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Chemical Substances and Biological Agents

Studies and Research Projects

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Characterization of Dusts In the Food Seasonings Sector

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SUMMARY

Spices and aromatic herbs contain organic substances (also called active substances) that can cause irritation or that have an allergenic potential for the respiratory system or the skin. The literature relating to the spice and aromatic herb sector reports cases of skin allergy, occupational asthma and other respiratory problems. Operators working in the grinding, mixing and packaging of seasonings and spices are exposed mainly to concentrations of dusts. The purpose of this project is to characterize the airborne dusts in companies producing spice- and aromatic-herb-based seasoning mixtures in terms of total dusts, inhalable fraction and respirable fraction, as well as the particle size distribution of the dusts generated during various operations.

The reported results focus on three workstations during the production of food seasonings into which spices and aromatic herbs are incorporated. The stationary samples covered the complete duration of the operations at the workstations. The median concentration of total dusts (Dt) was 5.9 mg/m³ (range from 1.9–48 mg/m³) in packaging, 3.0 mg/m³ (< 0.4–11 mg/m³) in mixing, and 7.4 mg/m³ (1.1–12 mg/m³) in grinding. For the inhalable dust fraction (Fi), the median concentration was 12 mg/m³ (range from 3.9–150 mg/m³) in packaging, 4.8 mg/m³ (0.9–16 mg/m³) in mixing, and 9 mg/m³ (1.9–22 mg/m³) in grinding; for the respirable fraction (Fr), it was 0.5 mg/m³ (< 0.3–0.6 mg/m³) in packaging, 0.3 mg/m³ (< 0.1–0.5 mg/m³) in mixing, and 0.5 mg/m³ (< 0.1–1.1 mg/m³) in grinding. The geometric mean of the mass median aerodynamic diameters (MMAD) determined using eight-stage impactors was 25.9 µm in packaging, 22.4 µm in mixing, and 16.7 µm in grinding.

The daily average exposure values (DAEVs) obtained at the studied workstations were below the Québec permissible exposure value (PEV) of 10 mg/m³, except in packaging in one establishment. However, some were above the recommendation of 3 mg/m³ issued by the Seasoning and Spice Association (SSA) in the United Kingdom.

LIST OF ACRONYMS AND ABBREVIATIONS

ACGIH®	American Conference of Governmental Industrial Hygienists
AM	Arithmetic mean
BEI®	Biological Exposure Indices
CAEQ	*Classification des activités économiques du Québec* (Québec Economic Activity Classification)
$Conc_i$	Ambient dusts collected by an impactor
CSST	*Commission de la santé et de la sécurité du travail* (Québec workers' compensation board)
DAEV	Daily average exposure value
DRI	Direct-reading instrument
Dt	Total dusts collected on a 37-mm diameter filter placed in a closed cassette with a 4-mm orifice.
Dti	Total dusts collected by the impactor calculated from $Conc_i$ in relation to the collection efficiency curve
Est	Establishment visited
Fi	Inhalable fraction, dust fraction corresponding to the mass of particles with aerodynamic diameter (d_a) between 0 and 100 µm collected by a sampler corresponding to the collection curve (ACGIH® 2010; IRSST 2005)
Fii	Inhalable fraction of the dusts collected by the impactor
Fr	Respirable fraction, dust fraction corresponding to the mass of particles collected by a sampler whose median aerodynamic diameter is 4 µm (ACGIH® 2010; IRSST 2005)
Fri	Respirable fraction of the dusts collected by the impactor
GM	Geometric mean
GSD	Geometric standard deviation
HSE	Health and Safety Executive
INRS	*Institut national de recherche et de sécurité* (France)
IOM	Institute of Occupational Medicine
LCL-UCL 95%	95% lower-upper confidence limit
MMAD	Mass median aerodynamic diameter
MRV	Minimum reported value
n	Number of samples
NAICS	North American Industry Classification System
OSHA	Occupational Safety and Health Administration
PEV	Permissible exposure value
PNOC	Particulates not otherwise classified, according to the ROHS
PVC	Polyvinyl chloride, 5 µm porosity

ROHS	Regulation respecting occupational health and safety
S	Sensitizer
SD	Standard deviation
SSA	Seasoning and Spice Association
TLV®	Threshold Limit Values for chemical substances and physical agents

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1. INTRODUCTION

Spices and aromatic herbs contain organic substances (also called active substances) that can cause irritation or that have an allergenic potential for the respiratory system or the skin. The effects of these substances, such as capsaicin, are mentioned in numerous scientific publications. The literature relating to the spice and aromatic herb sector reports skin effects, occupational asthma and other respiratory problems (Chirane *et al*. 2009). Seasoning and spice grinding, mixing and packaging operators are exposed to rather high dust concentrations (Chan *et al*. 1990; Lankatilake and Uragoda 1993; Uragoda 1992). In Québec, there is little information on this segment of the food industry (Chirane *et al*. 2009; Lemière *et al*. 1996).

Over a 12-year period (1995–2007), the *Commission de la santé et de la sécurité du travail* (CSST) compensated nine cases of asthma whose causal agent was dust for sector 1099 of the CAEQ Classification des activités économiques du Québec (Québec Economic Activity Classification), namely "*all other food manufacturing*." Spice and aromatic herb processing is part of this classification. Workers in this economic sector (Chirane *et al*. 2009) are potentially exposed to organic dusts classified by the Regulation respecting occupational health and safety (ROHS) as *particulates not otherwise classified* (PNOC). This term comprises all types of inert dusts (or nuisance dusts), mineral or organic, that are not regulated under the name of a specific substance. A similar definition is found in the French regulations where PNOC are called "*poussières réputées sans effet spécifique*" meaning that alone cannot cause any effect other than overload on the lungs or any other organ or system of the human body. Some spices have occupational health effects, and the levels of exposure to these dusts should not be compared to the generic standard for PNOC (Gérin 2010).

Québec regulations are based on measurement of the so-called total dust (Dt) fraction or respirable fraction (Fr). In recent years, the use of filters with an Accu-Cap® has improved the evaluation of the dust concentration. According to several scientists, Dt samples do not always seem relevant for evaluating the workers' health risk.

The present project establishes a preliminary portrait of the concentrations evaluated by different methods for sampling the inhalable fraction (Fi), the Fr, the Dt as well as the particle size distribution of the dusts present in the establishments in this sector of the food industry.

