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QUALITY OF PROTEIN DECLARATION ON PREPACKAGED FOOD PRODUCTS MODELLED IN FUZZY LOGIC

BY

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A THESIS SUBMITTED TO THE DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENT TO THE AWARD OF MSC. DEGREE IN FOOD QUALITY MANAGEMENT.

JUNE 2019.

DECLARATION

I do hereby declare that this research paper is my own work towards the Masters of Science in Food Quality Management and that it contains no material previously published by another person or material which has been accepted for the award of any other degree of any other University, except where due acknowledgement has been made in the text.

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DEDICATION

I dedicate this project to all generational thinkers of my beloved Country, Ghana.

ACKNOWLEDGEMENT

I would like to acknowledge my parents, siblings and the man behind my dreams, for believing in me and supporting me throughout my education and career. My sincere gratitude also goes to my lecturer and supervisor Dr. Isaac Williams Ofosu and his wonderful family for their support and encouragement and to all lecturers and mentors in my life as well as the team members of MS Food Safety Consultancy, thank you all for believing in me and for your kind support.

ABSTRACT

Food labelling laws aim to protect consumers from deception. This study was to determine the accuracy of food protein labelling in prepackaged food products on the Ghanaian market and to identify the need for the establishment of a national tolerance criterion. Twenty-six (26) food products from Accra and Kumasi were grouped into Dairy, Cereals, Fish, Peas and Confectionery products. Their protein contents were determined using Kjeldahl with 5.7 Jones factor for Cereals and 6.25 for other samples. Fuzzy logic and modelling (MATLAB toolbox) was used to analyze the two input variables (product category and net weight) of the products and their output variable (Confidence quotient). The term confidence quotient, which was used to describe the degree of accuracy, was defined in the study as the difference between the declared and the mean laboratory analyzed protein values. The accuracy of the declared protein was considered “low” or “high” according to the confidence interval; 90%, 95%, and 99%, used and the principal protein tolerance acceptance criterion (≥80%). The results from the distribution and fuzzy model demonstrated significant variations at which most protein contents were misrepresented in the products. It was revealed that the categories and net weight of the products appeared to have contributed to this variation. The results offer a prediction tool to understand the likelihood of inaccuracy of declared nutrient contents on prepackaged food products using protein as a test factor in establishing a national tolerance criterion.

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CHAPTER ONE

INTRODUCTION

1.1 Background

Adaptation to changes in lifestyle especially in developing countries such as Ghana has exposed consumers to embrace the usage of prepackaged food products to keep up with the rapid demand of convenience and variant food products (Alvarez and Boye, 2012). A global concern in the food industry is food safety and quality. Bottaro *et al.* (2014) stated that one of the main food quality-related issues is the authentication of food contents. Even if food fraud is hardly a new phenomenon (Shears *et al.*, 2001), the authenticity of foods and the veracity of food labels are currently major concerns for scholars, consumers, regulators in the food industry at all levels of the food continuum (Charlebois *et al.*, 2016).

An authentic prepackaged food product label must comply with labelling regulations, especially in relation to ingredient composition and nutrition fact declaration. However, there is massive uncertainty of the quality of information usually put on the label of prepackaged food products. A research on macronutrients compliance between food labels and marketing package content values objectively determined the compliance between information presented in food labelling of widely consumed foods with their true values, which revealed results showing a significant difference between analyzed values to the food labels nutrition facts (Pasdar *et al.*, 2017).

In situations whereby communicating essential information of a nutrition label to consumers shows imprecise variables, the imprecise variables have to be studied simultaneously in making a concise decision. In recent years, rapid and reliable sensor, spectroscopic and chromatographic techniques are used to authenticate food products (Borras *et al.*, 2015). Fuzzy logic comes in handy because it has the potential to arrive at a decision in the absence of precise mathematical models. Few studies have been conducted in Ghana in the area of food nutrition labelling, specifically in the area of nutrition fact authentication.

This study intends to identify the variation between the laboratory determined food proteins on the Ghanaian market relative to their reported food proteins. The study is also expected to review from literature, the tolerance level of the nutrient declared with guidance from other countries and regions and to ascertain if product category and product net weight stand to be some of the several causes of the variation in nutrition contents of prepackaged foods on the Ghanaian market. The research finding is based on modeling the variation in protein content of the prepackaged food labeling in fuzzy logic. It is hoped that findings from this research would be a prediction tool to open up for more research on nutrition labeling authentication as well as research studies pertaining to factors that could lead to nutrition content variations in prepackaging food products.

1.2 Problem Statement and Justification

Prepackaged foods on the Ghanaian market are either locally produced or imported. Regulations on nutrition labelling in Ghana is by the Food and Drugs Authority. The FDA has not established a defined regulatory guideline on tolerances on nutrition fact declaration on prepackaged food products. It has been noted that the FDA regulates declared nutrition facts (when voluntarily declared) using laboratory evidence from the manufacturer. Under a routine surveillance program, the FDA, Ghana does not verify the accuracy of nutrient values on nutrition labels which are bound to vary according to a country or region's tolerance control of compliance of declared nutrient values on prepackaged food labels.

Variations between the declared values and the actual nutrition content takes place over time because of variations in raw materials, product category, product net weight, and their corresponding laboratory and environmental factors. Nevertheless, the nutrient content of foods should not deviate substantially from labelled values to the extent that such deviations could lead to consumers being misled. The possibilities of these assumptions make it difficult, if not impossible for consumers to know with high accuracy of the details of the products they purchase in Ghana. Currently, in Ghana, there are no studies that focus on comparing declared nutrition fact to laboratory analyzed nutrition contents of prepackaged food products to determine the accuracy of the declaration made. Also, there has not been studies on potential factors that may lead to possible variations in nutrition facts of prepackaging food products. This explains the need for studying the regulation gap by ascertaining the deviation in the difference in protein content (declared and analyzed) from commonly used tolerance limit. The study was also to explain with Fuzzy logic using output variable (Confidence Quotient) to confirm the effect of product category and product net weight on the protein content variation (declared and analyzed) of the prepackaged food products.

1. 3 Objective

The study sought to determine the degree of accuracy of declared protein on prepackaged food labels on the Ghanaian market using fuzzy logic model.

CHAPTER TWO

LITERATURE REVIEW

2.1 Prepackaged foods

According to the Codex Alimentarius Commission (1985), prepackaged foods are foods packaged in a container, ready for an offer to the consumer or for catering services. They help to reduce post-harvest losses and facilitate the transport of foods from one geographical location to another (FAO, 2011). Prepackaged foods are mostly affordable and easily accessible (Davey, 2004) especially in developing countries (Kasapila and Shawal, 2011). Most foods are prepackaged to enhance handling, transportation, preservation, and hygiene. Adaptation to changes in lifestyle especially in developing countries such as Ghana has exposed consumers to embraced the usage of prepackaged food products to keep up with the rapid demand of convenience and variant food products (Alvarez and Boye, 2012). Ghanaian diet comes in various types of packaging including cans, glass, plastic, and paper. A wide variety of foods on the Ghanaian market come in prepackaged forms which include fruits juices, breakfast beverages, soft drinks, canned fish and beef, breakfast cereals, milk products, oil, biscuits, and several others.

2.2 Labelling of prepackaged foods

A food label may be described by the Codex Guideline on Labelling of Prepackaged Foods as any tag, brand, mark, pictorial or descriptive matter attached to a food package (CAC, 1985). The General Labelling Rules of the Food and Drugs Authority, Ghana (2013), require that food labelling should be informative and accurate.

According to the Ghana Food and Drugs Authority (2013), a prepackage food product shall not be sold, distributed, imported or disposed unless the food is marked or labelled with the name of the food, ingredient list, manufacturing and expiration date, storage and handling conditions. The label shall also depict instructions for use, net weight, batch codes, country of origin and name and address of the producer, importer or distributor. Food labelling policies have a dual purpose to protect consumers and to ensure fair marketing.

