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A quality cost model for food processing plants

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Abstract

A HACCP-based system is a recognized food safety management program aiming at the control of all the factors affecting food safety. It is also possible to add factors related to food quality. To evaluate the effectiveness of a quality system, a realistic estimate of quality costs is essential. The purpose of this work is to develop a mathematical model for the calculation of the costs associated with a specific quality level due to HACCP-based system implementation. Experimental results obtained at Argentinean hake freezing plants (*Merluccius hubbsi)* are presented and compared with those calculated with the proposed model. The proportion of variance explained by the model was 0.903 for total quality costs; proving its optimum performance.

Keywords: HACCP; Quality costs; Food; Fish freezing plant

1. Introduction

The HACCP system constitutes a food safety management system based on a scientific, systematic, rational, multi-disciplinary, and cost-effective approach, controlling safety problems in food processing, especially for high-risk foods such as meat, poultry or fishery products (Deodhar, 2003; Huss, 1995; Jensen & Unnevehr, 2000; Ziggers, 2000; Zugarramurdi, Parin, Gadaleta, Carrizo, & Lupin, 1999). Properly applied, there is no other system or method able to provide the same degree of safety and quality assurance at a lower cost (Huss, 1994; Jensen & Unnevehr, 2000).

Few studies have addressed the costs and benefits of HACCP implementation in the food business. As a consequence, it is difficult to evaluate the extent to which costs and benefits to businesses act as an incentive/disincentive to the further adoption of HACCP within the food sector (Henson, Holt, & Northen, 1999).

Many food processing plant managers feel that quality programs decrease plant productivity, thereby making such programs a costly "luxury". This may be true for an initial implementation period, but it is not indefinitely true (Bonnell, 1994). A study of HACCP adoption in the UK dairy industry shows that firms are adopting HACCP in order to meet customer as well as legal requirements and to gain improvements in operating efficiency (Henson et al., 1999).

To evaluate the effectiveness of a HACCP-based system, a realistic estimate of quality costs is essential. Quality costing activities can be carried out to gain top management commitment, direct improving efforts, and, above all, estimate the benefits of quality improvement (Huss, 1995; Saita, 1991).

Quality costing is the first step for preparing a case for Total Quality Management (TQM) initiative. Moreover, a realistic estimation of quality costs is an essential element of any TQM initiative. However, only a minority of organizations uses formal quality costing methods because quality costs are hard to measure.

This work aims to develop a mathematical model for the calculation of the costs associated with a specific quality level due to HACCP-based system implementation. Experimental results obtained at Argentinean hake freezing plants (*Merluccius hubbsi*) are presented and compared with those calculated with the proposed model.

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2. Model and assumptions

Quality-related costs are divided into: prevention costs, appraisal costs and failure costs (PAF model), so stated by Feigenbaum (1974).

The proposed Quality Cost Model consists of two sub-models. The controllable costs sub-model is made up of prevention costs (P_i) and appraisal costs (A_i). Controllable costs are those that the manager or decision maker can control directly so as to assure product quality. They are associated with investments in the non-conformances prevention and product appraisal for conformances to requirements. Each component of the controllable costs is affected by coefficient Ω that depends on quality levels.

The sub-model of failure costs consists of those expenses incurred by the firm as a consequence of all its activities associated with defective products failing to meet quality requirements, prior or after delivery to the customer. In this category both internal and external failures are included. Failure costs were evaluated as direct company losses.

Quality costs are analysed following the Pareto principle: few factors account for the largest portion of costs (Sandholm, 1987). Generally speaking, in order to estimate quality costs, good judgment is necessary to avoid excessive attention to minor items that, even if severely over-or underestimated, will not have a significant effect on the overall estimate. The model assumes that quality costs can be calculated from eleven different components, as shown in Table 1.

To calculate the quality costs associated with a specific product quality level, the relationship between the raw material and final product quality should be known. The chemical, physical, biological and sensory quality characteristics of the raw material should be studied together with the product quality. The proposed model was developed considering the full quality range within the limits required by sanitary and safety regulations for both raw materials and products.

Table 1
List of categories and elements of quality costs

Controllable costs	Resulting costs
Prevention costs	*Internal failure costs*
P_1. Design, development and implementation of a quality assurance plan	F_1. Scraps, reprocessing or spoilage
P_2. Quality training programs for suppliers and production personnel	F_2. Low labour productivity and low process yield
P_3. Hygiene and sanitation of the plant	F_3. Inefficient use of plant capacity
P_4. Preventive maintenance and additional supervision	
Appraisal costs	*External failure costs*
A_1. Receipt and control of incoming material	F_4. Claims, rejected and recalled products
A_2. Sampling and laboratory analysis	
A_3. In-process inspection	

It is also important to recognize the variations in raw material quality levels and their effects on process yield and labour productivity in the food processing plant under analysis.

Quality, market, and production parameters used in the proposed model are defined in Table 2.

2.1. Controllable costs sub-model

2.1.1. Prevention costs

In food processing plants, the most representative prevention costs are the following:

P_1. Design, development and implementation of a quality assurance plan. Quality planning costs, C_{P_1}, include the expenses arising from designing the quality plan and audit system, from the design and development of quality measurements as well as from the purchase of control equipment. Properly applied and established, the great advantage of the HACCP system is that the main effort of quality assurance is directed towards the Critical Control Points and away from endless final product testing (Huss, 1994; Jensen & Unnevehr, 2000).

C_{P_1} can be estimated as follows:

$$C_{P_1} = \Omega_{P_1} I_F / dK \quad (1)$$

Before HACCP is implemented, food plants must follow prerequisite programs such as GMPs, and a Sanitary plan (US Food & Drug Administration & Institute of Food Technologists, 2001).

The coefficient Ω_{P_1} can be estimated as a percentage of the fixed investment (I_F), and it represents about 3–5% of the fixed investment for a food plant working at very high

Table 2
Quality, market and production parameters

Quality parameters	Q_m = raw material quality (dimensionless parameter) Q_p = product quality (dimensionless parameter) $Y^*_{Q_m}$ = yield for optimum quality level Q^*_m (kg product/kg raw material) $X^*_{Q_m}$ = productivity for optimum quality level Q^*_m (kg product/h-worker) Nscp = number of sanitation control points Nccp = number of critical control points
Market parameters	P_{Q_m} = purchase price of raw material (US$/kg) P_{Q_p} = selling price for quality level Q_p (US$/kg) $P^*_{Q_p}$ = selling price for optimum quality level Q^*_p (US$/kg)
Production parameters	d = number of working days per year K = daily production (kg product/day) R_i = raw material sampling inspection rate (kg raw material/h) S = average labour rate for trained workers (US$/h) I_F = total fixed investment (US$) X_{Q_m} = productivity for quality level Q_m (kg product/h-worker) Y_{Q_m} = yield for quality level Q_m (kg product/kg raw material) L = total labour cost (US$/kg product)