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Design of traceability system models for potato chips agro-industry based on fuzzy system approach

Ririn Regiana Dwi Satya[1,2], Eriyatno[1], Andes Ismayana[1], Marimin[1]
[1]Department of Agro-Industrial Technology, Faculty of Agricultural Engineering and Technology, IPB University (Bogor Agricultural University), Bogor, Indonesia
[2]Department of Industrial Engineering, Faculty of Engineering and Computer Science, Indraprasta PGRI University, Jakarta, Indonesia

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ABSTRACT

Identification of recorded information is the most important requirement for developing an effective traceability system. This paper aimed to develop an information technology (IT)-based traceability system combined with an intelligent system in potato chips agro-industry. In this paper, we present a business process in potato chips agro-industry which consists of three activities, i.e. raw materials receiving, processing, and warehousing of final products. First of all, a traceability system architecture was developed. To develop computational models, quality, food safety and environment criteria using fuzzy inference system (FIS) and adaptive neuro fuzzy inference system (ANFIS), and intelligent decision support system (IDSS) traceability model using android front end. An internal information capture point was identified for each step and corresponding traceability information to be recorded was determined. Furthermore, a prototype IDSS was developed to represent method of information modeling on products, processes, quality, and transformation at each node in potato chips agro-industry. In this study, intelligent systems have been developed for decision making in quality control good agricultural practices.

Corresponding Author:

Ririn Regiana Dwi Satya
Department of Agro-Industrial Technology, Faculty of Agricultural Engineering and Technology
IPB University (Bogor Agricultural University), Bogor, Indonesia
Email: ririn.regiana86@gmail.com

1. INTRODUCTION

Potato is foodstuff widely consumed by Indonesian people. Therefore, it is essential for potato processing industries to produce high quality and safe products. A quality management system is required to oversee and control foodstuffs during raw material receiving, processing, storing, transporting, and distributing to consumers [1]. In Europe, a traceability system is mandatory for business actors or industries engaging in the food sector. A traceability system provides the ability to present information related to the history and movement of a product in every step of the production process [2]. The major aspect of a traceability system is the connection between raw materials and all processing-related information, which is recorded in documentation for an effective and efficient traceability implementation [3]. In Indonesia, traceability systems in the potato chip agro-industry are still paper-based and manually implemented. According to Mgonja and Kussaga [4], this method has a number of drawbacks, that is proneness to damage or breakage and human error. The other problem faced by potato chip processing industries is the large number of steps required for the processing of potato into potato chips. Raw materials from different areas, such as Garut and Bandung, are processed into one production batch. Horticulture commodities, such as potatoes, continuously perform respiration and metabolism after harvesting. They can undergo 20% to 40%

deterioration due to inaccurate harvesting time as well as mechanical, physical, and physiological damage [5]. Both domestic and overseas marketing of holticulture products often experience obstacles that are due to imperfection in post-harvest handling, resulting in higher losses from quality and physical damage. According to the Regulation of the Minister of Agriculture No. 48, 2009, regarding good agricultural practices (GAP), which consider the criteria of quality, food safety, and environment, a traceability system model of potato chip agro-industry should be designed for ease in information traceability focus on the product quality assessment system and correct decision making on problems related to those criteria.

An adaptive neuro-fuzzy inference system (ANFIS) is an adaptive response to demand uncertainty that works by combining two intelligent techniques (fuzzy logic and artificial neural network) [6]. Fuzzy logic is excellent in reasoning qualitative aspects of rule-based human knowledge and decision-making processes, while artificial neural network (ANN) is a method that resembles the human brain in illustrating its learning process [7]. The implementation of this learning process employs a computer program that is able to complete computation during the learning process [8]. Thus, the ANFIS method has the advantages of more efficient mapping of an input room into an output room for the ANN and fuzzy logic capability as compared to other approaches, achieving a more effective prediction model through a learning process, and capability of data classification and to conclude fuzzy rules or expert knowledge of numerical data [9].

Research on traceability of the food supply chain in Indonesia has been conducted, such as a traceability system to identify and register cows using the computer-based information system (CBIS) approach [10], assessment of frozen tuna loin supply chain using ISO28000-based traceability decision tree [11], and frozen shrimp supply chain in a digital business system that develops a traceability system using cosine similarity and fuzzy associative memory [12]. Some researchers have proposed an electronic traceability supply chain, such as that in the vegetable supply chain [13] and soybean [14]. Therefore, potato traceability system must also be developed with integrated information technology, considering that the existing traceability system in potatoes is still implemented manually (paper-based traceability) [4]. This traceability system architecture will be able to perform information exchange through the internet by means of sensors. This system architecture consists of three main sections: the perception, transport, and application layers. The perception layer collects data, electronically establishes codes, and produces unique codes. This layer acts as a data collector and processor [9]. Application layer is a layer containing traceability management modul of raw materials, management modul of food production, management modul of food warehousing, management modul of food transportation, management modul of sales, and modul of food traceability [15]. However, fuzzy inference systems (FISs) and adaptive neuro-fuzzy inference systems have not been employed in traceability research.

