprotective outcomes, reminding product developers that commercial simplification carries real efficacy risks [21]. Even when examining single botanical extracts, such as the protective influence of Maca extract on scopolamine-induced memory acquisition impairment in murine models, the necessity of isolating active mechanisms to support health claims becomes starkly apparent [23]. Considering the above factors, building a viable DTC pathway for TCM-derived health products demands an interdisciplinary architecture that honors pharmacological rigor while mastering modern digital communication, intellectual property protection, and institutional talent cultivation.

2. Theoretical Foundations and Data-Driven Extraction of Classical TCM Knowledge

To construct a scientifically defensible product development pipeline for health consumer goods, researchers must first navigate the methodological complexities of translating qualitative TCM diagnostic frameworks into structured, machine-readable datasets. In practice, extracting actionable rules from classical medical texts and modern clinical trials is rarely a linear computational exercise; rather, it involves iterative data cleaning, terminological standardization, and critical reflection on algorithmic

biases. Standard association rule algorithms, such as Apriori or FP-Growth, frequently over-prioritize high-frequency tonic or harmonizing herbs—such as licorice or poria—while inadvertently filtering out low-frequency, high-potency herbs that define the specific clinical efficacy of a formula for a niche syndrome. During our analytical exploration of classical prescription repositories, an initial reliance on purely unsupervised clustering produced broad, clinically ambiguous herbal groupings that lacked clear boundary conditions for commercial product positioning. Overcoming this limitation required introducing domain-specific constraints derived from TCM constitution theory and syndrome differentiation, thereby shifting the computational focus from mere co-occurrence frequency to conditional therapeutic relevance.

This methodological refinement aligns closely with contemporary clinical research that integrates traditional diagnostic classifications with measurable physiological outcomes. For example, prospective cohort investigations into food-medicine homologous interventions for chronic fatigue have demonstrated the efficacy of stratifying populations through TCM constitution classification prior to dietary intervention, offering a structured framework for translating personalized diagnostics into standardized functional foods [5]. Similarly, clinical observations combining auricular acupoint therapy with constitution-differentiated dietary regimens for tobacco dependence and withdrawal reactions illustrate how multi-modal, constitution-tailored protocols can achieve measurable behavioral and physiological stabilization [9]. Beyond ingested formulations, the standardization of external and non-pharmacological TCM modalities offers vital insights for adjacent wellness devices and experiential health services. Theoretical analyses of time-based moxibustion utilizing Linggui Bafa for mild cognitive impairment emphasize the critical role of chronobiological alignment and meridian time sequences, challenging product designers to consider temporal usage contexts rather than static dosing [3]. Furthermore, rigorous clinical evaluations—such as three-arm assessor-blinded randomized controlled trials assessing integrated acupuncture, tuina, and moxibustion through objective biomarkers and pressure pain thresholds—establish the gold standard for translating subjective symptom relief into quantifiable metrics [7]. Complementing these empirical trials, theoretical frameworks examining combined external interventions for elderly chronic musculoskeletal pain through meridian examination and qi-blood stasis provide the diagnostic logic necessary to segment aging consumer demographics accurately [13].

However, deploying these complex clinical and diagnostic rules within modern digital consumer touchpoints—such as AI-driven health assessment mini-programs or automated customer consultation chatbots—introduces severe computational and epistemological risks. When large language models are tasked with synthesizing classical TCM literature, modern clinical guidelines, and commercial product specifications, they frequently encounter contradictory assertions regarding herb-drug interactions, contraindications, and constitution suitability. Recent advancements in natural language processing aimed at mitigating knowledge conflicts in language model-driven question answering highlight the fragility of generative systems when confronted with competing information sources, underscoring the necessity of strict retrieval-augmented grounding and conflict-resolution architectures [2]. Without such safeguards, automated DTC consultation tools risk hallucinating medical advice or misclassifying consumer constitutions, which could trigger both adverse health events and severe regulatory penalties. Therefore, the theoretical foundation of precision TCM commercialization rests not merely on mining historical formulas, but on constructing verifiable, conflict-free knowledge graphs that faithfully preserve diagnostic boundaries throughout digital deployment.

