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A model for implementation of HACCP system for prevention and control of mycotoxins during the production of red dried chili pepper

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Abstract

Hazard analysis and critical control points (HACCP) is a process control system describes the potential hazards during food production flow chart. In contrast to the conventional way of ensuring product safety by end-product testing, HACCP establishes control systems, focuses mainly on preventive measures. Quality of red dried chili pepper (RDCP) should be assured by taking special care from harvesting of the peppers to retailing of the packaged product. RDCP is susceptible to fungi growth and mycotoxin contamination depending on the atmospheric and processing conditions such as humidity, temperature, storage and drying. Mycotoxins, are toxic metabolites to human health and strict control measures are required for preventing their occurrence in RDCP. In this study, HACCP system was implemented during the production of RDCP to ensure the food safety and quality characteristics of products and to expand the market. The most important critical control points (CCPs) during the production of RDCP was determined as sorting and drying. It is evident that development and use of the GMP, GAP, GSP and hygienic rules as well as HACCP during handling and processing of dry chili pepper are a must for processing plants.

Keywords: dry chili pepper; HACCP; aflatoxin.

Practical Application: Implementation of HACCP system during the production of red dried chili pepper.

1 Introduction

Mycotoxins are toxic natural products arising from fungal infection, and can exist in a variety of agricultural products and subsequently transferred into processed foods. Mycotoxins represent a risk to human health when contaminated food is consumed, and therefore the EU has strict regulatory limits for a number of mycotoxins (European Commission, 2006). These limits are imposed as a food safety measure. A number of foods of economic significance exported from Turkey (e.g. hazelnuts, dried figs, dried vine fruits and paprika) are prone to mycotoxin contamination and economic losses due to failure to meet the safety standards are estimated to be from $25-$85 million per annum.

Aflatoxins are the group of toxic secondary metabolites produced mainly by the species of *Aspergillus*. Aflatoxins B1 and B2 are produced by *Aspergillus flavus* while aflatoxins B1, B2, G1 and G2 are produced by *A. parasiticus*. Studies demonstrated that aflatoxins contribute to liver cancer formation (Liu & Wu, 2010). Moreover, when the food contaminated with mycotoxin are consumed by human and animals, it may cause diseases called mycotoxicosis and poisons even resulting in death (Yu et al., 2002).

Legal regulations was put into force in more than fifty countries all over the world. By these regulations, limits were set according to just aflatoxin B1 level or total aflatoxin or the combination of both. Countries can be categorised mainly into two groups. One group set 20 ppb regulational limit for total aflatoxins as in USA (Erdoğan, 2004), the other group follows a harder policy as in EU, setting a limit twice as low as previous one (10 ppb) (European Commission, 2006). Usually, agricultural commodities are naturally contaminated with *Aspergillus* spp. in the field and after that stage it is more difficult to completely prevent aflatoxin(s) formation in Aspergillus-contaminated commodities (Reddy et al., 2009). Aflatoxins are resistant to heat treatments and other applications in food processing and therefore they can be detected in the food chain and final product.

Red pepper (*Capsicum anuum L.*) is from the family of Solanaceae, which are cultivated and consumed in a variety of ways in Turkey. It grows in hot or warm seasons, and harvested in summer season. It is a sensitive product for aflatoxin formation depending unsuitable processing conditions. *Aspergillus fumigatus, A. flavus, A. niger, A. ochraceus* were detected in many pepper samples previously (Erdoğan, 2004). Aflatoxin contamination in red pepper was also defined in several different countries including Australia (Klieber, 2001), China (Hu et al., 2006), Turkey (Set & Erkmen, 2010), Portugal (Martins et al., 2001), Korea (Cho et al., 2008). Red dried chili pepper (RDCP) is produced by drying of plant fruits which are grinded as leaf, with or without stem and stone, and mixing with salt and vegetable oil and dampening by water (Bozkurt & Erkmen, 2004).

Hazard analysis and critical control point (HACCP) is a preventive method that is used to control food processing procedures by identifying the hazards of food production and furthermore, to ensure food safety by controlling the hazards and reducing the risks. Instead of checking only the properties of the end product, the CCPs in the process are monitored

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continuously to prevent a possible major hazard in advance. Codex Alimentarius Commission describes CCPs as control stages to prevent, reduce or eliminate hazards. Therefore, HACCP was proven to be effective in inhibiting the growth of toxigenic fungi and formation of mycotoxins in RDCP production. Our study was designed to implement the HACCP system in RDCP processing plants for ensuring the quality and safety of the final product.