The above background indicates that annual potato production is increasing, which may interfere with the safety of potato-based food products. The large number of potato-based food products causes difficulties in overseeing without the existence of a system that can facilitate the overseeing from upstream to downstream. The traceability of the product quality assessment system research on the environmentally friendly potato industry in Indonesia, starting from post-harvest to potato processing industries, has not been conducted, therefore it adds importance to this research. This research aimed to elaborate the potato supply chain, design a traceability product quality assessment system model of potato chips agro-industry green supply chain using artificial intelligences, that is FIS and ANFIS, as well as an integrated traceability information system for the production of potato-based food products, which is in accordance with quality, food safety, and environmental concerns, where the carbon footprint used in every activity of the production process or supply chain process can be investigated. Implementation of this system will facilitate the actors involved in the potato supply chain network. Information can be accessed easily and rapidly.

2. RESEARCH METHOD

This research was initiated by observing every activity in the supply chain steps of potato products, particularly in a traceability system with regard to food safety, quality, and environmental aspects. Food safety aspects were observed based on GAP and related regulations. This observation aimed to observe conformities and inconformities in business processes with applicable rules. In accordance with the Regulation of the Ministry of Agriculture No. 48, 2009, in which policies regarding fruits and vegetables, including potato, should consider aspects of quality, food safety, and the environment. Moreover, the government has implemented Prima certification for farmers who have implemented the GAP. Observation based on food safety and quality as well as environmental aspects related to carbon footprint becomes a basis for designing, intelligent decision supporting system traceability of potato chips agro-industry green supply chain.

In the present study, a method of traceability system development on potato chips was carried out using the system development life cycle (SDLC) approach. The steps in this research include: 1) field observation, by direct observation of the business process and data management of potato chips in West Java, Indonesia; 2) system analysis, to identify the needs for information of a system that will be established; and 3) system design, a modelling step of system requirements. Models designed includes models of post-harvest losses with weight loss test, carbon footprint model with life cycle assessment approach, intelligent decision supporting system of potato chips agro-industry green supply chain with fuzzy inference system and adaptive neuro fuzzy inference system implemented by an android-based traceability system design. The steps in this research are shown in Figure 1.

2.1. Data analysis technique

A traceability system model was established for potato processing industries to provide assurance of environmentally friendly products and food safety of distributed products (forward tracability). The other traceability system (backward traceability) will be used when consumers complain about the unsafety of the potato products, which results in product recall based on the investigation of product origin and causes of product inconformities. The steps in designing a traceability model in a potato chip agro-industry green supply chain are as follows:

- The first step is the identification of closely related traceability factors in every stakeholder based on the Regulation of the Ministry of Agriculture No. 48, 2009, which regulates the GAP of fruits and vegetables in terms of quality, food safety, and environment. Each of these factors was identified based on expert opinion and literature studies, the attributes of which were determined as presented in Table 1.
- In this step, attribute classification with a fuzzy inference system was carried out in order to identify criteria assessment based on quality, food safety, and environment, followed by aggregation of results from three criteria mentioned with an ANFIS.

Table 1. Factors and atributes affecting potato quality [16]

Stakeholder	Factors affecting potato quality based on GAP	
Farmers group	Quality:	Size, color losses
	Food safety:	Spesific gravity, seed variety, black spot
	Environment:	Carbon
Agro-industry	Quality:	Size, color, losses
	Food safety:	Spesific gravity, seed variety, black spot
	Environment:	Carbon

ANFIS consists of variables of model input and output and is arranged from five adaptive and non-adaptive layers. In layer 1, all nodes are adaptive, and are marked with a square diagram. An adaptive node means that the node may change and be modified in the presence of training data. Assuming that the ANFIS model on layer 1 is composed of a Gaussian membership function, the formulation is given in (1) [17].

$$O_i^1 = \mu_{Al}(x) = e^{-\frac{(x-Cl)^2}{2\sigma l^2}} \quad (1)$$

Variabel A is a linguistic label of variable x, such as 'moderate', 'high', and 'sufficient', l is a variable describing linguistic level of variable A, while c and σ are parameters in a Gaussian function. All nodes on ANFIS layer 2 is non-adaptive or a normal multiplication function, marked with p. This knot multiplies every input entered into it, callses as firing strength (w). An ANFIS model on layer 2 is given in (2) [17].

$$O_l^2 = w_l = \mu_{Al}(x) \times \mu_{Bl}(x). \; l = 1.2 \quad (2)$$

All nodes in layer 3 of the ANFIS model are non-adaptive and, marked with N. This layer determines the normalization of the firing strength, as shown in (3) [16].

$$O_l^3 = \overline{w} = \frac{w_l}{w_1+w_2}. \quad l = 1.2 \quad (3)$$

Furthermore, layer 4 is an adaptive layer, marked by a square diagram. The parameters on this layer are determined from the consequent parameters (p, q, r), as given in (4) [17].

$$O_l^4 = \overline{w_l} f_l = \overline{w_l}(p_l x + q_l x + r_l x). \quad l = 1.2 \quad (4)$$

Layer 5 is the last layer in an ANFIS model, which is a model output summing up all inputs into a model, as illustrated in (5) [17].

$$O_l^5 = \sum_{i=1}^{2} \overline{w_l} f_l = \frac{w_l(p_l x+q_l x+r_l x)+w_2(p_2 x+q_2 x+r_2 x)}{w_1+w_2}. \quad l = 1.2 \quad (5)$$