2. OBJECTIVE OF THE STUDY

The project aims to characterize the airborne dusts in establishments producing spice- and aromatic-herb-based seasoning mixtures in terms of total dusts, inhalable and respirable fractions, and the particle size distribution of the dusts generated during various operations.

3. STATE OF KNOWLEDGE

3.1 General information

Spices and aromatic herbs are valued for their organoleptic properties. Despite food intolerances and allergies, certain spices and herbs are associated with health and sensitization problems when they come in contact with skin, or when their dusts are inhaled by workers during processing activities.

According to Chirane *et al*. (2009), spices and herbs originate mainly from bark (cinnamon), flowers (saffron, cloves), leaves (tea, bay), fruit (pepper, dill, mustard), bulbs (garlic, onion, ginger), or grains (fennel, coriander). They contain volatile organic substances, often called *aromas*. These substances belong to different chemical groups such as alcohols or aldehydes. They stimulate olfactory and gustatory perceptions. They are therefore responsible for odours, aromas and flavours. Richard (2008) proposes classification of spices and aromatic herbs by family (partially reported in Table 3.1-1).

Table 3.1-1: Family and active substances of some spices and aromatic herbs

Spice/aromatic herb	Family	Active substance
Mustard	Cruciferae	Sinalbin, sinigrin
Saffron	Iridaceae	Crocetin, safranal
Rosemary	Mint family	1,8-cineole, camphor, carnosol and rosmanol
Thyme		Thymol, Carvacrol
Cinnamon	Lauraceae	Cinnamaldehyde, eugenol
Garlic	Liliaceae	Allyl propyl disulfide, allyl propenyl disulfide, etc.
Onion		
Cloves	Myrtaceae	Eugenol
Allspice		Eugenol
Nutmeg and mace		Terpenes, myristicin
Coriander	Ombelliferae	Aldehydes, linalool
Cumin		Cuminaldehyde
Dill		(+)-carvone
Fennel and anise		Anethole
Peppers	Piperaceae	Piperine
Chili pepper	Nightshade	Capsaicin
Paprika		Capsanthine, capsorubin
Ginger	Zingiberaceae	Gingerols, shogaols, β-zingiberene
Turmeric		Curcumin
Cardamom		α-terpenyl acetate

3.2 Health effects

Some organic substances mentioned in Table 3.1-1 are suspected or known to be irritants or allergenic to the skin and respiratory tract. According to the literature, occupational exposure to spice and herb dust can cause respiratory symptoms and diseases.

3.2.1 Respiratory tract

Lemière *et al*. (1996) reported the case of a butcher reacting positively to a skin prick test with garlic, bay leaves and thyme. Garlic is the most significant allergen in this case. Fraj *et al*. (1996) also described the case of a butcher suffering from non-specific bronchial hypersensitization caused by exposure to aniseed dust. A study by Sastre *et al*. (1996) reported one case of asthma due to paprika, coriander and mace (shell of the nutmeg seed). One female worker in the meat processing industry received a diagnosis of occupational rhinoconjunctivitis whose causal agent was pepper (Arias Irigoyen *et al*. 2003). Finally, Rosenberg (2006) discussed cases of rhinitis and asthma, mainly in deli meats which involve numerous seasonings. García-González *et al*. (2002) described a case of rhinoconjunctivitis related to pastry and confectionery work.

According to Laraqui *et al*. (2005,2002), the prevalence of clinical symptoms (cough, asthma, rhinitis, dermatitis and conjunctivitis) is significantly higher in sellers of spices (41.1%) than in workers not exposed to spices (21.7%). A change in respiratory function, of variable degree, was observed in 61.1% of exposed workers and a prevalence of asthma of 7.1%. These authors reported more frequent cases of cough, expectoration, shortness of breath, rhinitis, conjunctivitis, symptoms of asthma and chronic bronchitis in the population of grocers exposed to garlic, ginger and cumin. In the study of Uragoda (1992), 76% of the spice workers experienced various symptoms when they worked mainly with cloves, pepper and cinnamon. In one study by Uragoda (1984), 87.5% of the spice workers reported various respiratory symptoms and 22.5% had asthma.

In seasoning processing plants, Niinimäi *et al*. (1989) showed that 19.7% of atopic subjects responded positively to one or more spices, compared to 1.3% in non-atopic subjects. The spices and herbs responsible for sensitization were cloves, coriander, pepper, mustard, ginger and cinnamon, and paprika. Some studies (Lankatilake and Uragoda 1993; Uragoda 1992; Blanc *et al*. 1991; Chan *et al*. 1990) were on workers in chili or pepper grinding showing symptoms of cough, sneezing and nasal discharge. In 1967, Uragoda had already demonstrated that 95% of chili grinding workers presented such symptoms.

The population studied by Hamdam *et al*. (2000), consisting of spice factory workers, was exposed to coriander, turmeric, chili, pepper, cardamom and cloves dust. The spirometric results of workers with more than five years on the job demonstrated a significant difference in respiratory function associated with regular exposure to spice dust over a long period. Ando *et al*. (2006) described one case of non-specific interstitial pneumonia for a worker in the production of curry sauce containing curry powder and pepper. A significant relationship was found between the symptoms and a reduction in respiratory capacity. According to the conclusions of Golec (2006), long-term exposure to herb dust causes a reduction in respiratory function.

Study results (Van der Walt *et al*. 2010; Ebo *et al*. 2006; Añibarro *et al*. 1997; van Toorenenbergen *et al*. 1985; Molina *et al*. 1984; Lybarger *et al*. 1982; Falleroni *et al*. 1981) showed that the inhalation of garlic, onion, coriander, curry, mace and chili powder dust can cause respiratory allergies, rhinoconjunctivitis, asthma, contact dermatitis, and occasionally anaphylaxis.

Schwartz *et al*. (1997) reported cases of rhinitis and asthma following exposure to paprika, pepper and fennel. Paprika has also been recognized as a causal agent for rhinitis (Niinimäi *et al*. 1989) and asthma (Sastre *et al*. 1996).

In conclusion, the prevalence of chronic respiratory symptoms in workers in spice and aromatic herb processing is significantly higher in exposed subjects, particularly for shortness of breath (57.6%), chronic cough (22.8%), chronic bronchitis (19.6%), acute inflammation of the mucous membranes (37.0%), and sinusitis (22.2%) (Zuskin *et al*. 1988b).