A Food label is a legal requirement which has to be fulfilled by food processing companies for the consumer's better health and safety (Ababio *et al.*, 2012). An effective food label plays a multidimensional role in providing nutritional information (Grunert and Wills, 2007; Mackison *et al.*, 2010), controlling food-related allergies, expiry date and providing food safety (Voordous *et al.*, 2009; Sanlier and Karakus, 2010). Food label information assists consumers to better understand the nutritional value of food and enables them to compare the nutritional value of similar food products which guides them to make informed and healthy food choices based on the relevant nutrition information (AL Tamimi and Company, 2004).

2.3 Nutrition fact declaration on prepackaged food labels – A global overview

Nutrition fact declaration is a component of food labelling that provides consumers with information on the nutrition content of food products and allows comparison of the nutritional content of similar foods (Grunert and Wills, 2007). It can be in numeric or non-numeric format. Provision of food labels on prepackaged foods is mandatory in most countries but the provision of nutritional content information on the food labels is either mandatory or voluntary, depending on the legislative instrument or legal regulatory requirement governing food labelling in a country or region (Campos *et al.*, 2011). It is the responsibility of a country to decide on either adapting to mandatory or voluntary nutrition fact declaration and regulation.

In Ghana, a large proportion of prepackaged foods on the Ghanaian market are imported and prepackaged foods are regulated by the Ghana Food and Drugs Authority using the national guideline for the labelling of prepackaged foods (FDA, 2013) which was adopted from the Codex Guideline on Nutrition Labelling (1985). The Codex guideline allows for mandatory or voluntary labelling requirement by food manufacturers and importers. The mandatory labelling encompasses the name of the food, list of ingredients, instruction for use, declaration of name and address of the manufacturer or packer or importer or vendor, country of origin, lot identification, instruction for use, ingredient declaration and written statement of irradiated foods (Cowburn and Stockley, 2005). The purpose of the guidelines on nutrition labelling by Codex Alimentarius Commission (1985) is to ensure that nutrition labelling does not describe a product or present information about it which is in any way false, misleading, deceptive or insignificant in any manner.

According to the Ghana Food and Drugs Authority (2013), it is a voluntary act for a prepackaged food item to have its nutrition fact declared on the food label and when manufacturers/importers/exporters tend to declare the nutrition fact on their prepackaged food label, they must justify the declaration from an approved laboratory. In the United States of America, compliance to the Nutrition Labeling and Education Act of 1990 (NLEA, 1990) justifies the display of nutritional content information on prepackaged foods as mandatory with the exception of foods intended for immediate consumption.

In Canada, the law on mandatory nutrition labelling was first passed in December 2003 and became mandatory on virtually all prepackaged foods in 2005 (Health Canada, 2010). Health Canada and the Canadian Food Inspection Agency (CFIA, 2018) oversee the regulatory process of food labelling in Canada. The European Union has a new regulation in force which makes nutrition labelling mandatory for most prepackaged foods and roughly 84% of products in Europe have nutrition labels (Bonsmann, Celemín and Grunert, 2010). Kasapila and Sharifudin (2011) pointed out in their research that, analysis from ASEAN members' regulations on food and nutrition labelling indicated that Singapore, Malaysia, Brunei, Lao PDR, Vietnam, and Cambodia follows the Codex guidelines in preparing their regulations. Conversely, Thailand and the Philippines, to some extent have adopted the United States (US) nutrition labelling guidelines. Even within those member countries that have adopted the Codex guidelines, there are differences in their regulatory regime. Food regulators play a major role in monitoring the accuracy of food labels but while some countries proactively assess labels regularly, other countries respond to consumer complain (Charlebois *et al.*, 2016).

Proteins form part of the eight key nutrients depicted on a standardized nutrition fact declaration on a prepackaged food label. According to the Canadian Food Inspection Agency (CFIA, 2018), a food product is considered a low source of protein when the food contains no more than 1g of protein per 100 g of the food. It is also considered as a good source of protein when the food has a protein rating of 20 g or more. A food product is also considered an excellent source of protein/very high in protein/rich in protein when the food has a protein rating of 40 g or more.

It is categorized as higher protein food when the food has a protein rating of 20 g or more or contains at least 25% more protein, totaling at least 7 g more per reasonable daily intake than a reference food of the same food group or a similar reference food (CFIA.2018). According to the Codex Guideline on Nutrition Labelling (CAC, 1985), in calculating the amount of protein to be listed on a prepackaged food product, it is required of laboratories to adopt the Kjeldahl formula calculated as

$Protein = \text{Total Kjeldahl Nitrogen} \times 6.25.$

2.4 Accuracy of nutrition fact declaration- Protein tolerance.

According to the Ghana Food and Drugs Act 1992 under the P.N.D.C law (1992) on deception of consumers, a person who manufactures or sells food in a manner that is false, misleading or deceptive commits an offense of the law. The Canadian Food

Inspection Agency assesses the accuracy of nutrient values on food labels through laboratory analysis and subjects the results to their acceptance criteria (CFIA, 2018). The U.S FDA uses a nutrition labelling manual as a guide for the food industry for developing and using databases (NLEA, 1994). In determining whether the nutrient in question is in compliance with applicable regulations, the U.S FDA applies the mathematical representation of the laboratory value in reference to the label value expressed as a percentage as

$$\boldsymbol{Tolerance\ limit} = \frac{Laboratory\ value}{Label\ Value} \times 100\%.$$

The U.S FDA in accordance with the 1990 Nutrition Labelling and Education Act (NLEA, 1990) just like most other regulatory institutions through the Codex Nutrition label regulations allows pretty lax margin of error between declared nutrients and actual nutrient content of a product which sometimes limits the purpose of a prepackaged food label as a tool for providing clearer, more transparent information to consumers to enable them make better comparison of nutritional merits of products.

The challenge in ensuring sound judgment of prevalence of inaccuracy creates room for food regulators in the various countries and regions to establish guidelines on tolerance to the control of compliance of nutrient values declared on prepackaged food labels.

The Codex Guidelines on Nutrition Labelling (CAC 1985), recommends that tolerance limits be set in relation to public health concerns, shelf-life, accuracy of analysis, processing variability and inherent liability and variability of the nutrient in the product, and according to whether the nutrient has been added or is naturally occurring in the product. At the European level, mandatory tolerances for nutrition labelling has not been set but some EU member states have developed national guidelines for tolerances on the declaration of vitamin and mineral content as well as for macro-nutrients such as protein and fat.

However, Ireland has no national legislation or guidelines on tolerances for nutrient declarations for labelling purposes (FSAI, 2010). Experience from industry has proven that, in Ghana, just like Ireland and some other countries, there are no clearly defined national regulatory guidelines on tolerances for a nutrient declaration on prepackaged food labels. Prepackaged food products do not always contain the exact nutrient levels depicted on the prepackaged food label due to natural variations and some other variations from production and storage (EUFIC, 2018) but this does not dispute the fact that they should not deviate substantially from labelled value to the extent that such deviations could mislead consumers.

This is a more reason why nutrition labelling should conform to compliance test and therefore a necessity for various countries and regions to establish guidelines on tolerance to the control of compliance of nutrient values declared on a food label. Canada has established a one-sided test for naturally occurring nutrients under a principal acceptance criterion, European Union, United States of America, Hong Kong, Thailand, Taiwan, Korea, Japan, Singapore, and some other countries have established nutrient tolerance guidelines which include uncertainty and explains low and upper tolerance limits. The Center for Food Safety in Hong Kong (2013) published a nutrition labelling scheme on tolerance limits (CFS, 2013). From the scheme, for naturally occurring protein, two sets of tolerance limits ($\pm$20% or $\geq$ 80%) of the declared or label value were identified (Table 1).

Table 1: Tolerance limits in some countries for protein declaration on nutrition labels.

	U.S.A	CANADA	THAILAND	TAIWAN	KOREA	JAPAN	SINGAPORE
PROTEIN	≥80%	≥80%	±20%	±20%	≥80%	±20%	≥80%

2.5 Fuzzy theory

The fuzzy inference system as established from fuzzy logic is a decision-making tool used to arrive at timely decisions (Adeyemi *et al.*, 2017). It extends the principles of classical set theory and uses intersections of crisp sets, and extends to the "if-then" rules. In fuzzy logic, because of the imprecise nature of the elements in the set, crisp sets are transformed or fuzzified to fuzzy sets which imply that fuzzy sets contain elements that have variant degrees of memberships in the respective sets. Simultaneously, as fuzzy logic offers elements that have strong membership in one set, it also shows a weak membership in another set on a scale ranging from 0-1. By using the classical set operators of intersections, fuzzy variables are mapped to outputs in an "if-then" rule relations in order to arrive at a decision.