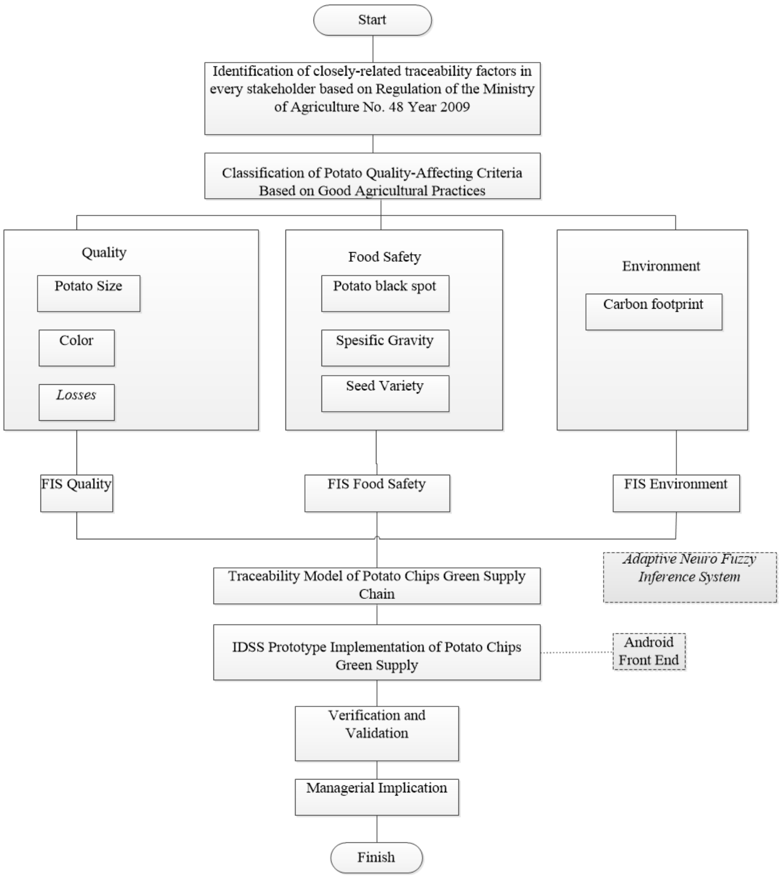


Figure 1. Research steps on traceability system model in green supply chain of potato chips agro-industry

– Verification and validation

In this study, verification was carried out when designing a traceability system on potato chips, the agro-industry green supply chain was objected to the business process, whether it would work in the field or not to implement the resulting model. Verification was conducted by practical experts in the agro-industry. Parameter identification in the design of a traceability system is based on situational analysis in the field. The experimental validation in this study used face validity. Face validity was carried out on users who have knowledge and expertise about the system [18], which is intelligent decision support system (IDSS) traceability on potato chips agro-industry green supply chain.

3. RESULTS AND DISCUSSION

This study uses a system approach. Goal-oriented efforts are carried out thoroughly, and the implementation of the green supply chain traceability system for potato chip agro-industry can be carried out using IDSS traceability on potato chips agro-industry green supply chain. This research will be explained through several stages and will be explained in each model can be seen in the results and discussion.

3.1. Design of traceability system model of potato chips agro-industry green supply chain

The initial step of identifying factors affecting potato quality is closely related to the implementation of traceability in every stakeholder, the criteria and attributes of which were in accordance with the Regulation of the Minister of Agriculture No. 48, 2009, which regulates the GAP of fruits and vegetables, including quality, food safety, and environment. Each criterion was identified based on experts and literature studies to determine their attributes, as presented in Table 1. Subsequently, post-harvest losses occur in potato receiving, potato checking, and classification of quality with grading, while weight loss was calculated by measuring the initial and final weights.

There were several activities carried out by agro-industry stakeholders, including receiving potatoes from farmer groups, checking quality loss and weight loss, and storing in a potato quarantine room before the warehouse. The weight loss of each potato size was less than 5%, with an average of 3.3% [19]. Post-harvest treatment during storage was conducted using open packaging. According to the above data, the weight loss of potato still met that set by the companies at 5% [20]. Potato chip agro-industry companies should make efforts to reduce greenhouse gas emissions on potato chip processing and carbon footprint transportation. Based on reports in all industries, the average direct emission from companies is around 14% of the total emissions from the supply chain [21], [22]. Therefore, sustainable measurement should take a supply chain perspective to limit emissions and environmental impacts.

3.2. FIS model of quality, food safety and environmental GAP traceability criteria of potato chips agro-industry green supply chains

The fuzzy inference system framework consists of five parts: input, fuzification, rule and regulation setting, defuzification, and output. FIS input to determine traceability criteria scores of supply chain were taken from quantitative and qualitative attributes score/data. Every qualitative and quantitative attribute data must be normalized according to the target of each attribute. Every attribute has different targets, units, and directions (min/max). Fuzification determines the member degree of input data of every qualitative and quantitative traceability attribute in a potato chip agro-industry supply chain. The scoring scale of supply chain traceability attributes was set through three linguistic levels (poor, fair, and good). The membership function chosen in this model was the triangular membership function triangular fuzzy number (TFN), as it is simpler and, can accommodate various views and opinions that are suitable for scoring traceability criteria [16]. The fuzzy membership functions for the four input criteria are presented in Table 2.

