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Measuring the effectiveness of the HACCP Food Safety Management System

Dimitrios P. Kafetzopoulos [a,*], Evangelos L. Psomas [a,1], Panagiotis D. Kafetzopoulos [b,2]

[a] Department of Business Administration of Food and Agricultural Enterprises, University of Western Greece, George Seferis Str., GR-301 00 Agrinio, Greece
[b] Department of Food Technology, Technological Educational Institution of Larisa, Temponera Str., GR-43100 Karditsa, Greece

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ABSTRACT

The Hazard Analysis and Critical Control Point (HACCP) is a Food Safety Management System (FSMS) that is recognized in the international food safety community as a world wide guideline for controlling food borne safety hazards. Nevertheless, the availability of a diagnostic instrument to assess the performance and effectiveness of the FSMS is rather restricted; therefore, the food sector needs an instrument to measure the effectiveness of FSMS. Based on the HACCP objectives identified in the literature, in this research, HACCP effectiveness is defined as the degree of achieving its objectives. A measurement instrument is developed and then empirically validated through collecting preliminary data from 335 Greek food enterprises. After testing the assumptions of multivariate analysis, Exploratory Factor Analysis as well as first and second order Confirmatory Factor Analysis are applied. This study reveals the three-dimensional nature of the HACCP objectives (hazard identification, hazard assessment and hazard control). Further analysis of the data also reveals a valid latent factor reflecting the successful achievement of the HACCP objectives, namely "HACCP effectiveness". This measurement instrument can be used by a food company as a self assessment tool and a benchmarking tool. In doing so, suitable strategies can be selected in order for a food company to allocate resources, increase HACCP effectiveness and improve its product safety.

1. Introduction

The food and drink industry is responsible for producing not only safe foods but also for demonstrating in a transparent manner how food safety has been planned and implemented. This is done through the development of a Food Safety Management System (FSMS) (Motarjemi & Mortimore, 2005). Major financial, technological and managerial investments have been conducted in the last 10 years in Europe in order to implement FSMS along the agri-food chain (Jacxsens et al., 2010). Hazard Analysis and Critical Control Points (HACCP) is a Food Safety Management System (Al-Kandari & Jukes, 2011), widely acknowledged as the best method of assuring product safety while becoming internationally recognized as a tool for controlling food borne safety hazards (CAC, 2003; Khandke & Mayes, 1998; Wallace, Powell, & Holyoak, 2005). HACCP is a systematic approach to the identification, evaluation, and control of hazards in those steps in food manufacturing that is critical to food safety (Ropkins & Beck, 2000).

Despite the widespread implementation of HACCP in food companies, its effective application has to be investigated (Wallace, Holyoak, Powel & Dykes, 2011). A variety of studies have studied the impact of implementing an FSMS without necessarily examining what ensures effective implementation (Mensah & Julien, 2011). The actual contribution and the effectiveness of the HACCP implementation have yet to be proved. Certifying the HACCP FSMS does not guarantee the optimum level of managing food safety hazards and consequently absolute food safety and the quality of the end product (Fotopoulos, Kafetzopoulos, & Psomas, 2009). Authors of technical and scientific articles (Azanza & Zamora-Luna, 2005; Henroid & Sneed, 2004; Taylor & Taylor, 2004; Vela & Fernandez, 2003) started to doubt the effectiveness of HACCP, especially in small and medium sized enterprises (SMEs) and began to search for potential causes, failures and reduction of the system's effectiveness. Taylor and Taylor (2004) state that there has been little work on done fully understanding the conditions under which HACCP effectiveness is fully achieved, which will help companies identify intervention strategies with regard to the improvement of their performance. Baş Yüksel & Çavusoglu (2007) suggest the

* Corresponding author. Tel.: +30 6945584404; fax: +30 2641074168.
E-mail address: dimkafe@yahoo.gr (D.P. Kafetzopoulos).
[1] Tel.: +30 6945584404; fax: +30 2641074168.
[2] Tel.: +30 2441041082; fax: +30 2441041080.

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effective implementation of HACCP be further explored, while Domenech, Escriche & Martorell (2008) point out that the HACCP system has inherent failure rates due to unavoidable and inherent process variation (i.e. deviation from the normal performance) for which no specific causes can be identified.