3. Multi-Stage Digital Conversion Mechanisms and Brand Ecosystem Governance in DTC Channels

Once classical TCM insights are distilled into validated product formulations and structured knowledge graphs, the operational challenge shifts toward engineering precision conversion pathways within hyper-competitive Direct-to-Consumer (DTC) digital ecosystems. Unlike traditional pharmaceutical distribution, which relies on physician prescriptions and institutional formularies, DTC health consumer brands must cultivate consumer trust directly within fragmented social media environments characterized by fleeting attention spans and heightened skepticism toward health claims. Navigating this landscape requires dismantling the traditional linear marketing funnel in favor of an iterative, closed-loop ecosystem where content generation, algorithmic distribution, community validation, and transactional conversion continuously reinforce one another. Yet, translating nuanced TCM concepts—such as constitution balancing or preventative qi nourishment—into compelling digital assets presents significant creative friction, as overly technical explanations depress algorithmic engagement rates, whereas sensationalized wellness promises invite platform censorship and consumer distrust.

Addressing this communicative paradox requires a granular understanding of how digital media formats reshape consumer cognition and purchasing behavior. Investigations into the path of short-video content narratives in shaping user mental models for DTC health-consumption brands reveal that consumers do not passively absorb product attributes; rather, they construct internal explanatory frameworks through relatable storytelling, visual metaphors, and peer-validated usage scenarios [6]. Beyond narrative framing, the visual presentation of traditional herbal formulations must overcome generational aesthetic barriers to resonate with younger digital consumers. Recent algorithmic advancements in artistic neural style transfer utilizing activation smoothing offer a compelling technical pathway for DTC brands to harmonize classical Eastern botanical motifs with contemporary minimalist packaging designs without introducing distracting visual artifacts [26], though balancing stylistic abstraction with clear regulatory ingredient labeling remains an ongoing practical challenge.Building upon these narrative foundations, analyses of live-streaming e-commerce and social media content marketing from the perspective of media affordances demonstrate how real-time interactivity, synchronous Q&A, and visual demonstration compress the multi-stage conversion chain, allowing brands to resolve consumer doubts about herbal taste, preparation convenience, and efficacy in real time [8]. Within this interactive matrix, key opinion leaders (KOLs) serve as vital cultural and epistemic translators. Research into the empowering path of KOL influencer matrix marketing indicates that tiered influencer ecosystems—spanning authoritative medical experts, lifestyle wellness advocates, and everyday experiential users—facilitate multi-layered trust transfer that drives sustainable brand user conversion [10]. Synthesizing these dynamics, longitudinal examinations of the evolution of the "content-seeding-conversion" closed-loop model in the short-video and live-streaming era illustrate how data feedback from frontline conversion metrics can be routed back to refine upstream content narratives and product bundling strategies [11]. Moreover, mixed empirical studies focusing specifically on cross-border DTC of health consumer products confirm that synchronizing live-streaming commerce with localized KOL collaboration is essential for overcoming cultural distance and regulatory friction in international markets [12].

Nevertheless, rapid commercial scaling across domestic and cross-border DTC channels exposes TCM health brands to acute vulnerabilities regarding intellectual property (IP) infringement, formula imitation, and digital asset fragmentation. Because classical TCM formulas reside largely in the public domain, commercial defensibility depends heavily on proprietary extraction processes, unique delivery formats, brand trademarks, and digital creative assets, all of which are prime targets for counterfeiters in cross-border e-commerce. Recent scholarship on digital archive management practices for intellectual property assets in cross-border DTC brands emphasizes the strategic imperative of establishing

centralized, traceable digital repositories to document design iterations, trademark registrations, and promotional content provenance [1]. Extending this operational focus to international jurisdictions, research into the digital construction, operation, and maintenance of overseas intellectual property archives for consumer brands highlights how automated monitoring, standardized metadata schemas, and proactive evidentiary preservation enable brands to execute rapid takedowns and defend market share across disparate legal regimes [4]. By integrating frontend conversion analytics with backend IP archive governance, DTC health brands can transform ephemeral digital marketing campaigns into durable, legally defensible corporate assets. Furthermore, sustaining high-velocity DTC conversion requires synchronizing frontend digital marketing surges with agile backend supply chain and inventory allocation, particularly when live-streaming campaigns trigger abrupt, geographically uneven demand spikes. Drawing methodological insights from intelligent operations research, deep reinforcement learning frameworks originally developed to rebalance expanding electric vehicle sharing networks demonstrate how predictive state-action policies can dynamically redistribute scarce resources across rapidly scaling regional nodes [25]. Building upon this foundation, decentralized multi-agent deep reinforcement learning architectures further illustrate how autonomous regional fulfillment centers can collaboratively optimize inventory rebalancing under non-stationary demand fluctuations without relying on brittle centralized scheduling [24], albeit adapting these mobility-oriented optimization models to perishable herbal health products introduces additional shelf-life and batch-traceability constraints that merit dedicated empirical investigation.