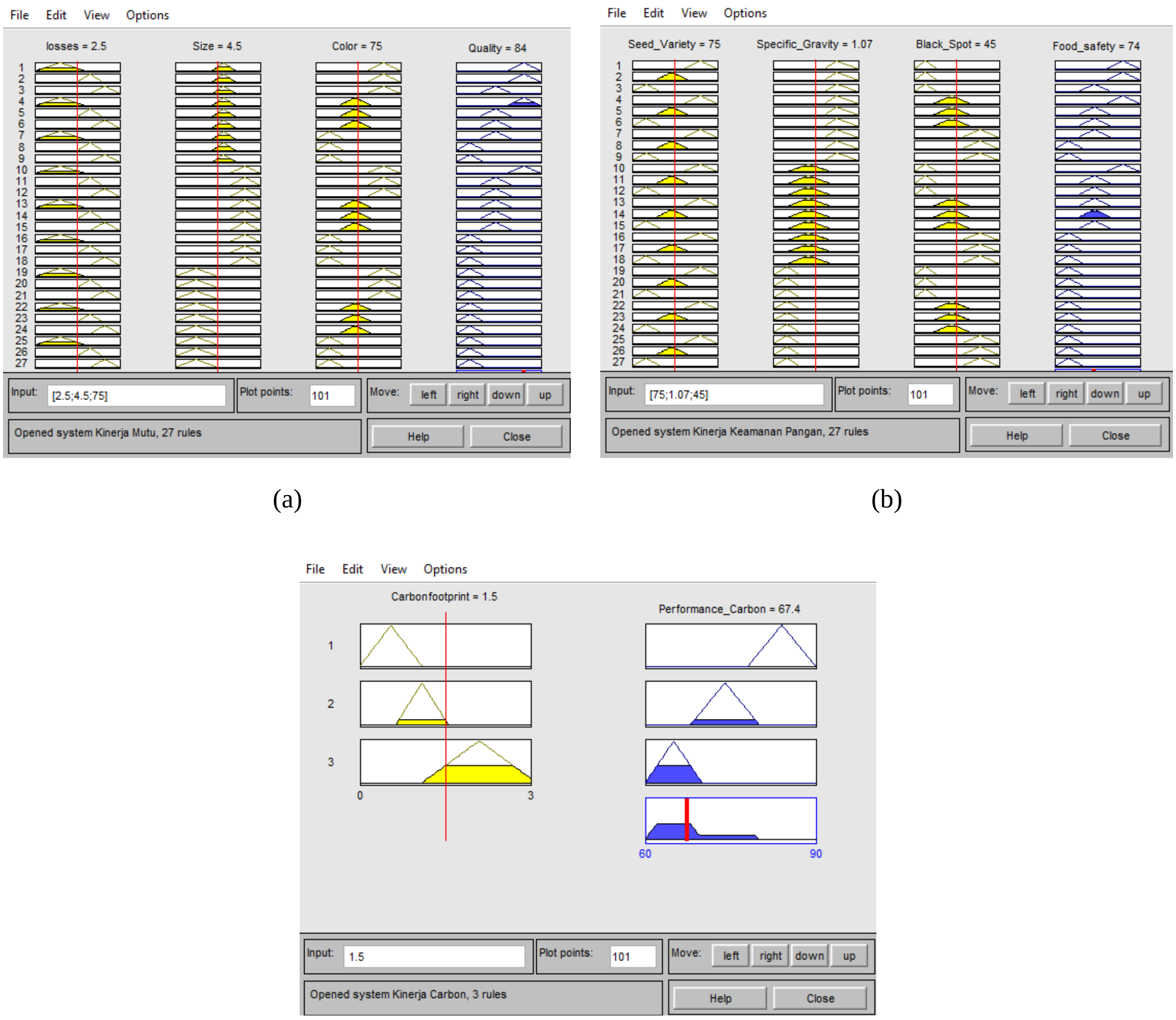
Based on the membership function in Table 2, the performance of the traceability criteria score can be obtained from Matlab. Meanwhile, the output of this membership function is the performance score of the traceability criteria consisting of three performance criteria, approximately ranging from 60 to 90. A score of 60 to 70 indicates poor quality, 68 to 80 indicates fair quality, and 78 to 90 indicates good quality. We have described and evaluated the design of FIS for quality, food safety, and the environment of the potato chip agro-industry, which was verified thereafter. Input and output score data were obtained from the measurement results and interviews with the quality manager where the research was conducted. The results showed that there were six stakeholders involved in the aggregation of quality, food safety, and environmental scores. A fuzzy inference system with the Mamdani method can be applied to obtain quality, food safety, and environmental scores. The Mamdani method is suitable for human linguistic reasoning.