2 Materials and methods

2.1 Principles and tasks of the HACCP

In the terminology of HACCP systems, "hazard" refers to conditions or contaminants that can cause illness. The HACCP concept is built on seven principles (Boccas et al., 2001). Principles and tasks of the HACCP method according to Codex Guidelines were given in Table 1.

2.2 HACCP system design of red dried chili pepper

Description of the product

Washed, sliced, dried, grinded and packaged RDCP after harvesting. Stored under controlled, monitored and clean warehouses. It is used as spices or used freshly in meals as gravy.

Assembling the HACCP team

Authorised people in their field as food engineer, quality control/ laboratory responsible, production responsible should be included in HACCP team.

Design of flow chart

RDCP production consists of eight steps: (a) harvesting and transporting; (b) sorting (elimination of stems, waste and moldy particles); (c) washing of the fruit surface; (d) seed removal; (e) drying (by oven or under the sun); (f) grinding of pepper to the required size; (g) packaging and storage of packed product or instead first storage in bulk than packaging and (h) transportation (Figure 1).

Determination of CCPs

During the production of RDCP the below stages were determined as the CCPs.

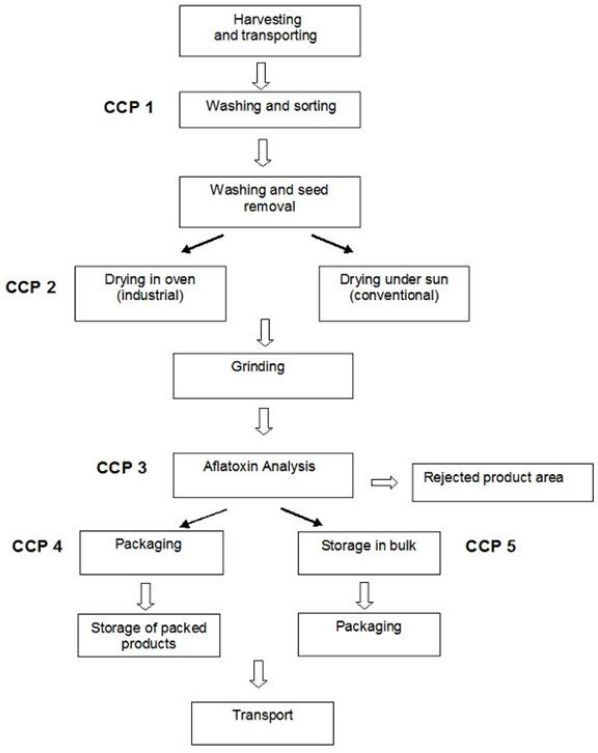

Figure 1. Flow chart of red dried chili pepper production.

Table 1. Principles- tasks of the HACCP method according to Codex Guidelines (Food and Agriculture Organization of the United Nations, 2004).

Principles
1. Conduct hazard analysis
2. Determine the critical control points (CCPs)
3. Establish critical limits
4. Establish a system to monitor control of each CCP
5. Establish the corrective action to be taken when CCP is not under control (a deviation from a critical limit)
6. Establish procedures for verification to confirm that the HACCP system is working effectively.
7. Establish documentation concerning all procedures and records appropriate to these principles and their application.
Tasks
1. Assemble HACCP team
2. Describe product
3. Identify intended use
4. Construct flow diagram
5. On-site confirmation of flow diagram
6. List all potential hazards associated with each step, conduct a hazard analysis, and consider any measures to control identified hazards
7. Determine Critical control points
8. Establish critical limits for each CCP
9. Establish a monitoring system for each CCP
10. Establish corrective actions
11. Establish verification procedures
12. Establish documentation and record keeping

CCP 1: Washing and sorting

After harvesting pepper fruits must be washed to remove dirt and other foreign materials. Injured fruits should be excluded to reduce the risk of fungal contamination. Removing the mouldy pieces, wastes and other foreign substances from peppers are important for not contaminating the healthy parts of peppers. Before acceptance, physical analysis (colour, odour, dirtiness) are performed. Following the homogenisation of the sample, microbiological and chemical analyses (humidity amount, volatile oil, non-volatile ether extract, ash amount, existence of dye) are executed. If the results of microbiological analysis are detected higher than the acceptance limits, then the products can be rejected without making chemical analysis because there is no process to reduce the microbial load. The analyses of washing water should be performed regularly. Processed and non-processed materials should be seperated for the prevention of contamination.