Several researchers have adopted the use of Fuzzy Logic Theory as the basis of their research. Burrough (1989) demonstrated the use of fuzzy sets for soil survey and land evaluation. The fuzzy set theory has been applied by Robinson (1990) for representing qualitative linguistic spatial relationships.

A rapid and reliable sensor, spectroscopic and chromatographic techniques were used to authenticate food products by Borras *et al.* (2015) while they focused on fuzzy logic as the basis of the analysis.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

A total of twenty-six (26) easily accessible prepackaged food products with nutrition fact declaration were categorized into Dairy, Cereals, Fish, Peas, and Confectionery. Products were randomly sampled from shops in Accra and Kumasi, Ghana. Out of the twenty-six (26) products randomly sampled from the Ghanaian market, eighteen (18) were imported products and eight (8) were manufactured in Ghana. The selected product net weight range was 10 g - 1000 g. Concentrated sulphuric acid, potassium sulphate, selenium tablet was purchased from Sigma-Aldrich (United States of America) to run a Kjeldahl analysis on the products sampled.

3.2 Methods

3.2.1 Sampling

A probability sampling method (random sampling) was used. A systematic random sampling of the prepackaged food products was utilized. The total population size was 80 prepackaged products. Twenty-Six (26) prepackaged brands out of the 80 prepackaged food brands had nutrition fact data voluntarily declared on their labels. Each of the 26 prepackaged brands had a representation of three products of the same brand, net weight and batch code to be used for the analysis.

3.2.2 Product classification

The products were grouped according to the foods that share similar nutritional properties or biological classification.

The products were characterized into the five categories; Dairy, Fish, Confectionery, Cereals, and Peas. The net weight of all the prepackaged products sampled was visually examined and recorded as depicted on their respective labels. Experiences from industry have placed low-density net weight within the range of 10-500 g and hence anything greater than 500 g is considered as a high-density product.

The declared protein content of all the products sampled was visually examined and recorded as stated on their labels. The declared protein contents were all expressed in g/100 g. With reference to the Canadian Food Inspection Agency (2018), the declared protein on the prepackaged products was categorized into low (≤1 g/100 g), medium (≥ 20 g/100 g) and high (≥ 40 g/100 g).

3.2.3 Protein determination using Kjeldahl analysis

Official method of analysis of AOAC International was used for the Kjeldahl analysis. A 1g of each of the 26 prepackaged products was pulverized using a laboratory mill (Crompton, Mumbai) through a 20 to 30 mesh size and quantitatively transferred into a 500 ml Kjeldahl digestion flask. It was then heated in the presence of 20 mg of concentrated sulphuric acid (H_2SO_4) with 2 g of potassium sulphate (K_2SO_4). One tablet of a catalyst containing selenium dioxide (SeO_4) was added.

The mixture was placed in a Kjeldahl heating block (Tector, Sweden) between 150-250 ^{o}C in a fume hood until the mixture turned colorless. An amount of 45% NaOH solution was carefully poured into the Kjeldahl flask and the subsequent solution boiled to trap the ammonia in Boric acid (H_3BO_3) after the distillation flask was connected to the digestion flask. The distillate was subsequently titrated with 0.1 N NaOH standard solutions and corrected for blank using all the reagents. The percentage nitrogen content was calculated and multiplied by a conversion factor of 6.25 for all other prepackaged products and a factor of 5.7 for cereals products to obtain the percentage protein. Each analysis was repeated on the other two different packages of the same prepackaged product with the same batch number and net weight and the mean was calculated as a representation of the protein content.

The mean protein contents of the prepackaged products were mathematically calculated (Equation 1 and 2) where x, A and B respectively represented the percentage of protein in the samples, the amount of acid used in titration and the number of tested samples in the study.

The conversion ratio of nitrogen gas to nitrogen liquid was 6.25 for all products and 5.7 for Cereals which were the Jones factors of the products in question according to Jones (1941).

$$\text{Cereals, } x = \frac{A \times 100 \times 1.4 \times 5.7}{1000 \times B} \qquad \textbf{\textit{Equation 1}}$$

$$\text{Other products, } x = \frac{A \times 100 \times 1.4 \times 6.25}{1000 \times B} \qquad \textbf{\textit{Equation 2}}$$

3.2.4 Statistical analysis

Data analysis was conducted using SPSS Statistics V21.0. The discrepancy between the declared protein and mean laboratory analyzed protein contents in grams per portion was the primary outcome variable. In obtaining the primary outcome, the declared protein content as compared to the laboratory analyzed protein using the t-distribution. The tdistribution was used because of the sample size ($n < 30$). The confidence quotient was used to describe the degree of accuracy using Minitab Statistical Package. The discrepancy between the stated and the laboratory analyzed protein contents of the products at 90 %, 95 % and 99 % confident quotients was calculated.

The difference between the mean analyzed protein and the declared protein of the prepackaged food products were stipulated as the protein error and in reference literature (Table 1), the most commonly used protein tolerance limit (≥ 80%) was used to ascertain the protein error deviation from the tolerance limit.

3.2.5 Fuzzy modelling analysis

The declared protein contents of the products were visually examined and recorded as stated on their respective labels. The term confident quotient (CQ) was used to describe the degree of accuracy which was defined in the study as the difference between the declared and the mean laboratory analyzed protein values based on Minitab Statistical Package at 99%, 95% and 90% confidence intervals (CI). The product categories were determined with reference to the major ingredients of the products as depicted on their respective labels. The active ingredient(s) of the prepackaged products were used to group the products.

From literature search, the products were characterized into the five categories by first determining their respective innate ingredient makeup. The net weight of all the prepackaged products sampled was visually examined and recorded as depicted on their respective labels. Experiences from industry have placed low-density net weight within the range of 10-500 g and hence anything greater than 500 g is considered as a highdensity product.

The fuzzy inference system, based on fuzzy logic was used as a decision-making tool to arrive at timely decisions. Ranges of the crisp inputs were set and the output variables were also set, together with their membership function. Triangular membership functions were intuitively used to characterize the fuzziness of the fuzzy set to show the degree to which the elements in the linguistic variable belonged to the fuzzy set. The first step was to link the input variables unit to a fuzzification interface which transformed the crisp numerical input variables into linguistic fuzzy variables. The fuzzy inference process was considered to be composed of a series of instructional units, designed to perform unique functions, followed by the database unit where selection membership functions of each fuzzy sets occur. Then, the fuzzy rule relation was established using the "if-then" command to generate the 26 rules together with their simulations and their relational graphs. Consequently, a fuzzy truth reference table, representing all possible outputs for all possible inputs was obtained.

The last step was the defuzzification step whereby the defuzzification interface transformed the fuzzy output results into crisp numerical output results. In the MATLAB (2013) fuzzy logic toolbox, the initial step of fuzzy modelling was the fuzzification process, where the numerical data set obtained in the study was expressed as fuzzy data. The simulation and their relational graphs of the input variables were deduced in the fuzzy logic model and used to predict the characteristics of the output variables at a 100% accuracy.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Declaration of Nutrition Labelling

Codex Guideline on Nutrition Labelling (1985) clearly explains that nutrition labelling is regarded as a voluntary act except when a nutrition claim is made on the prepackaged label. The research indicated that, 32.5 % of the sampled products had nutrition fact content declared on them and 67.5 % of the sampled products did not have their nutrition fact contents depicted on them (Table 2). The FDA, Ghana has adopted the Codex

Guideline on Nutrition labeling and the results from Table 2 elucidates the point that nutritional labelling is a voluntary act in Ghana.

Table 2 : Data representation of declared and undeclared nutrition fact labelling

PRODUCT CATEGORY	NUTRITION LABELLING	
	Declared	***Undeclared***
Dairy	12	22
Fish	2	6
Cereals	7	9
Confectionery	3	17
Peas	2	0
Total	**32.5 %**	**67.5 %**

Although Ghana and some other countries have adopted the voluntary nutrition labelling, it was recorded from literature that countries such as Canada (Health Canada, 2010) and the United States of America (NLEA, 1990) as well as several other countries have adopted the mandatory nutrition fact declaration act.