Attributes on potato quality criteria, including size, color, and weight loss, can be seen in the Indonesian National Standard of Potato. Based on these quality criteria, 27 rules on FIS quality were generated. The next step was to obtain the quality criteria score of every supplier based on the FIS module, as shown in Figure 2(a), which shows that the performance score of the quality criteria was 84, indicating a good level of quality. This score was obtained from an attribute loss score of 2.5, a potato size score of 4.5, and a potato color score of 75. Attributes for food safety criteria are seed variety, specific gravity, and black spots. Based on the information collected in the field, only the Atlantic seed varieties are suitable for making potato chips. According to the food safety criteria, 27 rules were produced in the FIS of quality. Then, the score of food safety criteria for each supplier was obtained based on the FIS module, an example of which is shown in Figure 2(b), which shows that the performance score of the food safety criteria was 74, indicating a fair level of food safety.

This score was obtained from a seed variety score of 75, a specific gravity score of 1.07, and a black spot score of 45. This means that the supplier food safety criteria score was fair. An attribute of the environmental criteria discussed in this study was the carbon footprint. Three rules in the FIS of the environment were generated from environmental attributes. The environmental criteria score for each supplier was obtained based on the FIS module, an example of which can be seen in Figure 2(c); it can be seen that the performance score of the environmental criteria was 67.4, indicating a fair level of environment. This score was obtained from a carbon footprint score of 1.5. This means that the supplier environment criteria score was in a fair category.

Table 2. Membership function of traceability criteria assessment of potato chip GAP [19], [20], [23], [24]

Quality criteria			Food safety criteria			Environment criteria
Size	Losses	Color	Spesific gravity	Potato black spot	Seed variety	carbon footprint
μpoor = {1 ≤ X1 ≤ 4.5	μpoor = {3.25 ≤ X2 ≤ 5[a]	μpoor = {0.6 ≤ X3 ≤ 0.7	μpoor = {1.04 ≤ X4 ≤ 1.059	μpoor = {0.5 ≤ X5 ≤ 0.9	μpoor = {0.6 ≤ X6 ≤ 0.7	μpoor = {1.09 ≤ X7 ≤ 3.1[b]
μgood = {4 ≤ X1 ≤ 6	μfair = {2.5 ≤ X2 ≤ 4	μfair = {0.68 ≤ X3 ≤ 0.8	μfair = {1.05 ≤ X4 ≤ 1.081[d]	μfair = {0.2 ≤ X5 ≤ 0.6	μfair = {0.68 ≤ X6 ≤0.8	μfair = {0.63 ≤ X7 ≤ 1.55
μfair = {5.5 ≤ X1 ≤ 8	μgood = {0 ≤ X2 ≤ 3	μgood = {0.78 ≤ X3 ≤ 0.9	μgood = {1.07 ≤ X4 ≤ 1.1	μgood = {0 ≤ X5 ≤ 0.25	μgood = {0.78 ≤ X6 ≤0.9	μgood = {0≤ X7 ≤ 1.09[b]



(a) (b)

(c)

Figure 2. Centroid score criteria assessment of (a) quality criteria, (b) food safety criteria, and (c) environment criteria

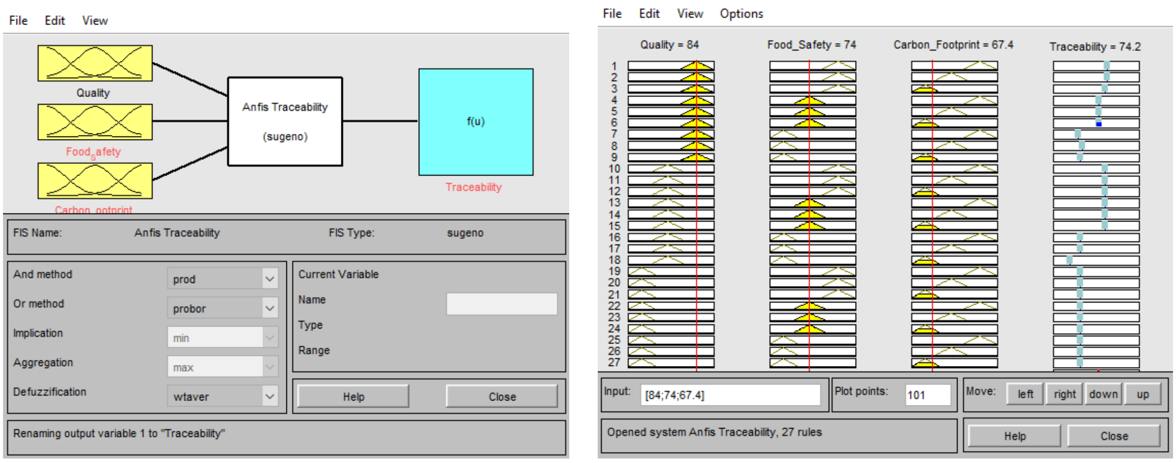
3.3. ANFIS model of green supply chain traceability of potato chips agro-industry

The attributes traced in the tracing and tracking processes here are based on quality, food safety, and the environment for overseeing potato GAP.