CCP 2: Drying

The most important factor for fungal growth and toxin formation is the water activity (Boccas et al., 2001). The growth of all microorganisms including fungi can be prevented by removing the water in the product by different methods. Usually 12-15 days of drying time under sun is applied for humidity loss approximately from 90.8% to 7.35%. Drying should be performed without damaging the product quality. During conventional drying (under sun), fungi usually stem from air and earth. They could be formed during or after the harvesting time due to bad drying and storage conditions. Drought and insect damages on the products on the field can increase the contamination level of fungi.

CCP 3: Aflatoxin analysis

Aflatoxins are the most important group of mycotoxins which are produced by Aspergillus species. The presence of aflatoxins is reported in herbs and spices (Colak et al., 2006), chillies (Paterson, 2007), processed spices (Cho et al., 2008).

Aflatoxin analysis should be carried out before packaging and storage to determine the contamination levels aflatoxins. The allowed maximum legal limits of total aflatoxin for red dried chili pepper is 10 ppb in Turkey (Turkish Standards Institute, 2003). If the determined amount is higher than the limits of standard, product have to be put in quarantine. Irradiation technique can be applied for the elimination of the mycotoxins in packed product. It is a method that can be applied for avoiding the presence/formation of the aflatoxins in the end product whereas it has no effect on the formation of mycotoxins during production or before packaging (Lu et al., 2014).

CCP 4: Packaging

Processed peppers should be packed as soon as possible, in case the humidity level of peppers might be increased and this condition may cause microbiological contamination. Moreover dirtiness from environment could be prevented by this way. Any chemical reaction or migration from packaging material into peppers should be avoided. The package material to be used should be durable to physical effects and transition of humidity to protect the product against extrinsic factors.

CCP 5: Storage in bulk

Instead of direct packaging, some plants store the dried and grinded product in bulk in a warehouse. Thus this stage is considered a CCP if applied. Bulk RDCP should not be stored in warehouses with the humidity level higher than 70% and temperature higher than 5 ^{o}C. This stage should not be over 1 day and carried out by hygiene and sanitation rules. Mainly, there shouldn't be any insects, rodents in the containers of products. These may cause contamination and decrease the quality of product. Warehouse conditions, temperature and humidity must be checked and also disinfection rules must be applied.

Determination of acceptance limits and criteria

Critical limits and tolerence values determined for critical control points during RDCP production should be identified according to standards by HACCP team.

3 Results and discussion

3.1 Hazard analysis

Determined hazard analysis of RDCP according to the CCPs is given in Table 2. From harvesting to the transportation of the final products, hazard analysis was performed at every stage to define any biological, chemical, and physical factors that may affect food safety.

3.2 HACCP Plan Development

The quality and safety of the final product can be effectively guaranteed through the application of the HACCP system. In the scope of HACCP Plan, according to the previously determined CCPs, preventive measures, corrective actions and verifications were determined during the production of red dry chili pepper.

Implementing HACCP plan in all stages requires the participation of all trained personnel (Boccas et al., 2001). Additionally, a logical and applicable HACCP plan canhelp food factories improve their management level and enhance their staff's safety consciousness (International Commission on Microbiological Specifications for Foods, 1988). HACCP Plan of RDCP is given in Table 3.

3.3 Monitoring

Monitoring should be planned for the definition of the observations at CCPs or the correction for actual recording. This step should explain the 4 Who/What/When/How questions about the control measures of the related step in which a CCP has been raised.

3.4 Application of corrective actions and verification

Corrective actions should be applied if deviation from critical limits is occurred. Uncertain products should be seperated, if needed process should be stopped, error source should be defined and all procedures are recorded. Preventive measures should be

Table 2. Hazard Analysis of RDCP.