Several studies on workers in the tea and herbal tea industry are cited in the literature, with a few mentioned in Table 3.2-1.

Table 3.2-1: Literature on workers in the tea processing industry

Authors (year)	Objective of the study	Highlights of the study
Schachter *et al*. (2009)	To study respiratory symptoms by work environment (textile, food processing, farmers) in 12 studies	There is a prevalence of respiratory symptoms (chronic cough, phlegm, bronchitis) in workers in the food processing industry (tea, spices, dried fruit, etc.).
Minov *et al*. (2007)	To identify cases of asthma in subjects exposed to herb and fruit tea dusts	The first case of tea dust asthma was documented in 1970. Since then, cases of asthma have been reported (Roberts and Thomson 1988; Cartier and Malo 1990; Zuskin *et al*. 1996).
Abramson *et al*. (2001)	To correlate respiratory symptoms with exposure to tea dusts in tea leaf packers	The mechanism of respiratory tract obstruction remains unknown, while tea-induced asthma seems to result from a sensitization similar to that of organic dust.
Jayawardana and Udupihille (1997)	To determine the prevalence of respiratory symptoms and the effects on workers' respiratory capacity	The inhalation of tea dust causes acute and chronic respiratory symptoms, particularly in tea leaf sifting.
Shirai *et al*. (2003, 1994)	To identify the causal agent of asthma in green tea dust	Workers in green tea processing have a positive reaction to tea extract.
Hill and Waldronf (1996)	To investigate the prevalence of symptoms during exposure to tea dust	Cases of rhinitis and cough are linked to tea fluff exposure.
Zuskin *et al*. (1996)	To study the change in respiratory function of fruit and tea processing workers	Workers exposed to organic aerosols can experience symptoms and changes in respiratory function.
Cartier and Malo (1990)	To describe three cases of occupational asthma in tea packaging workers	The prevalence of occupational asthma in workers exposed to tea dust must be further explored.
Lewis and Morgan (1989)	To describe one case of tea dust asthma	A female worker in tea processing reported wheezing after having been exposed to fine tea dust.
Zuskin *et al*. (1988a)	To study the respiratory functions of tea workers	These authors discuss the power of spices to induce respiratory symptoms in workers exposed to tea dust.
Zuskin *et al*. (1984)	To study the respiratory functions of five groups of tea workers	This study shows that exposure to tea dust can be the cause of acute or chronic respiratory symptoms.
Castellan *et al*. (1981)	To evaluate the health risk for workers in herb and black tea processing and packaging	Respiratory problems in workers exposed to tea dust are demonstrated.
Uragoda (1980)	To study the prevalence of respiratory symptoms in tea workers	Prolonged exposure is necessary for asthma to appear in these tea workers.
Uragoda (1970)	To describe a case of occupational asthma caused by tea aerosol	One worker experienced an immediate reaction when inhaling very fine tea aerosols.

3.2.2 Skin effects

Some studies (Anliker *et al*. 2002; Hjorther *et al*. 1997) report cases of butchers who developed eczema following the handling of coriander and rosemary in powder form. Paprika and cinnamon used in pastry making can cause urticaria on workers' hands and forearms (Ackermann *et al*. 2009; Crépy 2007; Foti *et al*. 1997; Niinimäi *et al*. 1989). One female pasta production worker suffered from contact dermatitis on the hands and forearms following the handling of turmeric, curcumin, curry and ginger added as colouring agents (Kieć-Swierczyňska and Krecisz 1998).

Kanerva *et al*. (1996), Kanerva and Soini (2001), and Ackermann *et al*. (2009) described cases of dermatitis in food service workers exposed to garlic, cinnamon, paprika, ginger, cloves, coriander and allspice.

Spiewak *et al*. (2001) concluded that thyme dust can induce occupational contact dermatitis. Cases of urticaria have been reported in grinding and packaging workers with the handling of coriander, chili powder or pepper (Ebo *et al*. 2006; Chan *et al*. 1990). In this seasoning processing industry, complaints of skin symptoms (dry skin, pruritis, skin lesions and eczema) were evaluated in the study of Meding (1993). According to Niinimäi *et al*. (1989), evaluation of these reactions is difficult, due to the irritant properties of spices.

3.3 Workers' exposure

Golec (2006) and Laraqui *et al*. (2005, 2002) concluded that long-term exposure to dusts of spices and aromatic herbs (duration and intensity) causes symptoms leading to a reduction in respiratory capacity.

In Québec, spice and herb dusts are considered as particulates not otherwise classified (PNOC), with a permissible exposure value (PEV) of 10 mg/m³ expressed as total dust (Dt). Table 3.3-1 presents exposure reference values from different international organizations (IFA Gestis-International Limit Values for Chemical Agents[1]) for PNOC.

[1] {On line} http://www.dguv.de/ifa/en/gestis/limit_values/index.jsp (October 2010).

Table 3.3-1: Reference values for PNOC or equivalent

Country/organization	PNOC (mg/m³)
Belgium (GWBB)	3 (Fr) 10 (Fi)
France (INRS)	5 (Fr) 10 (Fi)
Germany (DFG)	4 (Fi)
Québec (CSST)	10 (Dt)
United States (ACGIH®)	3 (Fr) 10 (Fi)
United States (OSHA)	5 (Fr) 15 (Dt)

Dt: Total dust F**r**: Respirable fraction F**i**: Inhalable fraction
DFG: *Deutsche Forschungsgemeinschaft* GWBB: *Greenswaarden vooc beroepsmatige blootstelling*

According to the results of Lacey *et al*. (2006), the dust concentrations (ambient) varied from 0.33 to 14.7 mg/m³ with an arithmetic mean (AM) of 3.21 mg/m³. According to these authors, the concentrations emitted by the processes (grinding and mixing) varied from 2.09 to 542 mg/m³.

Evaluation of the level of worker exposure in spice and aromatic herb processing is important so that action can be taken on its determinants (process isolation, local ventilation, wearing of protective equipment) (Zuskin *et al*. 1988a).

Spice dust concentrations have been reported in only a few environmental studies. The levels cited in the consulted studies are presented in Table 3.3-2.