– GAP = function (quality, food safety, environment)
– Quality = function (potato size, losses, potato color)
– Food safety = function (seed variety, specific gravity, black spot)
– Environment = function (carbon footprint)

The validated ANFIS model produced a FIS model for determining traceability in measuring the quality of potato chips agro-industry green supply chain. The FIS framework generated from ANFIS modeling with grid partition for traceability assessment of potato GAP criteria in the potato chip agro-industry green supply chain is shown in Figure 3(a). The FIS operator model was implemented in the Sugeno FIS model with 27 fuzzy rules and an AND operator between an input variable and Gaussian membership function to determine the traceability of potato quality assessment in the potato chip agro-industry green supply chain.

The analysis results in the previous stage succeeded in showing a quality score of 84, a food safety score of 74, and an environment score of 67.4. Furthermore, to determine the traceability of potato quality assessment in the potato chip agro-industry green supply chain, aggregation was performed using an ANFIS model with a grid partition. The simulation results of the ANFIS model showed that the potato chip quality score in the potato chip agro-industry green supply chain was 74.2, still in a fair category, as shown in Figure 3(b). Based on the scores of quality, safety, and environmental aspects of potato, a potato GAP traceability score of 74.2% was obtained, which was still in a fair category. Products that meet GAP requirements can continue potato chip processing to obtain a good and fair status. Meanwhile, products with a poor status cannot continue to the next process. An ANFIS model was implemented for green supply chain traceability with input variables of quality, food safety, and environment. In the input membership function section, a Gaussian membership function was modeled because it has been proven to perform well in describing the distribution of real data. In the development of this ANFIS model, a grid partition model, was developed in the initiation of the ANFIS architecture to distribute the membership function evenly throughout the range of variable scores.



(a) (b)

Figure 3. Model framework and simulation result for criteria assessment of potato chips agro-industry green supply chain: (a) FIS model framework and (b) simulation results

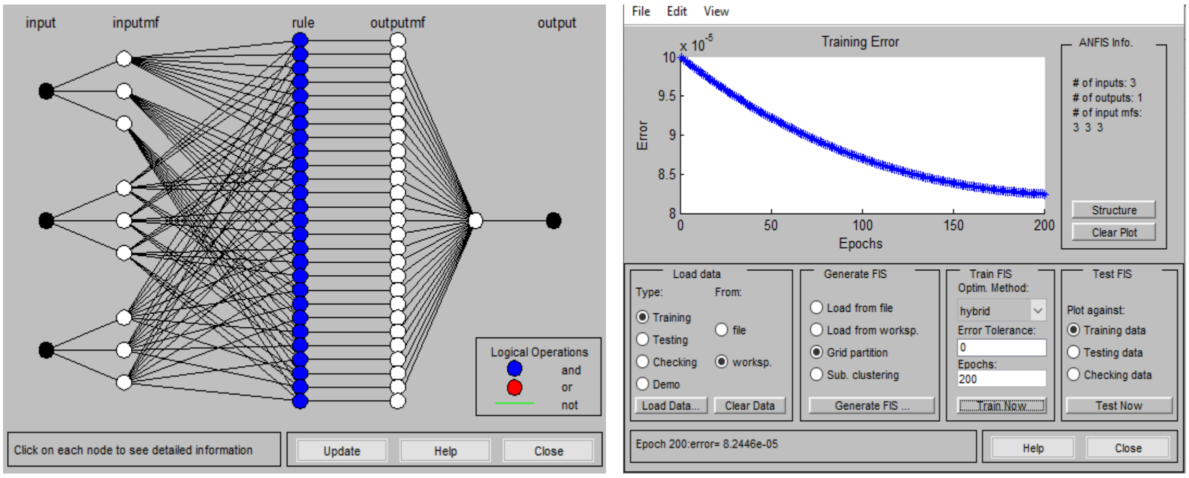
In an ANFIS model with the grid partition technique, each ANFIS input variable was composed of 3 membership functions with Gaussian type, namely good, fair, and poor categories, which were distributed evenly according to the principle of the grid partition technique. Referring to the membership function in Figure 4(a) with three input variables and three membership functions, there are 27 fuzzy initiation rules in the ANFIS model for the traceability of potato chips agro-industry green supply chain. The ANFIS model framework with the grid partition initiation model is shown in Figure 4(a).

The ANFIS traceability model was processed for which training data were required. The ANFIS architecture of the grid partition model shows 27 fuzzy rules. Therefore, at least 27 datasets were needed for training to allow all parts and rules in the ANFIS model to be trained. A simulation of the data training process for the ANFIS traceability model of the potato chips agro-industry green supply chain was performed, as shown in Figure 4(b). The ANFIS model training process was initiated at 200 epochs with an error tolerance level of 0. Simulation results of the ANFIS model training process with a grid partition showed that the model error rate was 8.245×10^{-5}, which met the minimum allowed error rate of less than 0.01 [25].

In previous traceability studies, there was no way to assess GAP traceability on horticultural products, especially potatoes, in potato chip agro-industry. Traceability research is usually conducted to assess the quality of a product, as in research [16]. Traceability research in this study [17] used fuzzy classification and adaptive neural network methods to produce quality assessments of meat products, therefore, this study developed a quality assessment of horticultural products, namely potatoes in potato chips agro-industry with the methods used, namely FIS and ANFIS, so that the resulting previous research and this study both conduct an assessment of product quality, which makes the difference for this research to add to the assessment criteria, namely for food safety and the environment. This model can also be applied to other horticultural product commodities only to identify the factor requirements of the product according to the physiological needs of each commodity.