The approach taken by government agencies (Kvenberg & Schwalm, 2000) and the work with multinational companies has identified a need for standardized tools for the assessment of HACCP effectiveness. There is a lack of models to measure the effectiveness of the HACCP plan accounting simultaneously for the role of both the control and monitoring systems at the critical control points (Domenech et al., 2008). Whilst positive results may be expected when the HACCP system has been applied correctly, it is also necessary to establish ways of measuring HACCP effectiveness that are not based solely on retrospective analysis of outbreak data. Many authors (Van der Spiegel, Luning, Ziggers, & Jongen, 2003, 2004; Wallace et al., 2005) argue that the availability of a diagnostic instrument to assess the performance and effectiveness of the FSMS is rather restricted, therefore, the food sector needs an instrument to measure the effectiveness of FSMS (Van Der Spiegel, Luning, De Boer, Ziggers, & Jongen, 2006). For any assessment programme to generate useful information, criteria to evaluate the effectiveness of the HACCP plan and its application need to be established, and assessment methods to be identified (Wallace et al., 2005). Reviewing the literature, several suggestions have also been made with regard to the need for measuring HACCP effectiveness (Cormier, Mallet, Chiasson, Magnusson, & Valdimarsson, 2007; Doménech, Amorós, Pérez-Gonzalvo, & Escriche, 2011; Luning, Bango, Kussaga, Rovira, & Marcelis, 2008; Mortimore, 2000; Sampers, Toyofuku, Luning, Uyttendaele, & Jacxsens, 2012; Van der Spiegel, Luning, Ziggers, & Jongen, 2005; Zugarramurdi, 2007). A number of studies (Merican, 2000; Torres, 2000) have used frameworks that include checklists and guidance for auditors. However, there is limited consistency and no internationally agreed approach. Previous studies have also produced auditing practice guidelines and/or identified key points to cover (Mortimore, 2000; Mortimore & Wallace, 1998; WHO, 1998). Recently, studies have developed a Food Safety Management System diagnostic instrument (FSMS-DI) (Luning et al., 2009) and a microbial assessment scheme (MAS) (Jacxsens et al., 2009) to assess the performance of a company specific FSMS, but none of these studies measure the effectiveness of the HACCP based on its prescribed safety targets.

In order to fill this gap, this study aims at developing an instrument for measuring the effectiveness of the HACCP system in connection with the extent to which its prescribed safety targets are met and the validation of this instrument in the food manufacturing sector. Thus, this paper goes beyond previous research, drawing from the food safety theory literature. For this reason, firstly, the concept of “HACCP effectiveness” is introduced and secondly, a measurement instrument for HACCP effectiveness is developed, based on the indicators of the HACCP objectives, in order to facilitate understanding of how the system operates. The research is based on a unique, comprehensive, longitudinal dataset from 335 Greek food organisations. Through Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (first and second order CFA), the measurement instrument is then empirically validated. We believe that the Greek food companies’ experience in implementing an HACCP-based FSMS can offer useful information to organisations, government officials and policymakers in other countries of the world. In particular, the conceptual framework that is tested in this study will help food companies to improve their various safety management and organizational practices.

The next section is concerned with the conceptual foundation and the formulation of hypotheses. A research model and the related hypotheses pertaining to the relationships among its constructs are offered. Section 3 describes the research methodology that was followed, including the development of the survey instrument and the sample of the study, while section 4 describes data analysis and presents the related results. The findings related to the testing of the structural model and the implications of this work for both researchers and practitioners are discussed in section 5. Finally, the paper closes with the conclusion and proposals for possible future research.

2. Conceptual foundation and hypotheses formulation

The success and effectiveness of the HACCP plan in preventing food borne diseases and reducing food safety risks to an acceptable level depend on its correct implementation and application (FAO/WHO, 2007; Kök, 2009; Lawley, 2007). When a food company adopts an HACCP system, it has to assure its performance and assess that the system is implemented effectively (CAC, 2008; Cormier et al., 2007; Domenech et al., 2008). But what is “effectiveness” of the HACCP? Stakeholders such as the government, food safety agencies and/or sector organizations are interested in this question. However, not many studies have been published regarding performance measurement of food safety (Jacxsens et al., 2010). The main purpose of HACCP assessment is to establish whether a food company is capable of producing or distributing safe products consistently, i.e. ensuring that the HACCP program is properly implemented and it is effective in maintaining product safety (Ababouch, 2000). So, the assessment approaches of HACCP are needed to demonstrate its effectiveness. The continued auditing and verification of an HACCP system is very important for the development of the HACCP plan (Sperber, 1997). Therefore, Kvenberg and Schwalm (2000) point out that objective and direct measures need to be developed that can be used in order to measure HACCP effectiveness. Nevertheless, regulators and food processors have different perspectives on how to measure its effectiveness. Although these perspectives include checklists and guidance for auditors, there is no accepted approach or common measure methodology available to HACCP practitioners, auditors or regulatory bodies in assuring the effective management of food safety. So, there is a need to establish criteria and assessment methods to identify the effectiveness of the HACCP plan. Wallace et al. (2005) say that it is necessary to establish ways of measuring HACCP effectiveness that are not based solely on retrospective analysis of outbreak data.