Table 3.3-2: Spice dust concentrations reported in the literature

Reference	Workplace or workstation		Type	F	Concentration (mg/m^3) Range	GM	GSD
Castellan *et al*. 1981	Tea processing and packaging		BZ	Dt	0.15–13.8		
				Fr	0.1–0.7		
			AA	Dt		1.0	
				Dt		12.2	
Chan *et al*. 1990	Chili, cumin and turmeric grinding			Dt	0.03–0.8	0.15	
Lankatilake and Uragoda 1993	Chili grinding		BZ	Fr	0.11–0.5		
			AA			0.06	
Minov *et al*. 2007	Herb and fruit tea processing		BZ	Fr	1.9–4.4	3.1	0.8
Hamdam *et al*. 2000	Spice processing (coriander, turmeric, chili, pepper, cardamom, cloves)			Fr		2.5	
Schachter *et al*. 2009	Food industries			Dt	0.12–35.6	12	
				Fr	0.5–6.6	5	
Van Der Walt *et al*. 2010	Garlic, onion, pepper processing						
	Mixing			Fi	8.7–29.9		
	Packaging			Fi	1.0– 26.4		
Zuskin *et al*. 1988a	Spice processing			Dt	0.5–10.1	2.9	
				Fr*		0.06	
Zuskin and Skuric 1984	Tea processing:	Dog-rose		Dt	3.2–24.2	11.4	
				Fr*		1.7	
		Gruzyan		Dt	5.3–24.9	16.8	
				Fr*		2.0	
		Sage		Dt	2.5–10.0	6.3	
				Fr*		1.0	
				Dt	2.4–5.6	3.7	
				Fr*		0.4	

GM: Geometric mean GSD: Geometric standard deviation
Type of sampling: BZ: Worker's breathing zone AA: Ambient air (stationary sampling)
Dt: Total dust Fr: Respirable fraction Fi: Inhalable fraction
Fr*: Concentration calculated from the % cited in the article by the cited authors

The ACGIH® (2010) recommends a value for allyl propyl disulfide (active substance for onion and garlic, among others) of 0.5 ppm with a mention of sensitizer and upper respiratory tract and eye irritant. According to Chirane *et al*. (2009), the Health and Safety Executive (HSE), based on the recommendations issued by the Seasoning and Spice Association (SSA) in the United Kingdom, proposes an exposure value of 3 mg/m^3 for irritant spices and recommends reducing to a minimum the exposure to allergenic spice dusts.

Chirane *et al*. (2009) present the results of sampling in seven seasoning processing establishments located in the western region of Montréal island. Their results, cited in relation to the percentage of the samples that exceeded the PEV in the ROHS and the value recommended by the SSA by establishment, are reported in Table 3.3-3, as well as the number of samples. According to this study, a high percentage of seasoning processing workers are exposed to concentrations above 3 mg/m^3.

Table 3.3-3: Exceedence percentage according to Chirane *et al*. 2009

Description of the establishment (workstation)	Year	n	% PEV > 10 mg/m³	% SSA > 3 mg/m³
Mustard processing		14	0	58
Production of dehydrated vegetable-based mixtures (grinding/sifting and packaging)	2002 2003	21 6	4 0	42 83
Production of soup bases, sauces and seasonings (mixing and packaging)	2001 2003	8	75 4,5	100 9
Mixing of spices (grinding/sifting)	1998 1999 2001	12 9 7	33 44 14	75 22 14
Mixing of seasonings and chips	2005	4	0	25
Production of juices, soups, spice mixtures	1993	3	66	100
Production of pasta and tomato sauces	2005	2	0	100

n: Number of samples collected, when indicated.

According to Chirane *et al*. (2009), a reference value specific to the irritant active substance is desirable in order to represent the risk. Gérin (2010) suggests that the PNOC range be specified in the ROHS and that consultation be initiated on the dusts and aerosols that should be excluded from this category.

3.4 Particle size distribution of the dusts

The particle size distribution in tea processing and packaging (Castellan *et al*. 1981) was below 10 µm for 50% of the collected mass and below 7 µm for 25%. Chan *et al*. (1990) reported that the average proportion of the respirable fraction (Fr) was 45.9% of the collected Dt (Table 3.3-2) and that particles smaller than 5 µm make up 34.5% of the mass of dust, and those smaller than 1 µm, 15.3% of the mass.

4. METHODOLOGY

4.1 Metrology

Dust characterization was done with three different sampling methods using filter and cassette to collect, depending on their manufacturer, different fractions of the airborne dust: 1) total dust (Dt), 2) inhalable dust fraction (Fi), and 3) respirable dust fraction (Fr). Also, cascade impactors were used to evaluate the particle size distribution of the airborne dust. The sampling equipment and methods used are presented in Table 4.1-1.

Table 4.1-1: Sampling and analytical methods

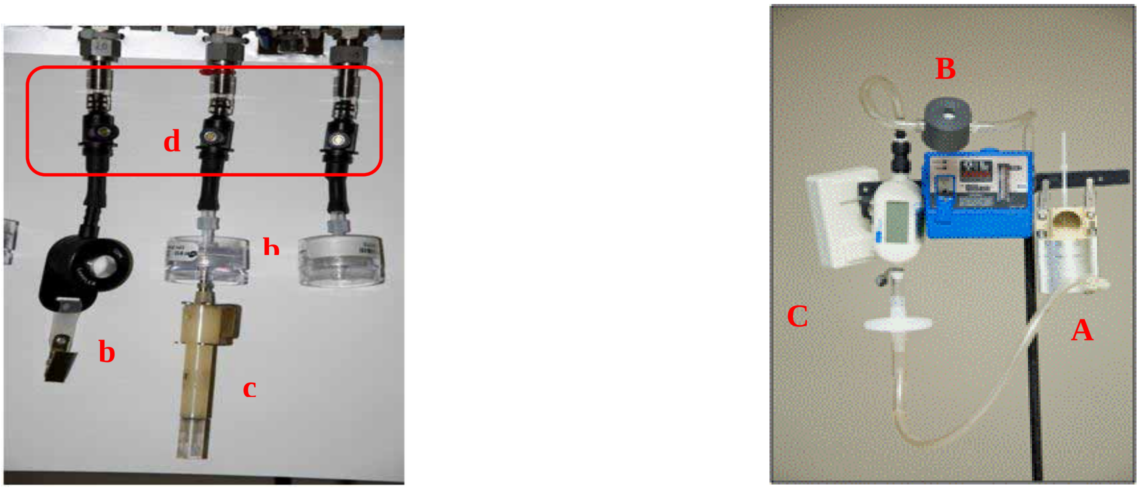
	Dt	Fi	Fr	Particle size distribution
Filter	Pre-weighed PVC, 37 mm, with Accu-Cap®	Pre-weighed PVC, 25 mm	Pre-weighed PVC, 37 mm, with Accu-Cap®	Silicone-coated Mylar® and pre-weighed PVCs, 34 mm
Sampler	Closed cassette, 37 mm, 4 mm orifice	IOM cassette, stainless steel, 15 mm orifice	Closed cassette, 37 mm, Dorr-Oliver cyclone	Marple 298 eight-stage impactor
Flow rate	1.5 L/min	2.0 L/min	1.7 L/min	2.0 L/min
Analytical uncertainty	4.9%	1.1%	4.9%	Not available
MRV	25 µg	40 µg	25 µg	25 µg
IRSST method	48-1	373	48-1	48-1 modified