3.4. Design of a decision support system for assessing GAP traceability criteria for potato chips agro-industry green supply chain

The development of an intelligent decision support system for the GAP traceability of potato chips agro-industry green supply chain refers to the system development life cycle (SDLC) with a waterfall model approach. SDLC with the waterfall model approach is a sequential system development process that becomes more complicated as it decreases [26]. The waterfall model approach for system development, in which each stage must be completed before executing the next stage. Stages of system development through the waterfall approach can be performed repeatedly, even though a new stage has been entered. This allows the system to be developed better and errors to be avoided during the system development. The IDSS development framework for GAP traceability of potato chips agro-industry green supply chain consists of 4 main stages, following a waterfall model framework.



(a) (b)

Figure 4. ANFIS architecture and training simulation of criteria assessment potato chips agro-industry green supply chain: (a) ANFIS architecture and (b) ANFIS model training simulation with grid partition

The system development framework began with a requirement analysis of the system and software, system design, system implementation, system testing, and improvement. In the early stages, system and software analyses were carried out to determine various aspects and system requirements to build the software. System analysis consists of system requirement analysis and system business process modeling that can be explained in a configuration design of the IDSS for GAP traceability of the potato chips agro-industry green supply chain, as shown in Figure 5. Based on Figure 5, it can be seen that the input data for each required model such as the amount of potato, initial weight of potato, product demand, final weight of potato, use energy, GAP standardization of potato quality, food safety, and environment can use the inference engine mechanism by using fuzzy inference system and adaptive neuro network fuzzy inference system to make decisions from the model assessing GAP traceability criteria for potato chips agro-industry green supply chain.

In designing a system, there are three main parts that must be designed; database, model base, and knowledge base. Implementation of the model into the system was carried out using an object-oriented model (OOM) technique, which is a programming technique that defines problems and all data into objects and classes. OOM allows each object and class to interact with each other, thereby increasing the efficiency of problem solving and system implementation [27]. The implementation of databases, models, and knowledge into the system with the OOM approach needs to be assisted by a data flow diagram (DFD) and class diagram. System implementation is a stage of operationally translating the system framework into a computer program. There are several tools that must be considered in preparing the DFD, which can describe the flow of data information needed by each stakeholder either from or to the system for assessing GAP traceability criteria for potato chips agro-industry green supply chain.

Verification and validation were performed according to the approach in [18]. Data simulation with computational verification was important to determine that the system had worked well, and the recommended outputs were also linear with the system framework. A conceptual model and operational validation were needed to determine whether the system was ready to use and met the requirements. Conceptual model validation was performed by looking at the system output in accordance with the system requirement analysis that was carried out at the beginning of the system analysis. Operational validation was carried out with face validation by asking experts if the system built was reliable or if the system was in accordance with the requirements.