2.1. Defining HACCP effectiveness

Dumond (1994), Nakeeb, Williams, Peter Hibberd, and Gronow (1998) and Cianfrani, Tsiakalas, and West (2002) define as effectiveness of a quality management system the extent to which its prescribed quality objectives/targets are met. In addition, Neely, Gregory, and Platts (1995), O’Donnell and Duffy (2002) and Oztas, Guzelsoy, and Tekinkus (2007) also describe “effectiveness” as the degree to which results (output) meet prescribed goals. Thus, it is clear that effectiveness is related to outcomes, consequences and results (Gounaris, Panigyrakis, & Chatzipanagiotou, 2007). Consequently, the effectiveness of an organization or a system (e.g. HACCP) focuses on the extent to which the objectives are met (Redshaw, 2000). So, the HACCP objectives are identified as the key driving forces behind its effective implementation. Psomas, Kafetzopoulos & Fotopoulos (2013) developed an instrument that measures the effectiveness of the ISO 9001 Quality Management System in the food sector related to measures of the three ISO 9001 objectives/goals. Based on this study and in order to assess the effectiveness of the HACCP; firstly, the objectives of the system as well as their indicators should be clearly identified; and secondly, based on them, a reliable and valid measurement instrument needs to be developed. This instrument will quantify the degree to which the HACCP objectives are achieved, in other words HACCP effectiveness.

2.2. Identifying the objectives of the HACCP system and their indicators

Fotopoulos et al. (2009) point out that in the literature there is a general consensus among authors regarding the aims of the HACCP system. Authors such as Sperber (1997), Manning and Baines (2004), Van der Spiegel et al. (2004), Eves and Dervisi (2005), Burlingame and Pineiro (2007), Trienekens and Zuurbier (2008) and Domenech et al. (2008) claim that the food borne hazards' identification, hazards' assessment and hazards' control are the 3 main aims of the HACCP system.

2.2.1. Hazards' identification

CAC (1997) defines as food borne safety hazards "a biological, chemical or physical agent in, or condition of food with the potential to cause an adverse health effect". Panisello, Quantick, and Knowles (1999) point out that incorrect hazards' identification is a disadvantage for the effective implementation of HACCP plan. CAC (2008) states also that food borne safety hazards' identification and their analysis is one of the most important steps in developing an effective HACCP plan. The HACCP team should list all of the hazards that may reasonably be expected to occur at each step according to the scope from primary production, processing, manufacture, and distribution until the point of consumption (CAC, 2005). Hazards' identification is accomplished via Hazard Analysis "the process of collecting and evaluating information on hazards and conditions leading to their presence to decide which are significant for food safety and therefore should be addressed in the HACCP plan" (CAC, 1997; NACMCF, 1997). Untermann (1999) and Satin (2002) mention that during all the food production steps, all the food safety hazards should be clearly identified and registered. The Critical Control Points (CCPs) identification results to satisfactory control and limitation of food hazards leading to reduced defective products (Arvanitoyannis & Mavropoulos, 2000).

2.2.2. Hazards' assessment

After the identification and formation of a list with all food borne safety hazards that may be expected to occur, the HACCP team should next asses the identified hazards. Which hazards are of such a nature that their elimination or reduction to acceptable levels is essential to the production of safe food? The assessment of specific hazards for consumer health caused by a given food item in connection with its specific production and processing technology is a very important element of the HACCP system. It is essential that the hazard analysis should provide a decision as to whether an identified potential hazard is significant for food safety and therefore should be addressed in the HACCP plan (Untermann, 1999). Assessing food safety hazards is a procedure that determines which of the identified food borne hazards are important in order to establish a Critical Control Point (CCP) for their effective control (NACMCF, 1997). In hazards' assessment two factors must be clarified and carefully considered: hazard severity and possibility. Hazard evaluation and assessment through the HACCP plan is considered essential for increasing the system's effectiveness (Satin, 2002). Each hazard analysis has to assess any potential hazard (microbiological, chemical, physical) in all production stages. It has to be decided whether those identified hazards are significant for food safety and preventive measures are called for. At the same time, it has to be evaluated whether hazards can develop during the production process, during storage or during the intended utilization of the food product (Untermann, 1999). Assessment and evaluation of food borne safety hazards of a food company through HACCP plan, is essential to assure that the HACCP system is implemented effectively and it is suitable for its target achievements (Satin, 2002).

2.2.3. Hazards' control

In the next step, control measures have to be defined that can be used to prevent or to eliminate the identified hazards or to reduce them to an acceptable level (Untermann, 1999). The food hazard control system is part of the HACCP plan and it aims at ensuring that the safety limits of the food borne safety hazards will never be exceeded (Mortimore & Wallace, 1996). Without suitable monitoring procedures, control measures do not fulfil the requirements for a CCP. Therefore, the effectiveness of the CCP depends on the accuracy and reliability of both the control and monitoring systems (Domenech et al., 2008; Untermann, 1999). Monitoring system consist of the scheduled measurement or observation of a control measure at a CCP relative to its critical limits. Among other purposes, the monitoring system is used to determine when there is loss of control as a deviation occurs at a CCP or to demonstrate that the product is otherwise safely manufactured (Domenech et al., 2008). Manning and Baines (2004) support the view that HACCP is truly effective only when it identifies suitable controls and a monitoring programme, which is validated to ensure that the critical limits determined will deliver safe food.