PVC: Polyvinyl chloride, porosity 5 µm. MRV: Minimum reported value

The laboratories of the *Institut de recherche Robert-Sauvé en santé et en sécurité du travail* prepared the sampling material and analyzed the samples. Cassettes equipped with an Accu-cap® were used to determine the Dt and Fr to avoid the underestimation caused by losses on the inside walls of the polystyrene cassette. The use of an IOM sampler with stainless steel cassettes minimized the impact of relative humidity on the weight measurements during the laboratory analyses. Marple type impactors were used with silicone-coated Mylar® membranes as recommended by the manufacturer to prevent bounce and resuspension during impaction on the collection substrates. The cutoff diameters for these impactors are between 0.52 and 21.3 µm.

Despite the fact that all the samplers used in this project were personal samplers, the samples were stationary samples (ambient air) for purposes of comparison. The six samplers were installed on a metal plate. Each sampling train consisted of six adjustable-flow sampler holders connected respectively to two closed cassettes for the Dt samples, to two cassettes equipped with a Dorr-Oliver cyclone for the Fr samples, and to two IOM samplers for the Fi samples. The samplers were installed alternatively and adjusted to the flow rate specific to each. Figure 4.1-1A illustrates the samplers [IOM cassette (a), closed cassette (b), cassette and cyclone (c), and the adjustable-flow sampler holders (d)]. Each of the sampling trains was connected by a Teflon® tube of variable length, depending on the location, to a 30 L/min vane pump. The flow rates were adjusted at the start and verified at the end of the sampling period by means of a DryCal model

Bios flowmeter with an accuracy of 3% of the reading according to the manufacturer's specifications. A 5% variation in flow rates (before and after) is acceptable.



A B

Figure 4.1-1: Sampling trains

Each sampling system was installed at a specific workstation at a height equivalent to a worker's breathing zone, on a tripod, or suspended from furniture depending on the space available in the workplace. An additional sampling system (Figure 4.1-1B) could be added to evaluate the fine structure of the ambient dust. This system consisted of a cascade impactor (A) installed in series with a Gilian brand Gilair model personal pump, an anti-pulsator device (B), and a TSI model 4146 flowmeter (C) with an accuracy of 2% of the reading according to the manufacturer's specifications.

The gravimetric analyses were done using a micrometric balance with a resolution of ± 1 µg. The details of the analytical methods are found in IRSST methods 48-1 and 373.

A direct-reading instrument (DRI) was used to evaluate the evolution in the concentration levels as a function of time and the particle size distribution of the dusts. A single workstation per visited establishment was evaluated using the DRI, which was a GRIMM PAS model 1.108 optical particle counter (Figure 4.1-2) operating according to the scattered light principle (laser source) with an accuracy of 5%, according to the manufacturer.

Figure 4.1-2: GRIMM PAS model 1.108 spectrometer

The optical diameters measured by this instrument are more or less proportional to the corresponding aerodynamic or geometric diameters (Ruzer and Naomi 2005). The instrument evaluates the concentration of airborne dusts every six seconds for fifteen particle size ranges

(< 0.23 to > 20 µm). To simplify data interpretation, these fifteen ranges were combined to produce four ranges.

It is important to note that the data from this DRI could be biased due to the fact that it was not calibrated in the laboratory with the target contaminant.

4.2 Establishments visited and sampling strategy

This project involved seasoning processing factories, four of which were visited. A total of 12 sampling stations were characterized: mixing (loading and unloading of the mixer), grinding, and packaging. The sampling stations were selected following preliminary visits during which the workstations and tasks more representative of the workers' risk of exposure to airborne dust were identified. The establishments visited are classified as CAEQ (Québec Economic Activity Classification) code 1099 or NAICS (North American Industry Classification System) codes 311940 or 311920.

The sampling time covered the ingredient handling period during the day shift. On the sampling days, information or determinants were collected that could explain the variations in the results. Some examples were the volume of the department, the amount and type of ingredients, the number of workers present during the intervention, and certain work practices, if relevant.

4.3 Data processing

4.3.1 Environmental analyses

The results reported in section 5 were determined by using the mean of the duplicates obtained for each type of sampler in each sampling train. The result for all the samples whose dust concentration was below the MRV was replaced by the value obtained using equation 4.3-a. The daily average exposure value (DAEV) was calculated from the mean of the concentrations of the duplicates using equation 4.3-b. It cannot be compared to the permissible exposure value (PEV) because the samples were stationary samples and not personal samples. It corresponds to an **estimation** that is equivalent to an 8-hour work shift. It should also be noted that no result for Dt, Fi and Fr was corrected in relation to the weight of the blank filter.

$$Conc_{MRV} = (MRV/\sqrt{2}) / V_s \qquad \text{equation 4.3-a}$$

Where $Conc_{MRV}$: Dust concentration < MRV used in the calculations (mg/m³)
MRV: Minimum reported value in Table 4.1-1 (µg)
V_s: Sampling volume (L)

$$DAEV = \frac{C_1T_1 + C_2T_2 + \ldots + C_nT_n}{480 \text{ minutes}} \qquad \text{equation 4.3-b}$$

Where DAEV: Daily average exposure value
C: Concentration over a given period (mg/m³)
T: Duration of the sampling period (minutes)

4.3.2 Particle size distribution by impactor

The masses collected by the Marple type impactors (Sierra series 290) were corrected in relation to the median variation observed for a group of six blank substrates.

