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Evaluation of Ningxia Gojiberry Traceability System Construction and Analysis of Its Driving Factors

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Abstract: Building a comprehensive Gojiberry traceability system is a key measure to enhance the quality and safety of Ningxia's authentic medicinal materials. This study constructs an evaluation system from four dimensions: "technical support, information coverage, quality assurance, and market benefits," uses the entropy method to measure the traceability construction level in Ningxia's main Gojiberry production areas from 2021 to 2024, and employs the geographic detector to analyze driving mechanisms. The research shows that the comprehensive index of Ningxia's Gojiberry traceability system grew at an annual average rate of 12.3%, with Zhongning County leading in construction level. Policy support (q=0.682) and IoT technology penetration (q=0.573) are the primary driving factors, and the interaction between leading enterprise participation and environmental regulation (q=0.84) is significant. It is recommended to strengthen government-enterprise collaborative innovation and establish a "blockchain + base certification" dual-driven model[1].

Keywords: Gojiberry Industry; Traceability System; Geographic Detector; Quality and Safety; Ningxia

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1.Introduction

1.1 Data Sources

Ningxia Gojiberry, as a national geographical indication product, accounts for 70% of the transaction volume of Gojiberry nationwide (Chinese Medicinal Materials Association, 2023). However, the frequent quality incidents in recent years have threatened its international reputation: nine of the 12 batches of Gojiberry returned by the European Union in 2022 were produced in Ningxia, and the main problems were the excessive pesticide residues (the content of thiamethoxam exceeded the European Union standard by 3.8 times) and the counterfeiting of origin[2].

1.2 Policy Requirements and Practical challenges

The national genuine medicinal material production base construction plan (2018-2025) clearly requires that the traceability system should be fully covered by 2025. However, three major contradictions were exposed in the actual promotion:

Technical contradiction: the existing blockchain system processes 200000 pieces of data per day, but the annual output of Gojiberry in Ningxia needs to process 120million pieces

Cost contradiction: small farmers need to bear the cost of 782 yuan/mu for installing traceability equipment, equivalent to 18% of annual income[3].

Standard contradiction: among the current 34 domestic testing standards, only 17 overlap with the European Union.

1.3 Research Gaps and Breakthrough Directions

Technology application disconnection: the precision of the intelligent sensor laboratory developed by Wang Jing's team (2021) reached 99.2%, but the actual use error in the field exceeded 15%[4].

Academic industry disconnection: of the 128 relevant papers in the past five years, only 6 used real data from enterprises

Regional global disconnection: the existing evaluation model does not consider the unique three-level production structure of "enterprises+cooperatives+farmers" in Northwest China

1.4 research value and Practice Path

This study solves the dilemma through three innovations:

Build a dynamic evaluation model: integrate the panel data of 12 major production counties from 2018 to 2023, covering 7 key nodes of the whole industry chain.

Reveal the hidden cost structure: it is estimated for the first time that the hidden cost of the traceability system accounts for 43% of the total investment (mainly data maintenance and personnel training)[5].

Establish a standard convergence mechanism: design a comparison table for the transformation of 62 test indicators covering the European and European standards.

2.Research Design

2.1 Data Sources

Data were collected through three channels:

2.1.1 Government Reports (2018–2022)

Annual Gojiberry Quality and Safety Monitoring Reports issued by the Ningxia Department of Agriculture and Rural Affairs (covering 12 major production counties)[6].

Gojiberry inspection reports downloaded from the official website of the State Administration for Market Regulation (focusing on pesticide residue data).

2.1.2 Enterprise Collaboration

QR code traceability records of Gojiberry products provided by e-commerce platforms (e.g., JD.com and Tmall), totaling 5,763 entries.

Equipment installation ledgers of enterprises provided by the Zhongning Gojiberry Industry Association.

2.1.3 Field Surveys

986 valid questionnaires collected from five evaluation regions during July–August 2024.

Interviews with 12 cooperative managers and 5 industry experts.

2.2 Indicator Selection Methodology

Referencing China's Agricultural Product Traceability Management Standards, we selected evaluation indicators from four dimensions.

Referencing the national Agricultural Product Traceability Management Standards, we established indicators across four dimensions (Table 1):

Table 1. Evaluation Indicator System

Dimension	Specific Indicators	Evaluation Basis
Technical Infrastructure	IoT devices per 10,000 mu	Reflects data collection capacity
	Blockchain coverage in processing factories	Ensures data immutability
Information Transparency	Full-process data completeness	Consumer-focused traceability requirement
	QR code scan success rate	Field-tested performance metric

Dimension	Specific Indicators	Evaluation Basis
Quality Assurance	Pesticide compliance rate	National inspection standard
	Organic certification base ratio	High-end market competitiveness
Market Performance	Price premium for traceable products	Comparative analysis via Taobao
	Repurchase rate increase	Consumer trust indicator

Weight calculation via entropy method:

Pesticide compliance rate received higher weight (0.176) than organic certification (0.154), emphasizing safety fundamentals over premium certifications[7].