The choice of the observed variables of the identification, assessment and food hazard control objectives comes from an extensive literature review. More specifically indicators are drawn from the guidance of the Food and Agriculture Organization (FAO, 2007) and also they have been widely used in previous studies of Sperber (1997), Ababouch (2000), Mortimore (2000), Wallace and Powell (2005), Jenner, Elliott, Menyhart, and Kinnear (2005), Luning et al. (2008, 2009).

2.3. Research hypotheses formulation

Research studies carried out so far, have assessed the successful implementation of the HACCP plan (Jacxsens et al., 2011; Mortimore, 2000; Wallace et al., 2005; Wilkinson & Wheelock, 2004). Moreover, reviewing the literature, no research studies have been found regarding the measurement of the effective implementation of HACCP by determining the degree to which the pre-specified objectives of the system are met. So, there is a gap in the literature that enhances the need for developing a valid and reliable measurement instrument of HACCP effectiveness, based on the level to which the HACCP objectives are met. Taking into consideration the objectives of the HACCP system (Hazards' identification, Hazards' assessment and Hazards' control) and their respective indicators identified in the literature, the following research hypotheses are formulated:

H1. The covariance among the indicators of the HACCP implementation can be accounted for by a restricted three-latent factor model, wherein each factor represents a particular objective of HACCP and each indicator is reflective only of a single objective (i.e. loads only on one factor). The three latent factors are correlated.

H2. Though "HACCP effectiveness" is conceptualised as meeting three distinct objectives (Hazards' identification, Hazards' assessment and Hazards' control); the covariance, firstly, among the indicators and secondly, among the HACCP objectives, can be accounted for by a single second order latent factor (i.e. HACCP effectiveness).

H3. Responses to each indicator are reflective of two latent factors: HACCP effectiveness (as a second order factor) and a specific factor corresponding to one of three HACCP objectives (as a first order factor). Thus, the covariance among the indicators can be accounted for by a four-factor model.

3. Research methodology

3.1. Survey population and measurement instrument development

A 3-page survey instrument was designed in order to test empirically and validate the measurement instrument of HACCP effectiveness. The first part of the survey instrument includes four questions on the demographic profile of the companies (education level of respondents, company sector, employee number and time since implementation of the system). The second part contains the three theoretical objectives of the HACCP system including 15 questions. All measurement variables were adopted following a comprehensive literature review and are listed in the Appendix. The final version of the questionnaire was emailed to 1100 Greek food companies – which constitute the population size – that have adopted and implemented the HACCP system. The food safety managers were asked to indicate the degree of agreement or disagreement with statements, representing the three dimensions of HACCP objectives, using a seven-point Likert scale (1 = very low to 7 = very high). Finally, 335 valid questionnaires were received after excluding some invalid questionnaires, yielding a response rate of 30.45 percent. Moreover, in order to ensure that the respondent sample was not biased towards the companies of the food sector, sub division comparisons of the organizations were made by the Mann–Whitney test. The Mann–Whitney is a non – parametric test that looks for differences between two independent samples. That is, it tests whether the populations from which two samples are drawn have the same location. It compares two conditions when different participants take part in each condition and the resulting data are not normally distributed (Field, 2005). In other terms, the Mann–Whitney test stipulates that the two independent groups are homogeneous and have the same distribution regarding the sub division comparisons of the food sector (Nachar, 2008). No statistically significant differences were found between these groups indicating that there is no bias regarding the subject examined. Furthermore, the common method bias is checked concluding that the data have no major problems in this study. From the above mentioned, it is apparent that non-response bias is not likely to be an issue in the final sample.

3.2. Data preparation

In our study, the respondents completed the survey instrument individually and independently, so the independence of each predictor variable was not violated. To measure the equality of variances for a single variable or pair of variables, the Levene test was used showing that the *p*-value for the test is greater than the 0.05 significance level, indicating variation in homogeneity (Feng, Terziovski, & Samson, 2008). According to Hair, Black, Babin, Anderson, and Tatham (2006) the number of the responding companies in the present study is large enough for multivariate data analysis (e.g. EFA, CFA). Screening for outliers from a univariate and multivariate perspective was carried out (Mahalanobis D^2/independent variables < 3) but none were detected (Hair et al., 2006). So, no data points were deleted from the analysis. As far as the normality of the data is concerned, histograms, p–p and q–q plots, skewness and kurtosis ($<\pm1$) and the standardized residuals ($<\pm2.5$) of the variables used in the proposed model (indicators of the HACCP objectives), indicates, although does not guarantee, multivariate normality (Hair et al., 2006).