Process stage	Potential Hazards	Preventive Measures	CCP/not
Pre-harvest, Harvest	B: Fungus, Bacteria, Insects, Rodents	B: In designing the lay-out of orchard, information concerning plant spacing will be obtained. Orchard surface should be prepared before planting for prevention the growth of mycotoxin producing fungi	CP
	P: Soil, materials, glass, wood, stone	P: GAP	
	C: High/low usage of Pesticide, Aflatoxin contamination	C: GMP, Good Hygienic Practises (GHP)	
Washing and Sorting	B: Fungus, Bacteria, Insects, Rodents, Dirty water/Contamination	B: Washing should be done with clean water, Personnel hygiene, GMP	CCP1
	P: Soil, materials, glass, wood, stone	P: Direct contact to soil must be prevented	
	C: Aflatoxin contamination	C:Peppers after harvesting will be sorted to remove demaged peppers and foreign materials. They should be transported as soon as possible for immediate processing in clean, dry, protected against humidity and free of insects and fungal growth containers	
Drying	B: Fungus, Bacteria, Insects, Rodents, contamination from personnel	B: Personnel hygiene, GMP	CCP2
	P: Soil, material	P: Direct contact to soil should be prevented.	
	C: Contamination of aflatoxin	C: Drying of pepper must begin as soon as possible.Then, insects, mites, wormin, domestic animals, fungi, chemicals, microbial contaminats and dust should be prevented by GMP. Fluidized bed can be used as quick drying.	
Aflatoxin Analysis	B: Generally not	B:-	CCP3
	P: Generally not	P:-	
	C: Aflatoxin amount determination	C: Aflatoxin level should be detected, if the total aflatoxin amount is higher than 10 ppb, quarantine the batch and apply correction practises. e.g. irradiation	
Storage in bulk	B: Fungus, Bacteria, Insects, Rodents	B: Containers and warehouse have to be clean, dry and free of visible fungal growth, insects and any contaminated material. The containers should be well constructed to withstand handling abuse without breaking or puncturing, and tightly sealed to prevent any access of dust, fungal spores, insects or other foreign material. Good Storage Practises (GSP) will be applied.	CCP4
	P: Generally not	P: -	
	C: Aflatoxin contamination	C: Relative humidity and temperature of warehouse have to be setas; RH <70%, T < 5°C for the inhibition of fungus growth and aflatoxin occurence.Water activity of product should be checked; Aw < 0.7. Controlled atmosphere storage (CAS), Modified atmosphere storage (MAS) might be applied	
Packaging	B: Fungus, Bacteria, Insects, Rodents	B: Areas where raw materials are going to be received or stored will be physically separated from areas in which final product preparation or packaging is conducted as to preclude contamination of the finished product. GMP will be applied. Yeast and mold number in the end-product should be max $1x10^2$ $cfu.mg^{-1}$	CCP5
	P: Contamination from packaging material	P: Analysis of packaging material	
	C: Aflatoxin contamination	C: Aflatoxin analysis	
Storage (Packed RDCP)	B: Fungus, Bacteria, Insects, Rodents	B: Good Storage Practices (GSP)	
	P: Generally not	P: -	
	C: Aflatoxin contamination	C: GSP	
Transport	B: Fungus, Bacteria, Insects, Rodents	B: Containers must be clean, dry, and free of visible fungal growth, insects and any contaminated material.	CP
	P: Generally not	P:-	
	C: Aflatoxin contamination	C: GMP	

B: Biological, P: Physical and C: Chemical, CP: Control Point, CCP: Critical Control Point.

Table 3. HACCP Plan of RDCP Production.