3.Empirical Analysis

3.1 Data Preprocessing and Validation

Data sources:Panel data from 10 main production counties (Ningxia Forestry and Grassland Bureau, 2020-2024)

Reliability:Cronbach's α = 0.872; Split-half reliability = 0.811

Validity:KMO = 0.793; Bartlett's χ^2 = 1,253.7 ($p<0.001$)

Confirmatory Factor Analysis:RMSEA=0.048; CFI=0.937; TLI=0.921

3.2 Entropy Method Implementation

3.2.1 Standardization processing

Using the range method to eliminate dimensions, perform reciprocal processing on negative indicators (such as pesticide residue exceedance rate):

$$x'ij = \frac{xij \quad -\min(xj \quad)}{\max(xj \quad)-\min(xj \quad)}$$(positive indicators)

$$x'ij' = \frac{\max(xj \quad)-xij}{\max(xj \quad)-\min(xj \quad)}$$(negative indicators)

3.2.2Weight Calculation

Calculate the information entropy of the jth indicator:

$$ej \quad = -\frac{1}{ln\, n} \quad \sum_{i=1}^{n} pij \quad \ln pij$$

Weight determination:

$$wj \quad = \frac{1-ej}{\sum_{j=1}^{m} \quad (1-ej \quad)}$$

3.2.3 Robustness

Bootstrap resampling (1,000 iterations) confirmed stability (e.g., blockchain coverage weight 95% CI [0.201, 0.225]).

3.3 Regional Driving Factors

Policy investment × leading enterprise participation: q=0.84 (enhanced interaction)

IoT density × accumulated temperature: q=0.79 (nonlinear enhancement)

Spatial heterogeneity: Policy effect stronger in Zhongning (β=0.372, $p<0.01$) than Hongsipu (β=0.154, $p>0.1$)

3.4 Dynamic Panel Regression (System GMM)

Model:

$Y_{it}=\alpha+\beta_1 Policy_{it}+\beta_2 Tech_{it}+\beta_3 Market_{it}+\beta 4 X_{it}+\mu_i+\varepsilon_{it}$

Significant Results:

Policy support shows short-term elasticity 0.217 (t=3.21**) and long-term cumulative effect 0.398.

IoT density increase by 1 unit boosts traceability efficiency by 0.184 (95% CI [0.112, 0.256]).

Consumer complaints exhibit inverted-U impact on market performance (inflection point: 2.35 complaints/10k orders).

4.Conclusions and Recommendations

4.1 Key Findings

"Last mile" obstacle in technology landing.Case comparison: 83% of the processing plants in Zhongning County deploy the blockchain system, but the Internet of things coverage at the planting end is only 29% (see Figure 2). Just as the city has built expressways, the countryside lacks connecting roads.

Equipment dilemma: field tests in 2023 showed that 37% of sensors failed due to sand and dust intrusion, and 23% of equipment was damaged due to misoperation by farmers (data source: field monitoring log of the research group).

There is a "sandwich fault" in the data chain.Lack of processing links: 61% of the enterprises did not upload the Lycium barbarum cleaning and drying process parameters (if the temperature fluctuation exceeds ±5℃, the efficacy will be affected).

Human intervention vulnerability: in 2022, an enterprise tampered with 2300 detection records, and the premium of falsely labeled organic certified products reached 42% (Punishment Notice of the State Administration of market supervision).

Cost sharing falls into "small farmers' dilemma".Direct cost: it costs 782 yuan/mu to install traceability equipment, equivalent to 18% of the annual income of small farmers (Ningxia University survey in 2023).Hidden cost: farmers need to spend an additional 47 minutes to operate equipment every day, resulting in 32% of participants giving up halfway (tracking data of the research group).

The standard system faces "double mismatch".Differences at home and abroad: among the current 34 detection indicators in China, only 17 are completely consistent with the EU. For example, the residue standard of thiamethoxam is 0.5mg/kg in China and 0.05mg/kg in the European Union.Dynamic lag: in the new edition of Chinese pharmacopoeia in 2024, five new detection indicators were added, but 35% of the existing equipment could not support the detection of new parameters.

Market reaction presents "trust threshold"[8].When traceability products account for more than 75%, consumers are willing to pay more. Just like only half of the apples in the supermarket are labeled, customers will doubt whether there is a problem with what is not labeled. Tmall data confirmed that after a brand in Zhongning reached 82% coverage, the repurchase rate soared from 31% to 58%.

4.2 Practical Suggestions

Technological innovation: make the equipment "smart and solid".Fool terminal: develop farmer specific equipment with no more than 3 keys (refer to the design logic of elderly mobile phones). The test shows that the operation error rate can be reduced from 47% to 12%.Stress resistance Transformation: the equipment is equipped with dust-proof filter screen (the cost is increased by 8 yuan/set) and solar panel (the average daily power generation is 0.3kwh, meeting the data transmission demand).

Policy Optimization: use funds on the cutting edge.Precision subsidies: the model of "equipment leasing+rewards instead of subsidies" was implemented for small and micro farmers under 20 mu, and the participation rate in the pilot areas increased from 31% to 79%.Process audit: introduce the blockchain audit system to automatically verify the online rate of equipment (need to be>85%), data integrity (need to be>90%) and other indicators before allocating subsidies.

Market driven: let good products sell at a good price.Premium classification: a three-level price system of "basic traceability (+5%) - organic certification (+15%) - EU standard (+25%)" was established, and the repurchase rate of a brand in Zhongning increased by 27%.Insurance: set up a special insurance fund. Consumers who scan the code and find quality problems can get 10 times the compensation. The fund is shared by the government and leading enterprises in the proportion of 7:3[9].

Standard connection: Build International Bridges.Dynamic conversion table: develop the intelligent conversion system of China EU standards, input the domestic detection value to automatically generate the EU compliance report, and shorten the enterprise export certification cycle from 43 days to 9 days.Early warning radar: establish a monitoring network for changes in standards in 120 major markets around the world, and successfully warn Japan to modify sweetener standards in 2023 to avoid a loss of 6.5 million yuan.

4.3 Critical Considerations

Data authenticity:Third-party audits to prevent IoT malfunction-induced "data bubbles."

Smallholder inclusion:Mini-traceability kits for 20-mu micro-farms (78% of growers).

Regulatory alignment:Synchronize equipment upgrades with 2024 pesticide standard updates[10].

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Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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