3.3. Method of data analysis

The analysis procedure adopted in this study initially included EFA in order to check whether the indicators of the HACCP objectives identified in the literature, are accounted for by the three-latent factors model that represents the HACCP objectives. Then, CFA was used to refine the resulting scales in EFA and determine if the number of factors and the loadings of the measured variables (i.e. indicators) on them conform to what is expected on the basis of pre-established theory (Narayan, Rajendran & Sai, 2008). Unidimensionality, multicollinearity, scale reliability and construct validity also were undertaken for the study variables as suggested by Lakhal, Pasin, and Limam (2006) and Hair et al. (2006). A second-order CFA was undertaken to reveal the structural relationships between the HACCP objectives and its effectiveness. The statistical packages SPSS 15 and AMOS 6 were used for data processing.

4. Data analysis and results

The responding food companies in the present research project are small-medium sized (91%). 59% of the responding companies are food manufacturing companies, 23% process agricultural products and 18% manufacture drinks and beverages. It is worth noting that 83% of the food companies participating in the present study have been implementing the HACCP for more than three years and the majority of the respondents have a bachelor's degree (63%). A profile of the responding firms is provided in Table 1.

The indicators of the HACCP objectives identified in the literature were used as the measured variables of an EFA (principal component extraction method, varimax orthogonal rotation). The results of EFA revealed three factors (Kaiser-Meyer-Olkin = 0.943, Bartlett's test of Sphericity = 4109.153, $p = 0.000$, eigen-value > 1, factor loadings > 0.685, MSA > 0.80) that explain 75.369 percent of the total variance. These factors were labelled in accordance with the three HACCP objectives identified in the literature, meaning "Hazards' identification", "Hazards' assessment", and "Hazards' control". The reliability of the extracted factor is confirmed, according to Hair et al. (2006) and Singh (2008) through Cronbach's alpha coefficients that are higher than 0.862 (Table 2). The unidimensionality of the measurement scale is supported and furthermore it seems that multicollinearity is not the case in the present study (correlation coefficient lower than 0.80 and VIF are situated between 1.120 and 2.930) (Hair et al., 2006; Kline, 2005).

Table 1
The sample demographic characteristics.

Profile of the responding firms	Number	%
Company sector		
Manufacturing food products	203	59
Agricultural products	80	23
Drinks and beverages	64	18
Employee number		
1–10	40	12
11–50	147	44
51–100	75	22
101–250	44	13
251–500	20	6
500 over	9	3
Time since HACCP application		
Less than 5 years	57	17
Greater than 5 years	278	83

Table 2
Constructs validity of HACCP objectives.

Latent factors	Cronbach's alpha	Average variance extracted*	Construct reliability**	Corr^{2***}
Hazards' identification	0.862	0.606	0.911	0.555
Hazards' assessment	0.917	0.685	0.950	0.560
Hazards' control	0.936	0.704	0.963	0.560

*AVE $= \sum \lambda_i^2/n$ (number of items $i = 1\ldots n$, $\lambda_i =$ standardized factor loading).
**CR $= (\Sigma\lambda_i)^2/[(\Sigma\lambda_i)^2 + (\Sigma\delta_i)]$ (number of items $i = 1\ldots n$, $\lambda_i =$ standardized factor loading, $\delta_i =$ error term).
***The highest squared correlation between the factor of interest and the remaining factors.

Table 3
Goodness of fit measures.

Goodness of fit measures	First order model	Second order model
Target coefficient (T) (Chi-square of first order CFA/Chi-square of second order CFA)	1.00	
The basics of goodness of fit		
Chi-square	166.042	166.042
Degrees of freedom	84	84
Probability level	0.00[a]	0.00[a]
Absolute fit indices		
Chi-square/degrees of freedom (χ^2/df)	1.977	1.977
Root Mean Square of Approximation (RMSEA)	0.054	0.054
Root Mean Square Residual (RMR)	0.027	0.027
Goodness of Fit Index (GFI)	0.938	0.938
Adjusted Goodness of Fit Index (AGFI)	0.911	0.911
Incremental fit indices		
Normed Fit Index (NFI)	0.960	0.960
Relative Fit Index (RFI)	0.950	0.950
Incremental Fit Index (IFI)	0.980	0.980
Tucker-Lewis coefficient (TLI)	0.975	0.975
Comparative Fit Index (CFI)	0.980	0.980
Parsimony fit indices		
Parsimony Comparative Fit Index (PCFI)	0.784[a]	0.784[a]
Parsimony Normed Fit Index (PNFI)	0.768[a]	0.768[a]

[a] Relatively high values represent better fit of the model – given that the respective values for the saturated model are 0.0.

The three-latent factor model, wherein each factor represents a particular objective of HACCP, was confirmed through a first order CFA (Fig. 1).

The goodness of the first order CFA model fit to the measured data is presented in Table 3. From this Table we observe that the Basics of Goodness of Fit, the Absolute Fit Indices, the Incremental Fit Indices and the Parsimony Fit Indices indicate an acceptable fit of the proposed model (Avella & Vazquez-Bustelo, 2010; Hair et al., 2006; Marın & Ruiz-Olalla, 2011; Singh, Powera & Chuong , 2011).

