

ELECTRONIC TRACEABILITY OF INDIAN HONEY USING BLOCKCHAIN TECHNOLOGY

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ELECTRONIC TRACEABILITY OF INDIAN HONEY USING BLOCKCHAIN TECHNOLOGY

by

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CERTIFICATE

This is to certify that the thesis entitled “**Electronic traceability of Indian Honey using Blockchain Technology**” being submitted by **Ms. Ayushi Srivastava** to the Indian Institute of Technology Delhi for the award of the degree of **Doctor of Philosophy** is a record of bonafide research work carried out by her. She has worked under my guidance and supervision and has fulfilled the requirements for the submission of this thesis, which has attained the standard required for a Ph.D. degree of this Institute. The results represented in this thesis have not been submitted elsewhere for the award of any degree or diploma.

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ABSTRACT

The percentage share of Gross Value added (GVA) of agriculture and allied sectors to the economy of India is around 20.2% in 2021. Among the allied sectors, beekeeping exhibits great potential to contribute to income generation and poverty alleviation. Beekeeping is a sustainable livelihood option owing to the favourable environmental conditions and diversity of bee species in the country. Honey being the major byproduct of beekeeping is of immense importance in terms of production and export value. Other products include bee pollen, propolis, bee wax, etc., The consumption of honey has gone up globally in times of COVID 19 pandemic due to its immunity-boosting properties. However, like several food products in India, it is susceptible to instances of food fraud. There is no mechanism to monitor the value chain of honey. Therefore, this study takes into account the value chain analysis of honey as the first step followed by exploring the factors responsible for the implementation of e-traceability using a suitable technology like blockchain. The study also forecasts the production of honey on the basis of climatic factors.

This research conducts a honey value chain analysis. As part of the study, it maps the value chain of honey in parts of Maharashtra. This area was selected primarily because it falls in the Western Ghat region. Western Ghats are the hotspot region in India and known for best source of natural honey in India. The value chain participants include producers i.e., the beekeepers or farmers, aggregators or collectors, processors, traders, and consumers. Honey production is found to be a profitable business in the area with a cost-benefit ratio of 1.57. The factors responsible for determining the production of honey are family size, experience in beekeeping, access to the market, and access to training. Further, the challenges in production are pests and diseases, pesticide application, deforestation, and lack of suitable equipments. On

the marketing front, the challenges are adulteration, variation in prices, unregistered beekeepers, and unlicensed traders.

The value chain study is further extended to the integration of e-traceability in agri-food supply chains. This required exploring the critical factors in the implementation of e-traceability. This was done through the methodology of Fuzzy-ISM and Fuzzy-MICMAC. The hierarchical model created revealed that appropriate technology for e-traceability, competitive advantage, coordination, and transparency are the driving forces in e-traceability implementation.

The production of honey is the outcome of environmental, economic, and social factors. On the environmental front, honey production largely depends on climatic factors and the flora of the place. With limited data on floral diversity, this research makes a forecasting model for honey production on the basis of climatic factors using the machine learning technique of ANFIS with a hybrid optimization method. The results indicate that temperature and relative humidity are important parameters in forecasting honey production. Overall, all the zones exhibited low RMSE values indicating the model can be effectively used for forecasting honey production according to Indian climatic conditions. The low value of RMSE of 4.88 % shows that the ANFIS-based honey forecasting model is robust for predicting honey production.

The literature reveals that blockchain with its decentralized database is appropriate for implementing e-traceability technology. Thus, the study explores the basics of technology and constructs an architecture for blockchain-based traceability using the case of honey supply chain. The factors required for the adoption of Blockchain are explored using Partial least squares-Structural Equation Modelling (PLS-SEM). According to the results, performance-driven factors like food safety, food quality, time and cost efficiency, consumer confidence, minimization of intermediaries, and data transparency are driving forces for the adoption of blockchain in the agri-food sector. Also, organizational factors like competitive advantage,

communication between stakeholders, and proper regulations in place are also critical factors responsible for the adoption of blockchain by food firms. Furthermore, a suitable platform for implementing the technology is explored. Hyperledger Fabric (HLF) with the highest weightage is considered for applying blockchain. Further, the performance of HLF is analyzed using the Hyperledger caliper tool with parameters, throughput, latency, and scalability. The throughput varied from 707 to 955 successful transactions per second and latency is as less as 150 milliseconds. The use of the Fabric platform can support up to 6 organizations.