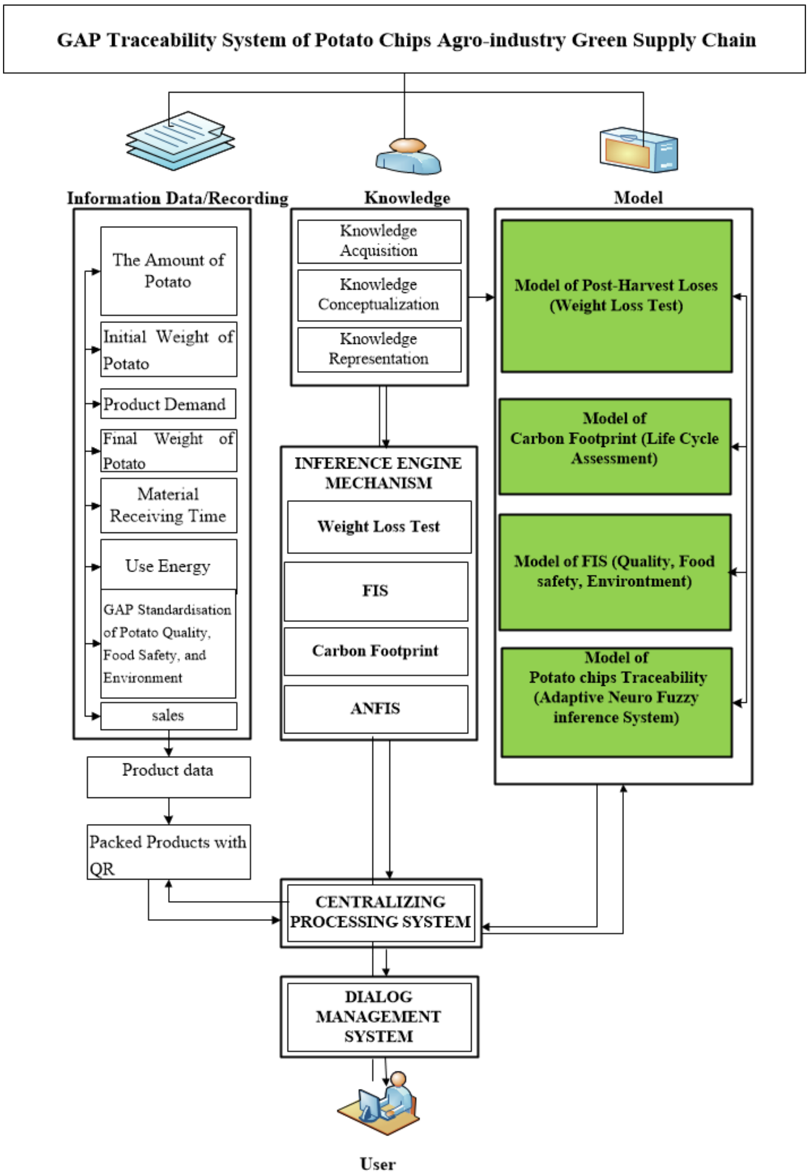


Figure 5. IDSS configuration of GAP traceability criteria assessment for potato chips agro-industry green supply chain

3.5. Implication managerial

Develop a traceability system as a monitoring tool for quality, food safety, and the environment based on information technology (IT) combined with an intelligent system to overcome problems in the supply chain of potato chip agro-industry. The traceability system applied to the supply chain, it will be able to guarantee quality, product safety and the environment. Thus the agro-industry can determine the results of the GAP criteria assessment for all potato suppliers. For supply chain actors, the implementation of traceability systems can create safer and more transparent business processes, guarantee production history, integrate all actors through interconnected communication, enable actors to comply with laws and regulations, increase added value because it can produce safe and high-quality products, increase the trust of business partners, minimize expenses if there are product recalls or problems in product distribution, and have the ability to identify problems that arise.

The contribution of this research is that it has succeeded in compiling criteria and attributes in conducting traceability of the green supply chain of potato chips agro-industry and has succeeded in determining the value of quality, food safety, and environmental criteria. This research has succeeded in developing a more adaptive and comprehensive supply chain traceability framework, starting from the assessment of each criterion to the aggregation of GAP values so that traceability can be carried out. The scoring framework was also modeled through intelligent inference.

4. CONCLUSION AND RECOMENDATION

The GAP traceability assessment criteria in accordance with the Regulation of the Ministry of Agriculture No. 48, 2009, include quality, food safety, and environmental criteria. The GAP traceability model for potato chips agro-industry with results for quality criteria of 84%, food safety of 74%, environment of 67.4%, and GAP aggregation of 74.2%. The prototype of the IDSS traceability design for green supply chain for potato chip agro-industry was successfully built by implementing the GAP traceability model, which is able to analyze quality, food safety, and environmental criteria. Products that meet the GAP requirements can continue to be processed into potato chips to upgrade into good and fair status, while products with poor status cannot continue the next process. It is necessary to continue research on green supply chain traceability in potato chip agro-industry with consumers as users. It is necessary to continue research to add shrinkage attribute quality and material handling. The resulting computational model will be developed into an android-based IDSS platform and can run in real time.

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BIOGRAPHIES OF AUTHORS

Ririn Regiana Dwi Satya, S.ST, MT received PhD Graduate Student IPB University (Bogor Agricultural University) Department of Agroindustrial Technology Faculty of Agricultural Engineering and Technology and Lecturer at Department of Industrial Engineering, Faculty of Engineering and Computer Science, Indraprasta PGRI University, Jakarta, Indonesia. In 2012, she received master degree in industrial engineering at the Trisakti University. Her research interests are Green Supply Chain Management, Decision Support System, fuzzy expert system. She can be contacted at email: ririn.regiana86@gmail.com.

Prof. Dr. Ir. Eriyatno, MSAE received lecturer at the IPB University (Bogor Agricultural University) Department of Agro-industrial Technology, Faculty of Agricultural Engineering and Technology. In 1979, he received his PhD degree in systems science at the department of electrical and system engineering after which he did Podt-Doctoral research on Decision support systems and expert management systems in the USA, France, UK and Japan. His research interests are Intelligent Systems, Decision Support Systems, Supply Chain Management, Agro-industry. He can be contacted at email: eriyatno@yahoo.com.

Dr. Ir. Andes Ismayana, MT received lecturer at the IPB University (Bogor Agricultural University) Department of Agro-industrial Technology, Faculty of Agricultural Engineering and Technology. He received MT degree in environmental engineering from the Bandung Institute of Technology in 1997. PhD degree from IPB University (Bogor Agricultural University) Department of Agro-industrial Technology, Faculty of Agricultural Engineering and Technology in 2014. His research interests are Environmental Engineering, LCA. He can be contacted at email: andesismayana@ymail.com.

Prof. Dr. Ir. Marimin, MSc received the B.S. honor in agro-industrial technology, from Bogor University (Bogor Agricultural University), Bogor, Indonesia, in 1984. In 1990, he received the M.Sc. degree in computer science from the University of Western Ontario, Canada, PhD degree from Faculty of Engineering Science, Osaka University, Japan in 1997. Since 2003, he has been a professor in Systems Engineering with IPB University. His research interests are intelligent and fuzzy expert systems, intelligent decision support systems, and sustainable supply chain management. Marimin is a member of the Indonesian Engineer Association and as well as Indonesia Logistic and Supply Chain Management and Institute of Electrical and Electronic Engineer (IEEE). He can be contacted at email: marimin@ipb.ac.id.