Content validity depends on how well the researchers create measurement items to cover the domain of the variable being measured (Hair et al., 2006). Usual method of ensuring content validity is an extensive review of literature for the choice of the items and getting inputs from the practitioners and academic researchers on the appropriateness, completeness (Avella & Vazquez-Bustelo, 2010; Hair et al., 2006; Li, Rao, Ragu-Nathan, & Ragu-Nathan, 2005). The selection of items in this study was based on an extensive review of the literature, further the measurement instrument was scrutinized by 10 experts in the area and pilot tested in 53 food companies in Greece. Thus, we believe that the constructs and their associated items have good grounding in the HACCP instrument and associated literature, and therefore possess sufficient levels of content validity.

As far as convergent validity is concerned, the three latent factors are confirmed by evaluating the factor loadings (>0.626), the average variance extracted (AVE) (>0.606) and the construct reliability (CR) (>0.911) in all cases (Table 2) (Hair et al., 2006). Discriminant validity is evidenced by the fact that the Corr^2 is less than the AVE for each construct (Fornell & Larcker, 1981; Hair et al., 2006). The nomological (significant correlations among the extracted latent factors) and criterion-related validity of the extracted latent factors are also tested. The results indicate strong evidence that the proposed latent factors meet rigorous tests of these types of validities.

According to Hair et al. (2006) and Avella & Vazquez-Bustelo (2010) when there is a latent factor with several correlated dimensions, and furthermore the structural relationships between the dimensions and the latent factor are strongly supported by the literature, then a second-order factor model is applicable. The second-order model explains the co-variations among first-order factors in a more parsimonious way (Hair et al., 2006). So, in the case of the present study, a higher order model is constructed using "HACCP effectiveness" as a second-order factor that explains the three first-order factors (the HACCP objectives). In the second-order factor model, it is hypothesized that the "HACCP effectiveness" factor explains the association between the three first-order dimensions of HACCP objectives, thus avoiding the problem of correlated measurement errors (Avella & Vazquez-Bustelo, 2010). The second order model is represented in Fig. 2.

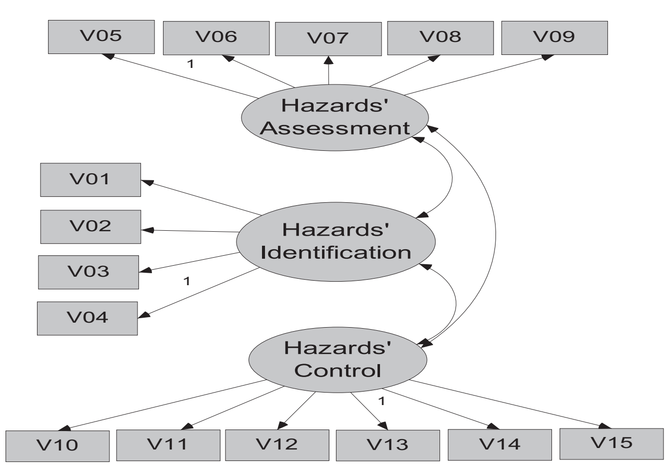

Fig. 1. Three-latent factor first order CFA.

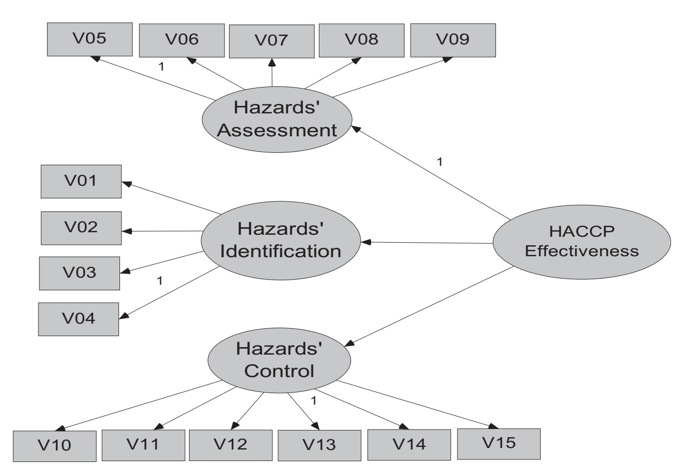

Fig. 2. The second order model of HACCP effectiveness.

The results of the second-order CFA indicate that the fit statistics represent a good fit of the data to the proposed second-order measurement model (Table 3). It is also worth noting that in the second order model, the standardized regression weights of the three first order latent factors and their squared multiple correlations are satisfactorily high (Appendix). This means that a high amount of the variance of the HACCP objectives is explained by the second order latent factor (HACCP effectiveness). This is also obvious from the Target coefficient (T) (Table 3): according to Doll, Raghunathan, Lim, and Gupta (1995) and Runge, Hames, and Shearer (2004) if it ranges between 0.8 and 1.0, a higher order latent factor can be refined explaining the covariance among first order latent factors.