4.2 Accuracy of declared protein content

The actual amount of nutrition in a product is bound to vary as compared to the value declared on a label. Causes of deviation have been attributed to the source of value (values derived from literature or calculated by recipe instead of analysis), variation in raw materials, effects of processing, nutrient stability, storage conditions, storage time and other factors.

From this study, the focus on potential causes of deviation was on product category and product net weight. Table 3 summarizes the discrepancy between the stated and laboratory analyzed protein contents of the products. As depicted in Table 3, the difference between the mean analyzed protein and the declared protein of the prepackaged food products were stipulated as the protein error. The most commonly used protein tolerance limit (≥ 80%) was used to ascertain the protein error deviation from the tolerance limit (Table 3).

Table 3: Declared protein content deviation from commonly used tolerance limit (≥ 80%).

CATEGORY	NET.WT.(g)	DECLARED PROTEIN(g / 100 g)	MEAN ANALYZED PROTEIN(g / 100g)	DECLARED PROTEIN ERROR	PERCENTAGE ERROR DEVIATION FROM TOLERANCE LIMIT(≥ 80%)
Dairy	37	13	13.94	0.94	107.23
Dairy	23	23.5	15.35	-8.15	65.32
Dairy	40	12	8.74	-3.26	72.83
Dairy	200	22	16.19	-5.81	73.59
Dairy	20	11.7	6.43	-5.27	54.96
Dairy	14	18	18.4	0.40	102.22
Dairy	40	14.2	11.27	-2.93	79.37
Dairy	400	24.5	19.14	-5.36	78.12
Dairy	78	7.3	6.21	-1.09	85.07
Dairy	170	4.1	2.890	-1.21	70.49
Dairy	160	7.0	3.94	-3.06	56.29
Dairy	160	8.2	9.22	1.02	112.44
Fish	425	11	11.46	0.46	104.18
Fish	90	12	5.33	-6.67	44.42
Cereals	500	13.5	4.39	-9.11	32.52
Cereals	500	14	15.17	1.17	108.36
Cereals	500	6.6	14.77	8.17	223.79
Cereals	500	12	17.85	5.85	148.75
Cereals	1000	10.3	7.99	-2.31	77.57
Cereals	250	6.1	13.48	7.38	220.98
Cereals	85	10.3	11.28	0.98	109.51
Confectionery	36	6.1	6.46	0.36	105.90
Confectionery	71	7.3	5.70	-1.60	78.08
Confectionery	23	7.0	9.05	2.05	129.29
Peas	300	5.5	1.54	-3.96	28.00
Peas	200	4.7	2.06	-2.64	43.83

The accuracy of the declared protein contents of the prepackaged food product samples were calculated as the difference between the duplicated mean analyzed protein and the declared protein (mean from three samples of same declared protein content) and represented as declared protein error. The declared protein errors were then computed to their respective percentages as percentage errors. Using the most commonly used tolerance limit of ≥80% as a reference limit, Dairy products recorded the highest number of products below the limit (≥80%) and Cereal products recorded the highest number of products within the limit (≥80%) as illustrated in Figure 1.

The high recordings of the Dairy products under the below tolerance limit, explains a likelihood of misrepresentation or a likelihood of adulteration since Dairy products out of all five product categories (Dairy, Fish, Cereals, Confectionery, Peas) are the most easily adulterated food products which are mostly adulterated with urea, formalin, ammonium sulphate and several others. These adulterants are likely to be lost in the product over time or during sample preparation for testing. It can therefore by said that product category stands to be a factor to the variations in protein contents between the mean analyzed protein contents and the declared protein contents of the products.

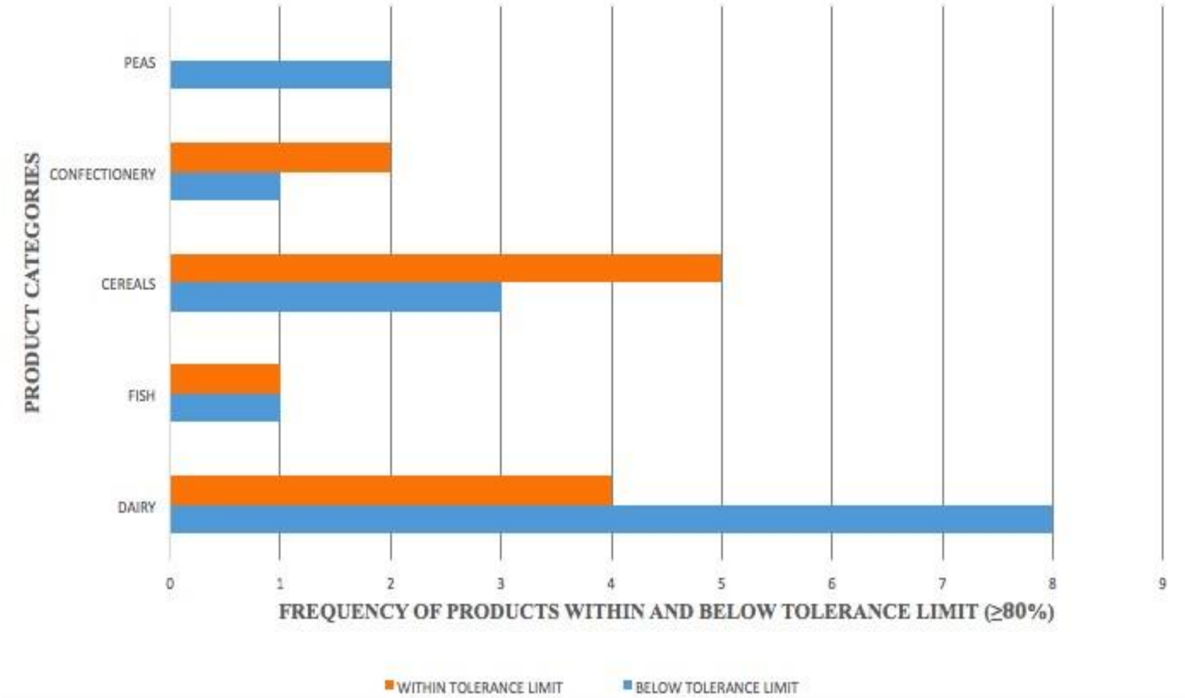

Figure 1: Declare protein content deviation from commonly used tolerance limit **(**$\geq$ **80**%**).**

4.3 Fuzzy Modelling Interpretation of data

Fuzzy logic and modelling was run in MATLAB (2013) fuzzy logic box where the product category and product net weight (input variables) were mapped to their confident quotients (Figure 2).

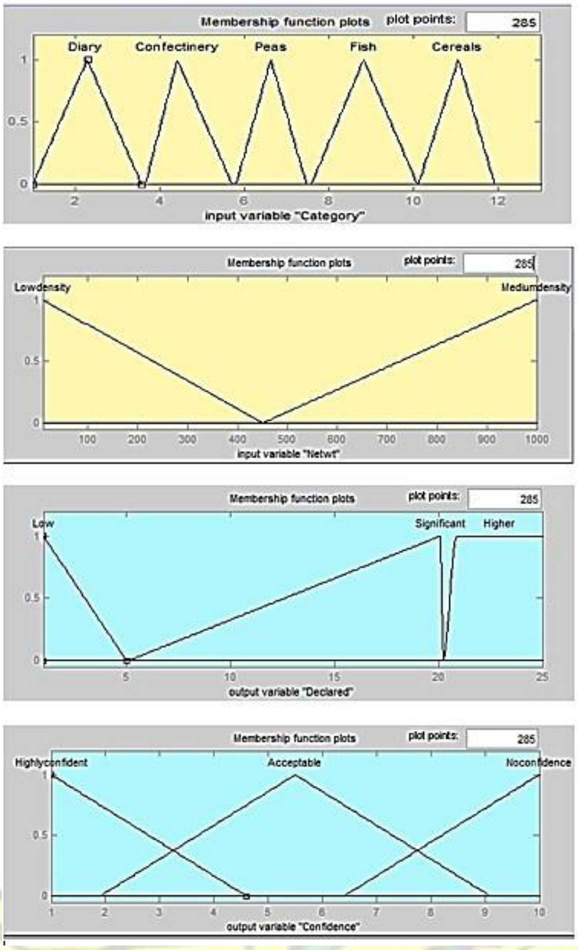

Figure 2: Plots of input and output variables against membership functions and resultant ranges.