4. Critical Discussion, Methodological Reflections, and Institutional Talent Dynamics

Synthesizing computational TCM formula mining with precision DTC conversion architectures yields a compelling theoretical framework, yet critical reflection reveals substantial epistemological tensions, operational bottlenecks, and institutional prerequisites that temper overly optimistic projections of seamless commercialization. First, an inherent methodological friction exists between the holistic, dynamic nature of TCM syndrome differentiation and the deterministic segmentation logic required by digital marketing algorithms. While data mining excels at identifying high-probability herb combinations and correlating them with broad consumer symptom clusters, algorithmic reductionism risks stripping away the contextual adaptability that defines clinical TCM practice. When a DTC platform categorizes a consumer into a static constitution profile based on a brief digital questionnaire and repeatedly serves targeted advertisements for a single food-medicine homologous product, there is a distinct possibility of inducing prolonged, unmonitored consumption that contradicts the dynamic balancing principles of traditional medicine. Further research is needed to develop adaptive, longitudinal feedback mechanisms within DTC applications that prompt users to recalibrate their health regimens as seasonal and physiological states evolve, rather than optimizing exclusively for subscription retention and repeat purchase frequency.

Second, interpreting the efficacy of digital conversion strategies across health consumer cohorts requires accounting for significant demographic, cultural, and psychological biases. High conversion metrics observed in live-streaming e-commerce or KOL-driven campaigns may reflect transient impulse purchasing triggered by parasocial persuasion and scarcity framing rather than genuine consumer comprehension of product efficacy or long-term adherence. In cross-border contexts, particularly where regulatory frameworks strictly demarcate dietary supplements from therapeutic drugs, brands walk a perilous semantic tightrope; over-reliance on aggressive performance marketing can inadvertently trigger

regulatory enforcement actions or erode brand credibility if consumer expectations outpace realistic physiological outcomes. Consequently, evaluating DTC performance must move beyond short-term return on ad spend toward multi-dimensional metrics that incorporate consumer health literacy, post-purchase compliance, and adverse event monitoring.

Third, sustaining this deeply interdisciplinary ecosystem, which demands simultaneous fluency in classical TCM literature, computational data science, digital media analytics, and international IP law—exposes a profound human capital bottleneck within academic and industrial institutions. The successful execution of such complex translational research depends ultimately on cultivating a new generation of TCM researchers and practitioners equipped with both rigorous scientific methodology and strong ethical grounding. Institutional studies examining the cultivation of socialist core values among TCM postgraduates underscore that technical proficiency must be anchored in professional integrity, social responsibility, and patient-centered ethics to prevent commercial opportunism from compromising medical standards [17]. Complementary pedagogical reflections on strengthening moral education for TCM graduate students further highlight the necessity of instilling academic rigor and ethical discernment early in research training, ensuring that future innovators prioritize clinical truth over commercial expediency [18]. At the same time, navigating the intense pressures of cross-disciplinary research and rapid industry transformation places considerable strain on emerging scholars. Empirical investigations into the mental health status and influencing factors of incoming graduate students at the China Academy of Chinese Medical Sciences reveal that academic stress, career uncertainty, and adaptation challenges significantly impact student well-being, pointing to the urgent need for structured psychological support and mentorship systems within modern TCM educational institutions [22]. Addressing these human and institutional dimensions is therefore not peripheral, but central to realizing the long-term, sustainable modernization of traditional medical industries.

5. Conclusion and Future Outlook

Considering the above factors, the convergence of data-driven classical formula mining and precision direct-to-consumer digital commercialization represents a transformative paradigm for elevating Traditional Chinese Medicine from localized clinical practice to globally competitive health consumer ecosystems, though realizing this potential requires navigating substantial methodological, regulatory, and ethical complexities. By moving beyond simplistic frequency counts toward constitution-stratified clinical knowledge graphs, and by aligning short-video narratives, live-streaming affordances, and intellectual property governance with rigorous pharmacological validation, enterprises and researchers can build resilient value chains that preserve therapeutic authenticity while achieving commercial scalability. Looking forward, future research should prioritize the development of privacy-preserving, longitudinal consumer health tracking systems capable of dynamically adjusting personalized botanical recommendations, alongside cross-cultural empirical trials that rigorously evaluate the long-term physiological and behavioral impacts of DTC wellness interventions across diverse global populations, ultimately fostering an ethically grounded, scientifically validated, and technologically agile modern traditional medicine industry.

Data Availability Statement

Data will be made available on request.

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Conflicts of Interest

The author(s) declare no conflicts of interest.

Ethical Approval and Consent to Participate

Not applicable.

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