CCP	Potential hazards	Critical Limits	Monitoring				Corrective measures	Records	Verification of CCP
			Object	Method	Frequency	Personnel			
Washing and sorting	Fungus, bacteria, insects, rodents, soil, foreign materials (glass, wood, stone), contamination from washing water, aflatoxin contamination	GMP and GAP regulations,	Conditions (hygiene, sanitation, temperature, humidity) of sorting area, washing water.	PRP/oPRP, Metal dedector, Microbiological analyses of water	Every batch	Operator, laborant	Design of sorting lay-out, GMP and GAP. Antifungals can be used under controlled conditions.	GAP and GMP forms, microbiological analysis report	Regularly submit GAP and GMP management log books. Application to autonomous laboratories for water analysis.
Drying	Fungus, bacteria, insects, rodents, contamination from personnel, soil, foreign material, aflatoxin contamination	Prevention of fungal growth and contamination	Time and temperature of drying	Automatic temperature and humidity controller	Every batch	Operator and technician	Prevention of direct contamination from soil, Quick drying (drying in oven or in a fluidized bed can be applied without exposion to environment), GMP, GHP	Automatic temperature and humidity controlling plot	Drying Time-Temperature form, GMP and GHP forms,
		Aw product <1	Measurement of water activity	Water activity meter/analyzer					
		GMP, GHP reguations	Place of drying	PRP/oPRP					
Aflatoxin Analysis	Contaminated product with mycotoxin	Aflatoxin amount < 10 ppb	Amount of aflatoxin in RDCP	HPLC analyses, ready-use kits	Every batch	Technician	Analysis result, quarantina product, Irradiation technique can be used, check HACCP system.	Analysis records and log file	To verify the records apply to autonomous laboratories, analysis records, control forms, standards
Storage in bulk	Fungus, bacteria, insects, rodents, high humidity and temperature of the warehouses, re-contamination	RH<70% and T<5 °C, Aw product < 0.7. CAS, MAS, GSP regulations	Relative humidity and temperature of warehouse, water activity of product. Warehouse and storage area	Automatic humidity and temperature controller, water activity. Good storage practises	Every batch	Operator and technician	The structure of storage area and the conditions during storage need to be modified if fungal growth determined	Humidity and temperature controlling records. CAS, MAS and GSP records	Usage of a portable thermo-humidity meter to verify the automatic controllers, examine record everyday. Regularly submit storage management log book
Packaging	Contamination from/by means of packaging material	MAP and CAP regulations, no migration from package,		Automatic packaging without contamination from personnel or environment	Every batch	Results of packaging material analysis,	Agreement with supplier, analysis of aflatoxin and packaging material, GMP		Packaging material control form

Determined according to Turkish Standards Institute (2003). GMP: Good Manufacturing Practises; GAP: Good Agricultural Practises; GHP: Good Hygienic Practises; PRP: Prerequisite programs; oPRP: Operational Prerequisite programs; CAS: Controlled Atmosphere Storage; MAP: Modified Atmosphere Storage; GSP: Good Storage Practises; RDCP: Relative diffusing capacity; HACCP: Hazard Analyses and Critical Control Point; MAS: Modified Atmosphere Storage; CAP: Controlled Atmosphere Packaging.

taken for avoiding the repetition of mistakes. Effective auditing of HACCP system must be provided. It could be provided by the control of known potential hazards at control points by taking effective control measures

3.5 Recording

During monitoring the CCPs, recording should be done and documented in an appropriate format, verified and signed by authorized people. Records should be protected minumum 1 year (International Commission on Microbiological Specifications for Foods, 1988).

4 Conclusion

During RDCP production, implementation of the HACCP techniques should be applied carefully at the determined CCPs, namely washing-sorting, drying, storage and packaging. After harvesting, pepper fruits must be washed to remove dirt, and injured fruits should be excluded to reduce the risk of fungal contamination. Fresh fruits should be stored at the conditions of low temperature and relative humidity for the prevention of the fungal growth. Humidity should be regularly checked and monitored during production and storage because the fungal growth mainly relies on the presence of humid. Following the drying and grinding stage RDCP will be hygroscopic, therefore have to be packed quickly with a good package material that not cause migration to product, transition of humidty and durable to physical factors. Drying in oven would be better to drying under sun due to its short drying time request and prevention of the extrinsic factors such as birds, dust, wind or thermal changes. For the reason that aflatoxins are resistant to food processing such as heat treatment once they occurred they can remain in the food chain and product. Thus it is crucial, to prevent fungal growth and aflatoxin formation during the process.

Irradiation is a recent technique that is used for the elimination of the mycotoxins in packed red paprika (Nieto-Sandoval et al., 2000). It is a method that can be applied for avoiding the availability of the aflatoxins in the end product whereas it has no effect on the formation of mycotoxins during production or before packaging. Usage of antifungals under controlled conditions might also be an alternative to prevent the growth of fungi during production.

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