Simulations at low and high net weights of the product categories were performed at 90 %, 95 % and 99 % confident quotients (Appendix 3, Appendix 4, Appendix 5, Appendix 6 and Appendix 7). Results from the stimulation is as illustrated in Table 4 and Table 5.

Table 4: Simulation data of the five product categories at *low* net weights (g)

PRODUCT CATEGORY	LOW NET WT.(g)	CONFIDENT QUOTIENT
DAIRY	61.7	1
FISH	22.3	1
CEREALS	61.7	9.28
CONFECTIONERY	12.5	5.32

PEAS	66.6	1

Table 5: Simulation data of the five product categories at *high* net weights (g)

PRODUCT CATEGORY	HIGH NET WT.(g)	CONFIDENT QUOTIENT
DAIRY	825	4.42
FISH	934	5.5
CEREALS	948	1.0
CONFECTIONERY	934	5.5
PEAS	948	5.5

From the stimulations (Table 4 and Table 5), most of the products (Dairy, Fish, Confectionery and Peas), exhibited higher degree of confidence at low net weights as compared to their respective high net weight products. This can further be explained that, the higher the degree of confidence, the more accurate the declared protein contents of the various products are to their mean analyzed protein results.

It can therefore be stated that, product net weight is a variation factor (the lower the net weight, the higher the degree of confidence and the higher the net weight, the lower the degree of confidence).

A confirmatory research on a previous systematic review by Menayang (2016) on the accuracy of total protein declared on some Brazilian whey protein supplement labels to the actual protein content resulted in only three out of the ten products tested to have had the same protein quantity as the declared protein. Two reasons he stated for the likelihood for the existence of the discrepancy were the technology used for the manufacturing of the products or the protein composition of the cow milk used for obtaining the whey which could have been influenced by the breed, lactation stage or diet. Menayang's observation is premised on the fact that the protein composition of the cow milk for obtaining the whey could be likelihood for the existence in the discrepancy. The protein composition of the cow milk categorizes the whey protein supplement as Dairy. Hence it can be said that, from his research, product category was a potential factor of the variation in protein content declared from the analyzed protein content.

The output variables of the fuzzy logic analysis (Figure 3) on the expression of the effect on the product category and product net weight on the degree of accuracy (Confidence Quotient) reveals variations at low and high net weights

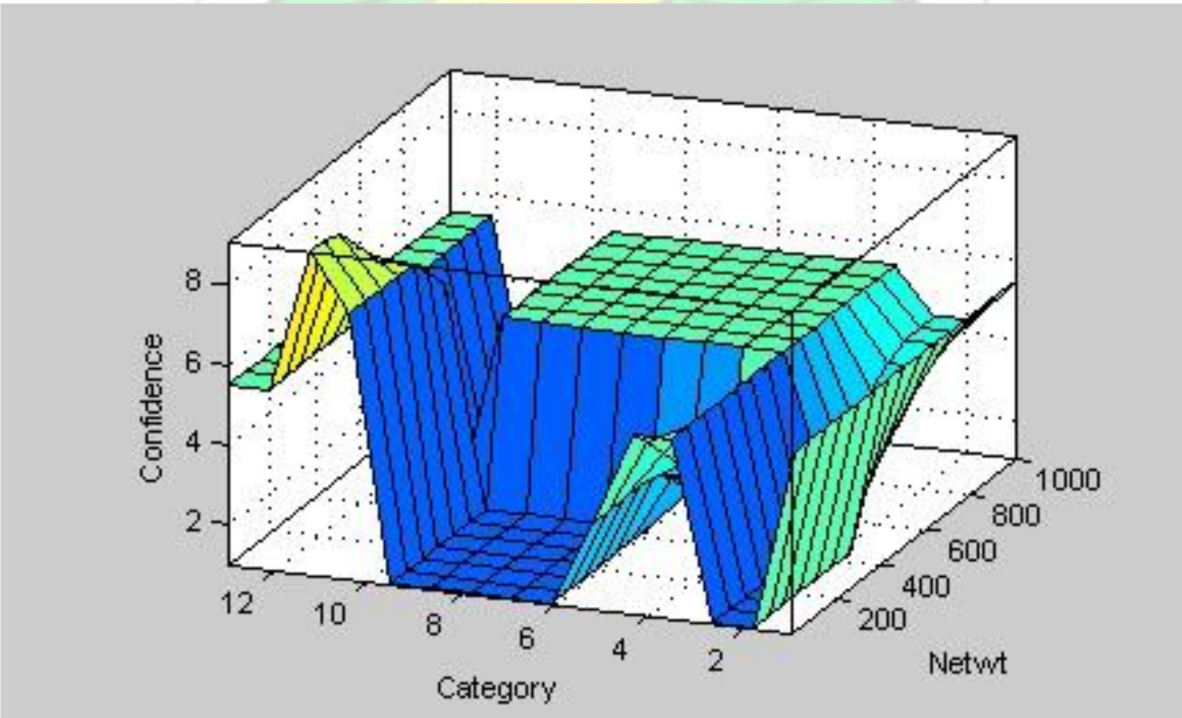

Figure 3: Surface view of the impact of two inputs (product category and product net weight) and output (confidence quotient).

The surface viewer of the model (Figure 3) is a graphical interface that shows the output surface for the output variable (Confidence Quotient) as mapped with their corresponding input variable (product category and product net weight). The curve represents a two-inputs and one-output case in one plot which explains the mapping. The degree of (output variable) ranges from 1-10, where 1 depicts the highest degree of confidence and 10 depicts the lowest degree of confidence. The net weights (an input variable) ranges from 0 – 1000 g (Figure 3). Figure 2 which illustrated the plotting of the input variables and output variable against their membership functions and resultant ranges revealed numerical figures from the fuzzy analysis as Dairy (0-4), Confectionery (4-6), Peas (6-8), Fish (8-10) and Cereals (10-12). It can be interpreted from the surface view model (Figure 3) that, Peas and Fish products (6-10) attained high degree of confidence (1) at low net weight (0-400 g), whereas Dairy (2-6) and confectionery (4-6) attained a low degree of confidence (4) at low net weight(0-400g), followed by Cereals (10 -12) at a degree of confidence of 8 and at low net weight (0 - 400g). It can also be explained that, all five (5) product categories (Dairy, Confectionery, Cereals, Peas and Fish) attained low degree of confidence between a range of 6 - 8 at high net weights ranging from 600 g -100 g. This explains inaccuracy of protein declaration of most of the products at higher net weights.

Literature review on compliance between values reported in food labels and values obtained from laboratory measurements in Iran confirms inaccuracy of nutrition facts labels, and that food labels of a remarkable number of evaluated foods were significantly different from their true values (Pasdar *et al.*, 2017). This with several other researches on nutrition fact authentication explains that there is always a likely for the declared nutrient contents of prepackaging food product to deviate from its actual nutrient content. Findings from this research explain clearly that the product category and net weight could be some of the several factors that may cause the actual value of prepackaging food products to varying from their declared nutrient values.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The relationship between the two inputs variables (product category and product net weight) and their corresponding output variable (confidence quotient) in Figure 3, revealed the impact of both product category and product net weight on the accuracy of the protein contents declared (degree of confidence). All five products (Dairy, Confectionery, Cereals, Fish and Peas) revealed levels of deviation from the ≥80% tolerance limit (Figure 1). Dairy products recorded the highest deviation at a frequency of 8 and Peas recorded the minimum deviation at a frequency of 1. Based on the findings of this study, all the declared protein contents on the five product categories deviated from their corresponding analyzed protein contents which explains inaccuracy of the declared protein of most of the products.