सारांश

भारत की अर्थव्यवस्था में कृषि और संबद्ध क्षेत्रों के सकल मूल्य वर्धित (जीवीए) का प्रतिशत हिस्सा 2021 में लगभग 20.2% है। संबद्ध क्षेत्रों में, मधुमक्खी पालन आय सृजन और गरीबी उन्मूलन की दिशा में योगदान करने की बड़ी क्षमता प्रदर्शित करता है। मधुमक्खी पालन देश में अनुकूल पर्यावरणीय परिस्थितियों और मधुमक्खी प्रजातियों की विविधता के कारण आजीविका का एक स्थायी विकल्प है। मधुमक्खी पालन का प्रमुख उपोत्पाद होने के कारण शहद का उत्पादन और निर्यात मूल्य की दृष्टि से अत्यधिक महत्व है। अन्य उत्पादों में मधुमक्खी पराग, प्रोपोलिस, मधुमक्खी मोम आदि शामिल हैं। COVID 19 महामारी के समय में शहद की खपत विश्व स्तर पर बढ़ गई है क्योंकि इसकी प्रतिरक्षा बढ़ाने वाले गुण हैं। हालांकि, भारत में कई खाद्य उत्पादों की तरह, यह खाद्य धोखाधड़ी के उदाहरणों के लिए अतिसंवेदनशील है। शहद की मूल्य श्रृंखला की निगरानी के लिए कोई तंत्र नहीं है। इसलिए, यह अध्ययन ब्लॉकचैन जैसी उपयुक्त तकनीक का उपयोग करके ई-ट्रेसिबिलिटी के कार्यान्वयन के लिए जिम्मेदार कारकों की खोज के बाद पहले चरण के रूप में शहद के मूल्य श्रृंखला विश्लेषण को ध्यान में रखता है। अध्ययन में जलवायु कारकों के आधार पर शहद के उत्पादन का भी अनुमान लगाया गया है।

यह शोध एक शहद मूल्य श्रृंखला विश्लेषण करता है। अध्ययन के हिस्से के रूप में, यह पश्चिमी महाराष्ट्र के कुछ हिस्सों में शहद की मूल्य श्रृंखला का मानचित्रण करता है। मूल्य श्रृंखला के अभिनेताओं में उत्पादक यानी मधुमक्खी पालक या किसान, एग्रीगेटर या कलेक्टर, प्रोसेसर, व्यापारी और उपभोक्ता शामिल हैं। 1.57 के लागत-लाभ अनुपात के साथ शहद उत्पादन क्षेत्र में एक लाभदायक व्यवसाय पाया जाता है। शहद के उत्पादन को निर्धारित करने के लिए जिम्मेदार कारक परिवार का आकार, मधुमक्खी पालन में अनुभव, बाजार तक पहुंच और प्रशिक्षण तक पहुंच हैं। इसके अलावा, उत्पादन में चुनौतियां कीट और रोग, कीटनाशकों का उपयोग, वनों की कटाई और उपकरणों की कमी हैं। विपणन के मोर्चे पर, चुनौतियां मिलावट, कीमतों में भिन्नता, अपंजीकृत मधुमक्खी पालक और बिना लाइसेंस वाले व्यापारी हैं।

मूल्य श्रृंखला अध्ययन को कृषि-खाद्य आपूर्ति श्रृंखलाओं में ई-ट्रेसेबिलिटी के एकीकरण के लिए आगे बढ़ाया गया है। इसके लिए ई-ट्रेसेबिलिटी के कार्यान्वयन में महत्वपूर्ण कारकों की खोज की आवश्यकता थी। यह फ़ज़ी-आईएसएम और फ़ज़ी-एमआईसीएमएसी की कार्यप्रणाली के माध्यम से किया गया था। बनाए गए पदानुक्रमित मॉडल से पता चला है कि ई-ट्रेसेबिलिटी, प्रतिस्पर्धात्मक लाभ, समन्वय और पारदर्शिता के लिए उपयुक्त तकनीक ई-ट्रेसेबिलिटी कार्यान्वयन में प्रेरक शक्तियाँ हैं।

शहद का उत्पादन पर्यावरणीय, आर्थिक और सामाजिक कारकों का परिणाम है। पर्यावरण के मोर्चे पर, शहद का उत्पादन काफी हद तक जलवायु कारकों और जगह की वनस्पतियों पर निर्भर करता है। फूलों की विविधता पर सीमित आंकड़ों के साथ, यह शोध हाइब्रिड अनुकूलन पद्धति के साथ एएनएफआईएस (ANFIS) की मशीन लर्निंग तकनीक का उपयोग करते हुए जलवायु कारकों के आधार पर शहद उत्पादन के लिए एक पूर्वानुमान मॉडल बनाता है। परिणाम बताते हैं कि शहद उत्पादन के पूर्वानुमान में तापमान और सापेक्षिक आर्द्रता महत्वपूर्ण मानदंड हैं। कुल मिलाकर, सभी क्षेत्रों ने कम आरएमएसई (RMSE) मूल्यों का प्रदर्शन किया, यह दर्शाता है कि भारतीय जलवायु परिस्थितियों के अनुसार शहद उत्पादन के पूर्वानुमान के लिए मॉडल का प्रभावी ढंग से उपयोग किया जा सकता है। 4.88% के आरएमएसई के निम्न मूल्य से पता चलता है कि शहद उत्पादन की भविष्यवाणी के लिए एएनएफआईएस आधारित शहद पूर्वानुमान मॉडल मजबूत है।