Two particle size distributions profiles were produced for each series of weight measurements. The first did not take into account internal losses on the surface of the first stage, visor, head, and all the other surfaces, except for the collection substrates and the filter; another did a correction based on the curves supplied by the manufacturer (corrected profile). The mass median aerodynamic diameters and geometric standard deviations (GSD) were calculated by assuming a lognormal distribution, therefore by drawing a regression line on the log probability graph of the particle size distribution. Only the most significant points were used, by giving less weight to the cumulative points below 10% and above 90% as recommended by Lodge and Chan (1986).

The concentration evaluated by the impactor ($Conc_i$) was obtained by adding all the masses collected for each stage. The inhalable fraction (Fii) and respirable fraction (Fri), as defined by the American Conference of Governmental Industrial Hygienists (ACGIH®), were calculated using the results from the impactors and the respective curves. The total dust (Dti) was also evaluated in this way, but from the best-fit trend curve obtained from the results of several studies on the efficiency of the 37-mm closed cassette. This curve[2] was described in the report by Roberge *et al*. (2011) and is repeated (Figure 4.3-1) here on a graph also showing the curve defining the Fi.

[2] This curve is adapted from the curve obtained by Vincent, James (2007). It was adapted using mathematical formulas by the authors of this report.

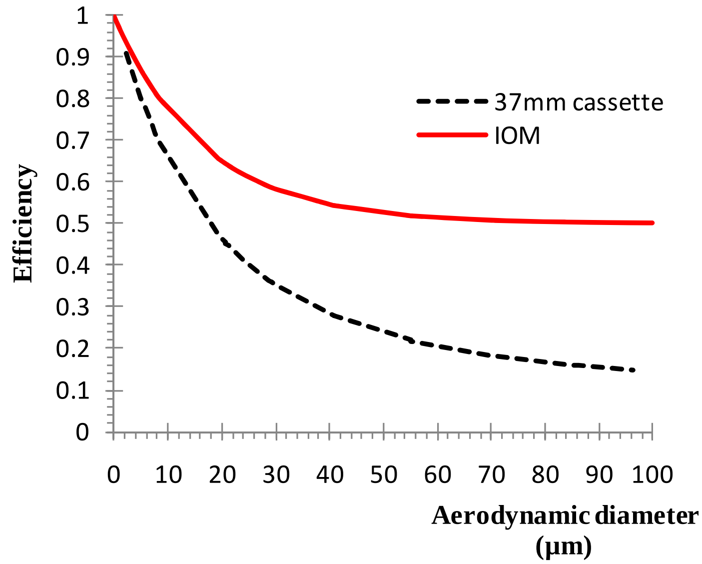


Figure 4.3-1: Best-fit trend curve for Dt compared to that for the IOM (Fi)

The efficiency percentages obtained from the curves and the cutoff diameters of a stage were multiplied directly by the mass collected on the stage by using Simpson's rule described in the monograph of Lodge and Chan (1986). The respirable and inhalable masses were obtained by adding these results for all the impactor's stages for the non-corrected and corrected masses.

To be able to compare the samples, the mass histograms were normalized. The mass percentages for each particle diameter can thus be evaluated directly from the histograms.

4.4 Statistics

The environmental data from this study were interpreted using statistical methods by means of computer-based tools. The results obtained from the different samplers were statistically compared using NCSS 2007 software, version 07.1.14 (Hintze J., Kaysville, Utah). The paired *t* test was used to compare the pairs of results obtained from the different samplers in relation to their type and the sampling station, when possible. A non-parametric test, the Wilcoxon signed rank test, was used when the distribution of the studied data was not considered normal. The null hypothesis (H_0) of the statistical tests was rejected when P (or Z) < 0.05 or when the value zero was not included in the 95% confidence interval of the average of the difference of the paired units.

5. RESULTS

This section includes a brief description of the processes involved in seasoning production, the establishments, as well as the environmental results for Dt, Fi and Fr and the results obtained from the impactors, namely the particle size distribution as well as the calculated inhalable fraction (Fii), the calculated respirable fraction (Fri) and the calculated total dust (Dti).

5.1 Description of the processes

Depending on the recipe, the worker manually weighs the different starting materials or pours the containers of pre-weighed starting materials.

One of the next steps is grinding of the starting material before incorporating it into a mixture or packaging it, as needed. The pre-weighed materials are loaded manually (loading) and then recovered (unloading) (Figure 5.1-1). Even though there is an automated mechanism for controlling the amount of unloaded mixture, the worker monitors and weighs this amount unloaded into a container, as needed.

Figure 5.1-1: Unloading of the grinder

In the mixer, the ingredients are loaded at the upper stage manually (loading, Figure 5.1-2). After homogenization of the seasoning (by stirring), the seasoning is unloaded and packaged at the lower stage. Despite an automated mechanism, the worker monitors and weighs the amount unloaded into a container.

The mixture can be packaged at the manual or automatic packaging station (Figure 5.1-3[3]). Both methods can generate significant quantities of dust, depending on the work methods, the pace and the presence of local exhaust, among other things. This operation, when automated, includes adjustment of the machine, verification of the weight, sealing of the bag, if applicable, metal detection (quality control), and then placement in the box and transport to the warehouse.

Figure 5.1-2: Loading of a mixer

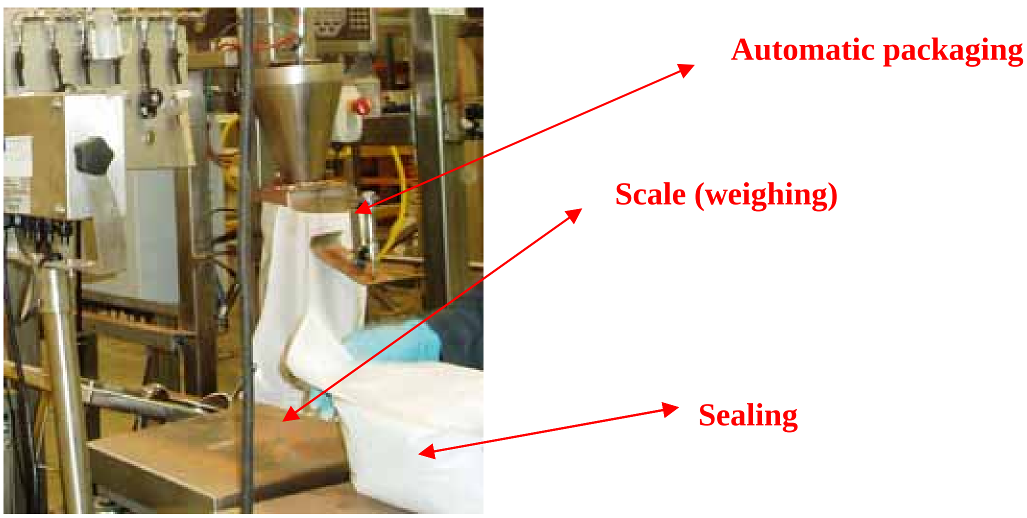


Figure 5.1-3: Automatic packaging

5.2 Description of the establishments

The work shift in the visited establishments is generally eight hours per day or 40 hours per week. The workers perform several tasks during the day. Cleaning with or without water is done when the recipe is changed or during the night shift. The ambient temperature at the time of the study was between 21° and 24°C and the relative humidity was around 37%, unless the recipe had ingredients with specific temperature and humidity requirements, such as pepper processing.