If tolerances were to be defined in Ghana (either legislation or guideline), nutrition labelling could have been improved which would also aid consumers in selecting healthy diets. It is clear that from this study, several nutrient levels could vary from their declared nutrient values on a product label, but the significance of the variance is, largely dependent on the principal tolerance acceptance level when applied to the results which makes it essential for the Food and Drugs Authority, Ghana to develop guidance on tolerances to the regulation of compliance of the nutrient values declared on a food label.

5.2 Recommendations

This research is intended to be a baseline for subsequent research work on the accuracy of the nutrient declaration on prepackaged food products. Subsequent research could be undertaken by policymakers and researchers to assess the inaccuracy of nutrition fact declaration.

Under routine surveillance program, the FDA, Ghana should adopt nutrition fact verification procedure in regulating the accuracy of the nutrient values on nutrition labels which are bound to vary according to a country's or region's tolerance control of compliance of declared nutrient values on prepackaged food labels on the Ghanaian market. It is therefore very essential for the FDA to develop guidance on tolerances to the control of compliance of nutrient values declared on a prepackaged food label.

Specific research on effect of product category and product net weight on other nutrients should be undertaken to bring out better understanding of the key parameters that can cause variations in nutrition fact declaration. The results presented in this research offers a prediction tool to understand the likelihood of inaccuracy of declared nutrient contents on prepackaged food products on the market using protein as a test factor and it could be used as a baseline study for policy makers in Ghana to monitor the nutrition fact information declared by manufacturers. It is hoped that this research shall provide alerting information which can be used by policy makers in Ghana and in most countries to draft new policies related to the accuracy of the nutrition label in the future.

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APPENDICES

Appendix 1: Tolerance limits for energy and nutrient declaration on nutrition labels.

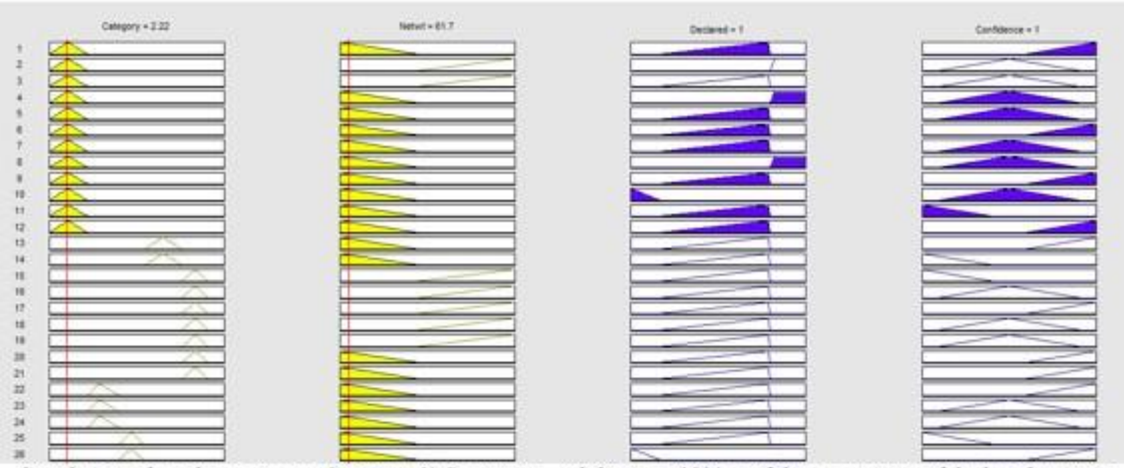
	U.S.A.	Canada	Thailand [1]	Taiwan	Korea	Japan	Singapore	The Mainland (proposed)
Energy	≤ 120%	≤ 120%	± 20%	± 20%	≤ 120%	± 20%	≤ 120%	± 20%
Protein	Added: ≥ 100% Other cases: ≥ 80%	≥ 80%	± 20%	± 20%	≥ 80%	± 20%	Added: ≥ 100% Natural: ≥ 80%	± 20%
Carbohydrate	≥ 80% (total and other carbohydrate)	≥ 80% (total carbohydrate and starch)	± 20%	± 20%	≥ 80%	± 20%	≤ 120%	± 20%
Total Fat	≤ 120%	≤ 120%	± 20%	± 20%	≤ 120%	± 20%	≤ 120%	± 20%
Saturated Fat	≤ 120%	≤ 120% (sat fat, transfat)	± 20%	± 20% [2]	≤ 120%	± 20%	≤ 120% [2]	± 20%
Other Fatty Acids (except transfat)	≥ 80% (Monounsat, Polyunsat fatty acids)	≥ 80% (Monounsat, Polyunsat, omega-3, omega-6 fatty acids)	---	---	---	---	---	---
Sodium	≤ 120%	≤ 120%	± 20% (?)	± 20%	≤ 120%	± 20%	≤ 120%	≤ 120%

Source – Thai FDA

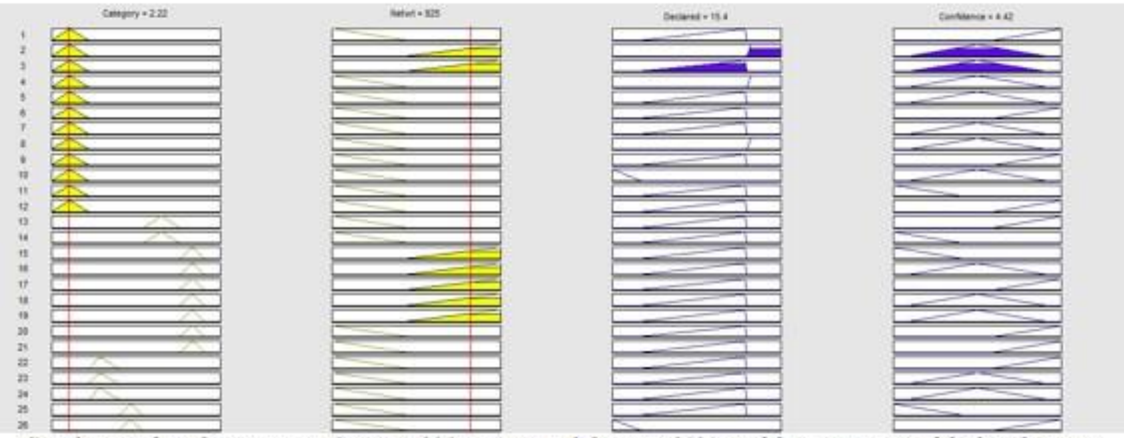
Appendix 2: If-then rules showing 26 rules truth reference table.

1. If (Category is Dairy) and (Net wt. is low-density) then (declared is significant)(Confidence is No confidence)
2. If (Category is Dairy) and (Net wt. is medium density) then (declared is higher)(Confidence is Acceptable)
3. If (Category is Dairy) and (Net wt. is medium density) then (declared is significant)(Confidence is Acceptable)
4. If (Category is Dairy) and (Net wt. is low-density) then (declared is higher)(Confidence is Acceptable)
5. If (Category is Dairy) and (Net wt. is low-density) then (declared is significant)(Confidence is Acceptable)
6. If (Category is Dairy) and (Net wt. is low-density) then (declared is significant)(Confidence is No confidence)
7. If (Category is Dairy) and (Net wt. is low-density) then (declared is significant)(Confidence is Acceptable)
8. If (Category is Dairy) and (Net wt. is low-density) then (declared is higher)(Confidence is Acceptable)
9. If (Category is Dairy) and (Net wt. is low-density) then (declared is significant)(Confidence is No confidence)
10. If (Category is Dairy) and (Net wt. is low-density) then (declared is low)(Confidence is Acceptable)
11. If (Category is Dairy) and (Net wt. is low-density) then (declared is significant)(Confidence is Highly confident)
12. If (Category is Dairy) and (Net wt. is low-density) then (declared is significant)(Confidence is No confidence)
13. If (Category is Fish) and (Net wt. is low-density) then (declared is significant)(Confidence is No confidence)
14. If (Category is Fish) and (Net wt. is low-density) then (declared is significant)(Confidence is Highly confident)
15. If (Category is Fish) and (Net wt. is low-density) then (declared is significant)(Confidence is highly confident)
16. If (Category is Cereals) and (Net wt. is medium-density) then (declared is significant)(Confidence is acceptable)
17. If (Category is Cereals) and (Net wt. is medium-density) then (declared is significant)(Confidence is no confidence)
18. If (Category is Cereals) and (Net wt. is medium-density) then (declared is significant)(Confidence is acceptable)
19. If (Category is Cereals) and (Net wt. is medium-density) then (declared is significant)(Confidence is acceptable)
20. If (Category is Cereals) and (Net wt. is low-density) then (declared is significant)(Confidence is no confidence)
21. If (Category is Cereals) and (Net wt. is low-density) then (declared is significant)(Confidence is no confidence)
22. If (Category is Confectionary) and (Net wt. is low-density) then (declared is significant)(Confidence is no confidence)
23. If (Category is Confectionary) and (Net wt. is low-density) then declared is significant)(Confidence is Acceptable)
24. If (Category is Confectionary) and (Net wt. is low-density) then (declared is significant)(Confidence is Acceptable)
25. If (Category is Peas) and (Net wt. is low-density) then (declared is significant)(Confidence is no confidence)
26. If (Category is Peas) and (Net wt. is low-density) then (declared is low)(Confidence is no confidence)

Appendix 3: Simulations of product category Dairy at 99% and 95% confident quotient representing low and high net weight respectively.