5. Discussion

5.1. The HACCP objectives

The attempt of the Greek food manufacturing to offer safe food, through implementing the HACCP system, is deemed successful. This is evident due to the high level of achieving the objectives of the system. However, there is still room for further increasing the level of achieving the HACCP objectives. Literature identified three HACCP objectives; the findings from the present study disclose also the three-dimensional nature of the HACCP objectives. So, a three – latent factor model was introduced supporting the notion that indeed, the HACCP objectives are concerned with identification, assessment and control for each food safety hazard. The three-latent factors extracted, wherein each factor represents a particular objective of HACCP, explain the measured indicator variables identified in the literature. So, it is obvious that there is strong empirical support for the acceptance of the first research hypothesis.

5.2. The HACCP effectiveness measurement instrument

From the preliminary data collected, the theoretical linkage between "HACCP effectiveness" and the three objectives of the HACCP system was confirmed and further validated. A second order latent factor was extracted where the HACCP objectives were used as measured variables. The reliable and valid second order model demonstrates that, indeed, a broad concept exists that expresses the successful achievement of the HACCP objectives, namely "HACCP effectiveness". This factor cannot be assessed directly, but indirectly through the assessment of its sub-factors (the HACCP objectives), which in turn can also be assessed indirectly through the assessment of their indicators that are directly measured. From the above discussion it is apparent that the empirical results of the present study strongly support the second and third research hypothesis. It is also worth discussing the amount of variance of the three HACCP objectives which is explained by the model. More specifically, the model explains 68.6%, 81% and 76.6% of the variance of the "Hazards' Identification", "Hazards' Assessment" and "Hazards' Control", objectives respectively. These values indicate that a high percentage of each objective's variance is explained by the model. The failure to explain higher proportions of variance in these constructs may come from the variance in HACCP effective implementation, as much as anything else.

5.3. The differentiation of the present measurement instrument compared to similar instruments

A broad range of measurement instruments have been identified in the literature to diagnose the performance of current FSMS in the processing industry (Jacxsens et al., 2011). A number of HACCP audit checklists and example questions have been published as a standardized audit framework to cover all required aspects and assess the effectiveness of HACCP implementation on food companies. For example, Mortimore (2000) presented a core checklist posed by the WHO consultation background paper that can used within the food manufacturing industry for assessing both HACCP plans and their implementation. Wilkinson and Wheelock (2004) published a checklist of questions for Irish food production plants, designed to be applied by trained auditors. Wallace et al. (2005) developed two audit checklist tools to provide a step-wise approach to HACCP Assessment. The tools were designed to assess the validity of the HACCP plan and the implementation and maintenance of the HACCP system. Domenech et al. (2008) presented an application example of a model to assess the effectiveness of CCPs based on the consideration of the performance of the couple control-monitoring system. Jacxsens et al. (2010) introduced a food safety performance diagnosis, based on seven indicators and corresponding assessment grids that have been developed and validated in nine European food businesses. The instrument (FSMS-DI) suggested by Jacxsens et al. (2011) for the lamb chain, is a tool that enables a systematic analysis and assessment of a company's unique FSMS. The instrument consists of comprehensive lists of indicators to analyse respectively which core control and core assurance activities are addressed in the company's specific FSMS, and which context factors could affect the FSMS.

The above instruments can be useful tools in a food business to give a first indication about the hazards present, but they don't measure the effectiveness of the HACCP plan in connection with the extent to which its prescribed objectives are met. The measurement instrument that is suggested in this study differs with the other food safety measurement instruments as it is based on achieving the objectives of the HACCP plan, so it differs in scope, implementation and in its measurement variables.

5.4. Practical implications of the proposed instrument of HACCP effectiveness

Food companies face difficulties such as strong competition, increased consumer demands with regard to food safety and frequent food scandals. The effective implementation of a food safety system is necessary to overcome the above difficulties. A measurement tool applicable to food companies and reflecting the HACCP objectives (hazard identification, hazard assessment and hazard control) should be used, and is here introduced and confirmed, in order to evaluate HACCP effectiveness. The proposed instrument of HACCP effectiveness introduces self assessment in a food company as a means of systematically reviewing the procedures pertaining to food safety in order to reveal the strong points and the fields that demand improvement. This instrument could encourage, facilitate and improve the food companies' self assessment process, guiding them in adopting the suitable manufacturing practices that concern food safety, leading to the achievement of aims and consequently improved business performance. Each target of the instrument includes measurement variables (items) that have to be assessed because they constitute fundamental conditions for the achievement of objectives and consequently the effectiveness of the safety system. The proposed measurement instrument of HACCP effectiveness is important for both food companies and researchers to help them to better understand, through empirical evidence, the status of HACCP implementation. It is considered that it is not only the exact implementation of the HACCP system's requirements that confirms a food company's ability to produce safe products, but also its ability to achieve to a high degree the system's objectives. The achievement of these objectives starts, obviously, from an initially low level and continuously changes. This level should always be evaluated in order for a food company to find ways to continuously improve its effectiveness. The present measurement instrument developed can be used by a food company as a tool for benchmarking to assess the degree to which the HACCP system is implemented effectively, and for measuring the food safety activities to obtain an appropriate safe product. The development of a measurement instrument of HACCP effectiveness, will give the food business operators information (know how and know why) to improve a certain activity in the FSMS (Luning & Marcelis, 2009) and will allow comparison of progress across a range of sites. Furthermore, knowledge about the effectiveness of the food safety system will support food manufacturers in deciding which quality and safety management activities are most suitable for achieving HACCP objectives. So they can decide to add or improve safety management activities (Van der Spiegel et al., 2005). As a consequence, a food company can identify its strengths and weaknesses in food safety, and based on strategic decisions, maximize strengths or decrease weaknesses in order to improve the safety of its products.