All the workers had to wash their hands before entering the production section, and to wear work clothes supplied by the employer and nitrile gloves. Some workers wore an N-95 or N-100 respirator, depending on the ingredients handled. All the establishments had a mechanical general ventilation system. Also, there was a local exhaust system at the mixer loading

[3] The photographs in this report were taken in the visited establishment with the consent of the person in charge.

workstations. From our observations, the work methods varied with the workers assigned to the tasks.

Listed in Table 5.2-1 are the number of workers assigned to the sampling station, the volume of the room where this workstation was located, the amount of seasonings produced during our intervention, as well as the ingredients used. Several seasonings contained other ingredients that are not listed in this table, such as salt, sugar, starch, etc.

Table 5.2-1: Characteristics of the establishments visited

Est	Sampling station	Number of workers	Volume of the room (m^3)	Amount produced (kg)	Ingredients
1	Unloading/mixing	1	472	2520	Dehydrated garlic, spices *, milk powder.
	Manual packaging	2	2081	4284	Spices*, bread crumbs, milk powder.
	Automatic packaging	1	2081	1600	Cheese powder, ground chili peppers.
2	Manual packaging	1	732	244	Dehydrated onions, garlic and celery, dehydrated parsley, butter flavour, bread crumbs, dehydrated beer, paprika, glutamate.
	Loading/mixing	2	732	1254 1084	1) Royal paprika, black pepper, orange powder, garlic powder, parsley, onion, chives, sweet pepper, celery. 2) Ground and grated basil, paprika, garlic, tomatoes, parsley, crushed black pepper.
	Unloading/mixing Seasoning 1	2	732	1254	Royal paprika, black pepper, orange powder, garlic powder, parsley, onion, chives, sweet pepper, celery.
	Unloading/mixing Seasoning 2	1	732	1084	Ground and grated basil, paprika, garlic, tomatoes, parsley, crushed black pepper.
3	Unloading/grinder	1	639	1266	White pepper.
	Sifter/mixing	1	732	3519	Sweet corn, sodium bicarbonate.
	Automatic packaging Seasoning 1	2	733	569	Black pepper, oregano.
	Automatic packaging Seasoning 2	2	733	860	White pepper.
4	Loading/mixing	1	554	260 560	1) Bergamot, Earl Gray tea. 2) Willowherb, ginseng, camomile flower, plantain flower, nettle flower, saw palmetto, cinnamon bark, blue lavender, nettle root, cranberry.
	Unloading/mixing	1	554	260 560	1) Bergamot, Earl Gray tea. 2) Willowherb, ginseng, camomile flower, plantain flower, nettle flower, saw palmetto, cinnamon bark, blue lavender, nettle root, cranberry.
	Grinding	2	405	25 277	1) Goldenrod. 2) Hibiscus flower, cinnamon, camomile, orange peel, allspice, roasted chicory, carob.

Est: Identification of the establishment. *: The spices in the seasoning were not divulged.

5.3 Dust characterization – Environmental results

5.3.1 Dt, Fi and Fr concentrations

A paired *t* test was performed on all the pairs of results obtained according to the fraction (Dt, Fi and Fr) in order to establish whether the results of the duplicates were equivalent so that their average could be used for the calculations. It seems that there was no statistically significant difference for the duplicates at the different workstations (Table 5.3-1).

Table 5.3-1: Paired *t* test – Comparison of the duplicate samples

Compared fractions	Number of pairs	LCL-UCL 95% /average difference	Average deviation (%)	Rejection of H_O
Dt 1 vs Dt 2	15	[-5.1 – 1.9]	-4	No
Fi 1 vs Fi 2	15	[-36.9 – 9.1]	-12	No
Fr 1 vs Fr 2	15	[-0.2 – 0.1]	-13	No

Table 5.3-2 summarizes the results of five packaging workstations, seven mixing workstations, and three grinding workstations, constituting a total of 10, 14 and 6 samples for the three fractions studied (Dt, Fi and Fr) since each was sampled in duplicate. The arithmetic means (AM) of the analytical results as well as an estimated daily average exposure value (DAEV), expressed as Dt, are grouped by workstation and by establishment. The main descriptive statistical data of the environmental results are summarized in Table 5.3-3.

Table 5.3-2: Environmental measurement concentrations

Est	Workstation	Duration (min)	Concentration (mg/m³) Dt	Fi	Fr	DAEV (mg/m³ Dt)
1	Unloading/mixing	374	11	15	0.5	**8.5**
	Automatic packaging	408	5.9	12	0.6	**5.0**
	Manual packaging	222	1.9	3.9	0.1	**0.9**
2	Manual packaging	179	2.8	6.7	< 0.1 *	**1.0**
	Loading/mixing	62	7.9	12	< 0.2 *	**1.6 ****
	Unloading/mixing Seasoning 1	89	2.7	16	< 0.1 *	
	Unloading/mixing Seasoning 2	29	< 0.4 *	0.9	< 0.4 *	
3	Unloading/grinder	383	1.1	1.9	0.1	**0.8**
	Sifter/mixing	400	3.0	4.7	0.1	**2.5**
	Automatic packaging Seasoning 1	100	48	120	0.6	**24 *****
	Automatic packaging Seasoning 2	217	30	150	0.5	
4	Loading/mixing	274	3.1	4.2	0.3	**1.8**
	Unloading/mixing	311	2.5	4.2	0.2	**1.6**
	Grinding Seasoning 1	207	12	22	1.1	**6.4 *****
	Grinding Seasoning 2	73	7.4	9.0	0.5	

*: Analytical results below the minimum reported value (MRV).
**: This calculation includes the mixer loading and unloading period, because the same workers performed these tasks.
***: This calculation includes the packaging or grinding of both seasonings, because the same workers performed these tasks.