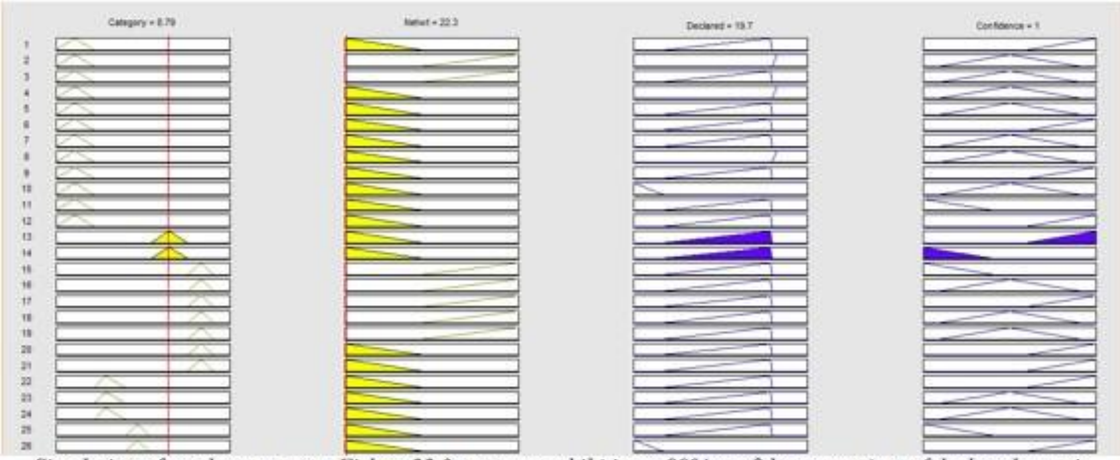


Simulation of product category Dairy at 61.7 g net wt., exhibiting a 99% confidence quotient of declared protein content of 1g.

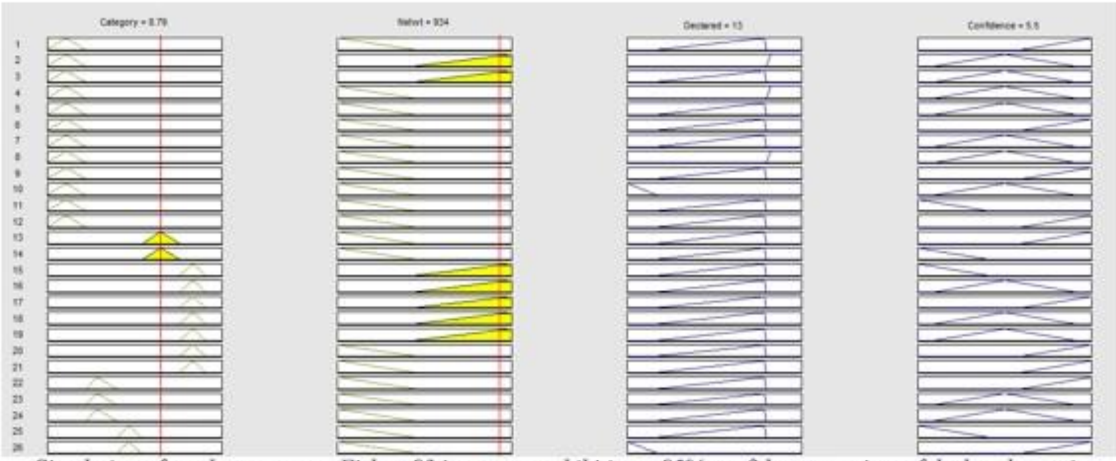


Simulation of product category Dairy at 825g net wt., exhibiting a 95% confidence quotient of declared protein content of 15.4g.

Appendix 4: Simulations of product category Cereal at 90% and 99% confidence quotient representing low and high net weight respectively.

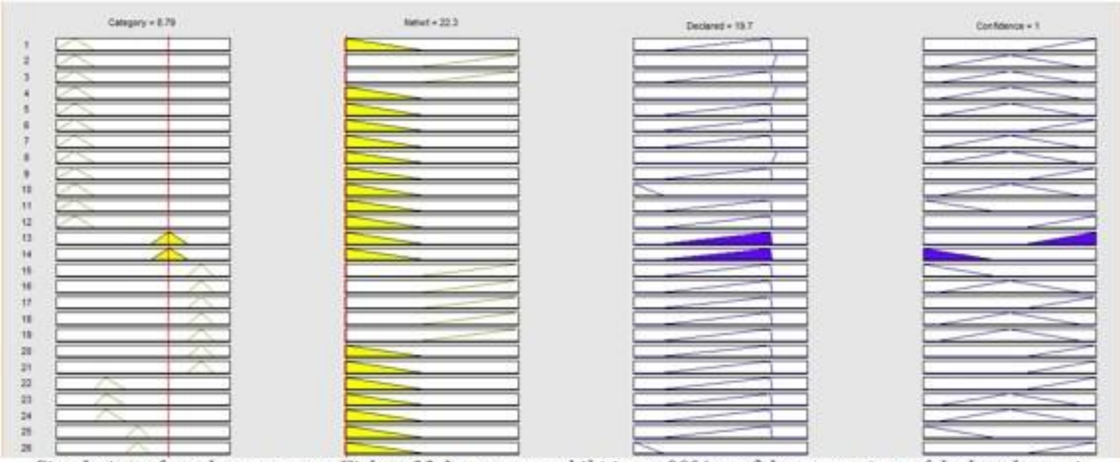


Simulation of product category Fish at 22.3g net wt., exhibiting a 99% confidence quotient of declared protein content of 19.7g.

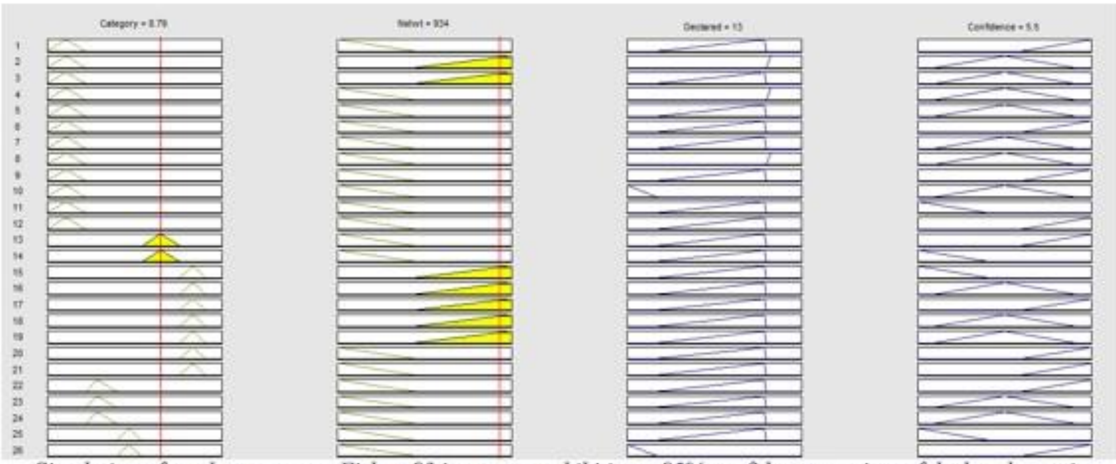


Simulation of product category Fish at 934g net wt., exhibiting a 95% confidence quotient of declared protein content of 13g.