साहित्य से पता चलता है कि ब्लॉकचेन अपने विकेन्द्रीकृत डेटाबेस के साथ ई-ट्रेसेबिलिटी तकनीक को लागू करने के लिए उपयुक्त है। इस प्रकार, अध्ययन प्रौद्योगिकी की मूल बातों की पड़ताल करता है और शहद आपूर्ति श्रृंखला के मामले का उपयोग करके ब्लॉकचेन-आधारित ट्रेसेबिलिटी के लिए एक वास्तुकला का निर्माण करता है। ब्लॉकचेन को अपनाने के लिए आवश्यक कारकों को आंशिक न्यूनतम वर्ग-संरचनात्मक समीकरण मॉडलिंग (पीएलएस-एसईएम) का उपयोग करके खोजा गया है। परिणामों के अनुसार, खाद्य सुरक्षा, खाद्य गुणवत्ता, समय और लागत दक्षता, उपभोक्ता विश्वास, बिचौलियों को कम

करने और डेटा पारदर्शिता जैसे प्रदर्शन-संचालित कारक कृषि-खाद्य क्षेत्र में ब्लॉकचेन को अपनाने के लिए प्रेरक बल हैं। इसके अलावा, प्रतिस्पर्धात्मक लाभ, हितधारकों के बीच संचार, उचित नियम जैसे संगठनात्मक कारक भी खाद्य फर्मों द्वारा ब्लॉकचेन को अपनाने के लिए जिम्मेदार महत्वपूर्ण कारक हैं। इसके अलावा, प्रौद्योगिकी को लागू करने के लिए एक उपयुक्त मंच का पता लगाया जाता है।

ब्लॉकचेन को लागू करने के लिए हाइपरलेगर फैब्रिक (HLF) पर विचार किया जाता है। इसके अलावा, पैरामीटर, थ्रूपुट, लेटेंसी और स्केलेबिलिटी के साथ हाइपरलेगर कैलिपर टूल का उपयोग करके एचएलएफ के प्रदर्शन का विश्लेषण किया जाता है। थ्रूपुट 707 से 955 सफल लेनदेन प्रति सेकंड और विलंबता 150 मिलीसेकंड से कम है। फैब्रिक प्लेटफॉर्म का उपयोग अधिकतम 6 संगठनों का समर्थन कर सकता है।

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LIST OF ABBREVIATIONS

ACSM	Access to market
ACST	Access to training (ACST)
AFSM	Agri-food supply chain management
APEDA	Agricultural and Processed Food Products Export Development Authority (APEDA)
ANFIS	Adaptive Network-based fuzzy inference system
AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
ANN	Artificial Neural Networks
AM	Autoregressive model
ARIMA	Autoregressive Integrated Moving Average
AVM	Autoregressive Moving Average
AFC	Average Fixed Costs
AVC	Average Variable Costs
BP	Backpropagation
BKCT	Blockchain Technology
CA	Certificate authority
CBRTI	Central Bee Research and Training Institute
CSCC	Configuration System Chaincode
CSF	Critical Success Factor
DB	Database
EDU	Education of the Household Head EDU
ESCC	Endorser System Chaincode (ESCC)

EMA	Economically Motivated Adulteration
EPCIS	Electronic Product Code Information Services
E-traceability	Electronic Traceability
EU	European Union
EXP	Experience in beekeeping
EIC	Export Inspection Council
FAMSIZE	Family size
FSCM	Food Supply Chain Management
FLS	Fuzzy Logic System
GARCH	Generalized Autoregressive Conditional Heteroscedasticity
HACCP	Hazard Access
HFM	Honey Forecasting Model
HLF	Hyperledger Fabric
IoT	Internet of Things
ISO	International Standard Organization
ISM	Interpretive Structural Modelling
KVIC	Khadi Village Industry Commission
LND	Land size
MF	Membership Function
NFC	Near Field Communication
OS	Operating System
PLS-SEM	Partial Least Squares Structural Equation Modeling
QHS	Quantity of honey supplied to market
RFID	Radio Frequency Identification

RMSE	Root Mean Square Error
SEX	Sex of the Household Head
SCP	Structure-Conduct-Performance
SSIM	Self-Structural Interaction Matrix
SEM	Structural Equation Modelling (SEM)
VAR	Vector Auto-Regression
TSK	Takagi-Sugeno-Kang
TC	Total Costs
TFC	Total Fixed Costs
TVC	Total Variable Costs
TRIFED	Tribal Cooperative Marketing Development Federation of India
UPC	universal product code (UPC)
VSCC	Validation System Chaincode
VCA	Value chain analysis
WSN	Wireless Sensor Networks (WSN)