6. Conclusion

This paper proposes a conceptual second order model that encompasses the 3 main objectives of the HACCP system (hazards' identification, hazards' assessment and hazards' control) with appropriate items. More specifically, the study provides a theoretical basis regarding the nature of HACCP effectiveness as well as the degree of achievement of its objectives and consequently the degree to which the system is effectively implemented.

The hypothesized model has acceptable fit with data. All the scales have been tested through rigorous statistical methodologies including the pilot test method, EFA, CFA, construct reliability and validation of the model's factors providing empirical support in the conceptual model. This study suggests that simply implementing the HACCP food safety system or conforming to its requirements does not guarantee that a food company is able to reach the highest level of product safety performance. There are many examples in the real world where food companies while implementing a food safety system, failed to control or eliminate some food safety hazards. It is obvious that HACCP is a dynamic system and its continuous effective implementation is what can help a food company to produce safe products in the long run. Reviewing the literature we observe that many studies have already been carried out in order to assess whether HACCP is implemented correctly. These studies introduce a checklist evaluating HACCP correct implementation by determining the degree to which the system's requirements are met or the degree to which an individual company's safety objectives are achieved. They do not truly depict HACCP effectiveness (that is measured through its objectives). Bearing in mind the definition of "HACCP effectiveness", it can be said that its 3 prescribed objectives depict the effectiveness of the system. So, it is evident that the measurement instrument developed in this study differs from previous ones and contributes significantly to the existing body of literature. This study provides valuable guidance on how to approach, manage and measure the HACCP plan effectiveness. The food manufacturing companies participating in the development of the instrument demonstrated a high degree of achievement of the HACCP objectives and consequently a high degree of effective implementation of the system.

There are a number of limitations associated with this study, which may suggest future research proposals. Given that the sample of the responding companies is limited to Greek food companies from all the food sectors, future research could attempt to extend the sample to multiple regions. It is also worth examining the applicability of the instrument through collecting empirical data from different specific sub-sectors, different business sizes and different chain actors of the food sector. Furthermore, the data collected through a single respondent from each participating company only represents one experience of HACCP effectiveness. Since this may generate some inaccuracy, future research should seek to utilize multiple respondents from each participating organization in an attempt to enhance the reliability of research findings.

Appendix. The HACCP objectives and associated items.

Latent factors	Measured variables	Code
Hazards' identification 0.828[a] 0.686[b]	The HACCP team uses brainstorming in order to identify food safety hazards and their causes.	V001
	The HACCP team uses literature data bases to identify food borne safety hazards.	V002
	Experts note the product characteristics that create food safety hazards.	V003
	Evidence is provided regarding the determination of food safety hazards.	V004
Hazards' assessment 0.900[a] 0.810[b]	Employees fully recognize the significance and criticality of any food safety hazard.	V005
	Documented procedures are implemented so that safety hazards can be assessed.	V006
	The HACCP team assesses and classifies each food safety hazard according to occurrence probability and its criticality.	V007
	The HACCP team collects data for assessing hazard criticality.	V008
	The HACCP team has the knowledge and the know-how in order to assess the food borne safety hazards.	V009
Hazards' control 0.875[a] 0.766[b]	The food company demonstrates the suitability of the methods and devices used for controlling food safety hazards.	V010
	Instructions are provided for monitoring each hazard that can be detected on raw materials or at any stage of food processing.	V011
	Reliable and valid procedures are used for monitoring and controlling food safety hazards.	V012
	External audit results confirm the suitability of the methods used for monitoring and controlling food safety hazards.	V013
	The programs for monitoring and controlling food safety hazards detect any excess of the limits in the Critical Control Points (CCPs).	V014
	When a new food safety hazard is detected on the product or at any stage of food processing, the HACCP team analyse the CCP and implement suitable actions for monitoring and controlling.	V015

[a] Standardized regression weight of a latent factor.
[b] Squared multiple correlation of a latent factor.

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