Appendix 5: Simulations of product category Fish at 99% and 95% confident quotient representing low and high net weight respectively.

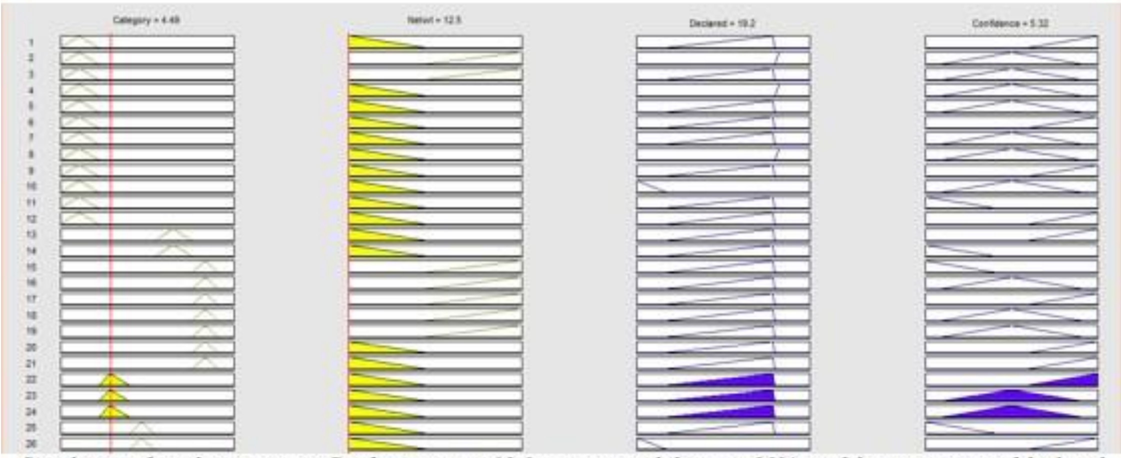


Simulation of product category Fish at 22.3g net wt., exhibiting a 99% confidence quotient of declared protein content of 19.7g.

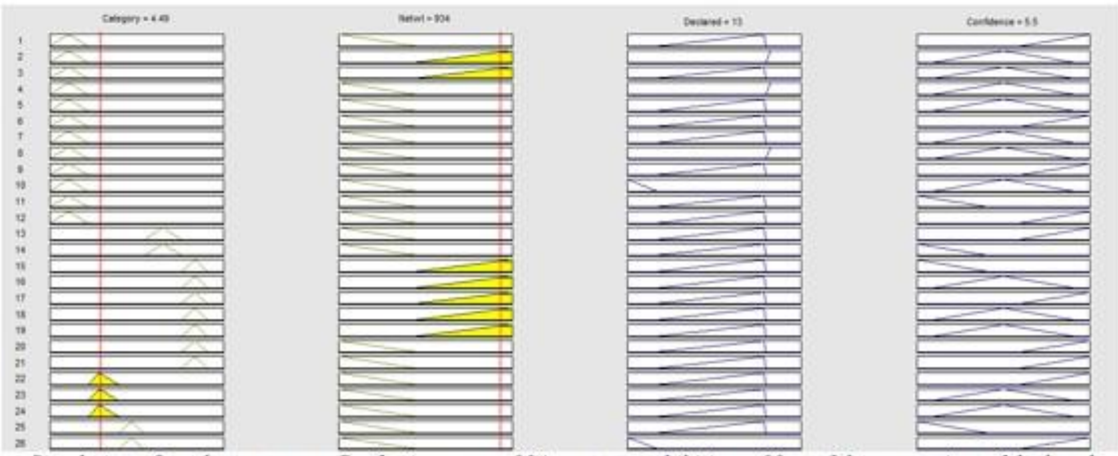


Simulation of product category Fish at 934g net wt., exhibiting a 95% confidence quotient of declared protein content of 13g.

Appendix 6: Simulations of product category *Confectionery* at 95% and 99% confidence quotient representing low and high net weight respectively

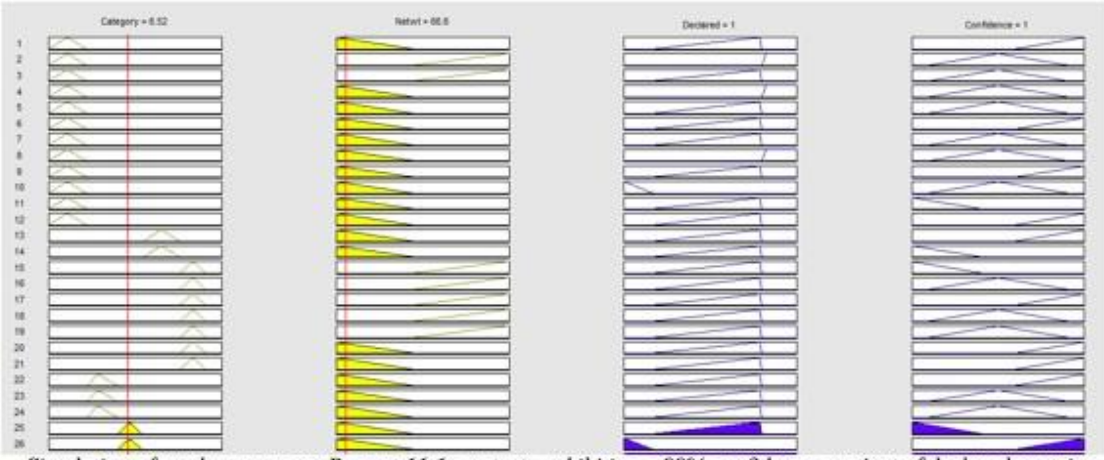


Simulation of product category Confectionery at 12.5 g net wt., exhibiting a 95% confidence quotient of declared protein content of 19.2g.

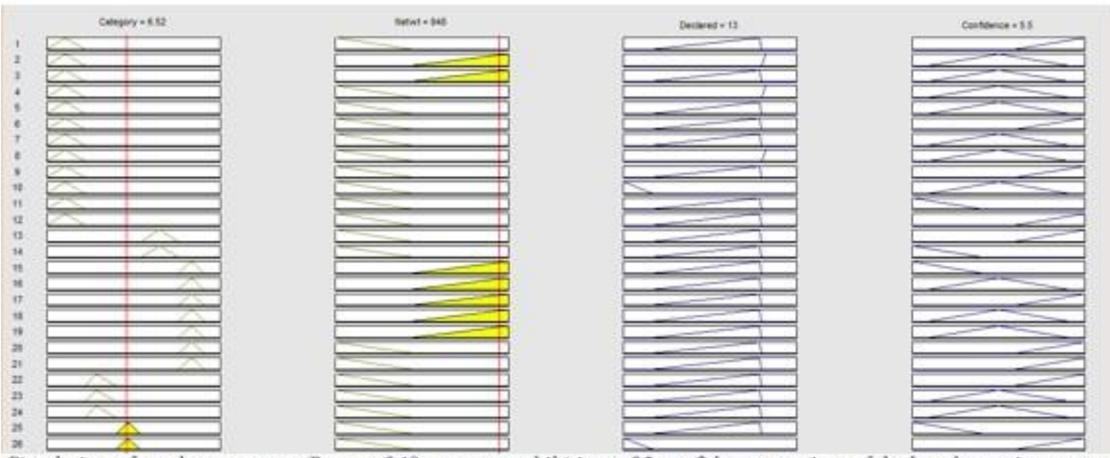


Simulation of product category Confectionery at 934g net wt., exhibiting a 99 confidence quotient of declared protein content of 13g.

Appendix 7: Simulations of product category Peas at 99% and 95% confidence quotient representing low and high net weight respectively.



Simulation of product category Peas at 66.6 g net wt., exhibiting a 99% confidence quotient of declared protein content of 1g.



Simulation of product category Peas at 948g net wt., exhibiting a 95 confidence quotient of declared protein content of 13g.