Table 5.3-3: Descriptive statistics by workstation

	Packaging Dt	Packaging Fi	Packaging Fr	Mixing Dt	Mixing Fi	Mixing Fr	Grinding Dt	Grinding Fi	Grinding Fr
n	5	5	5	7	7	7	3	3	3
n ≥ MRV	5	5	4	6	7	4	3	3	3
Average (mg/m³)	18	59	0.4	4.4	9.2	0.3	6.9	11	0.6
Standard deviation	21	71	0.3	3.7	5.9	0.2	5.6	10	0.5
Median (mg/m³)	5.9	12	0.5	3.0	4.8	0.3	7.4	9.0	0.5
GM (mg/m³)	8.5	23	0.3	3.0	5.9	0.2	4.6	7.2	0.4
GSD	4.2	5.4	3.1	2.9	2.7	2.0	3.6	3.4	4.0
Range (mg/m³)	1.9-48	3.9-150	0.1*-0.6	0.4*-11	0.9-16	0.1*-0.5	1.1-12	1.9-22	0.1*-1.1
LCL-UCL 95%	[0-43]	[0-150]		[1.0-7.8]	[2.7-14]		[0-21]	[0-36]	[0-1.9]

n: Number of samples MRV: Minimum reported value *: Value <MRV expressed as mg/m³
GM: Geometric mean GSD: Geometric standard deviation
LCL-UCL 95%: 95% lower-upper confidence limits.

Even though the GRIMM PAS 1.108 was not calibrated in relation to the substances present, its readings provide us with information on the dust concentration levels during the operations: packaging (Figure 5.3-1), unloading of the mixer (Figure 5.3-2), and automatic packaging for two seasonings (Figure 5.3-3). These three figures also show the weighted average of the DRI readings as well as the results of the corresponding environmental measurements (Table 5.3-2).

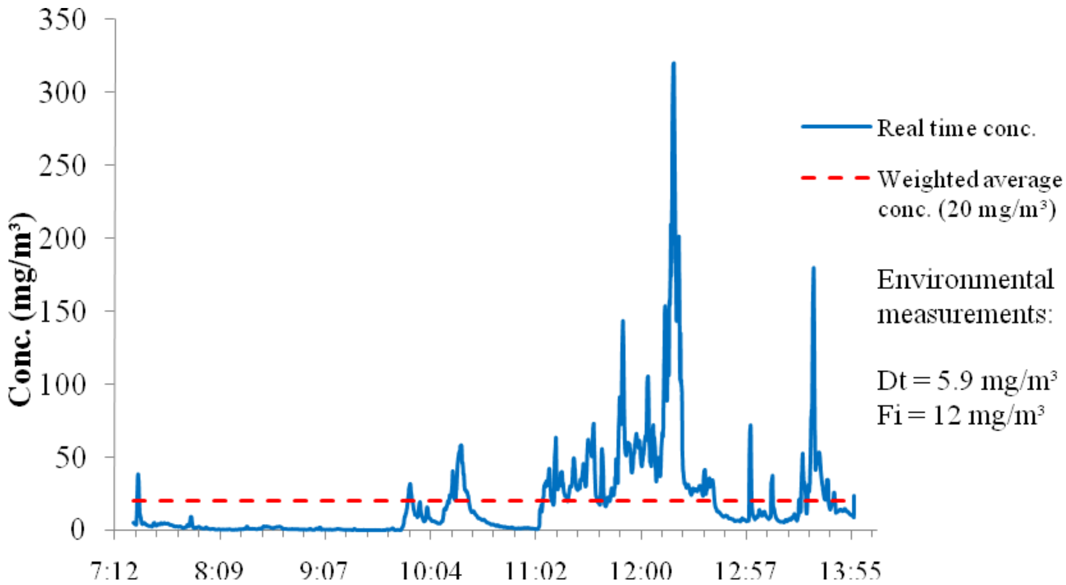


Figure 5.3-1: Concentration read by the GRIMM PAS 1.108 at establishment 1's packaging workstation

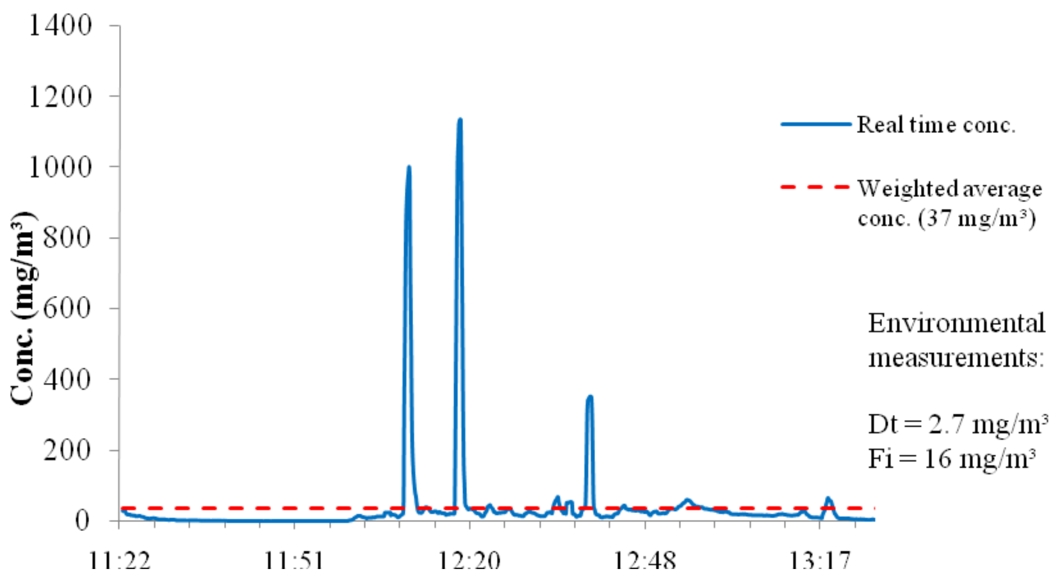


Figure 5.3-2: Concentration read by the GRIMM PAS 1.108 at establishment 2's unloading workstation

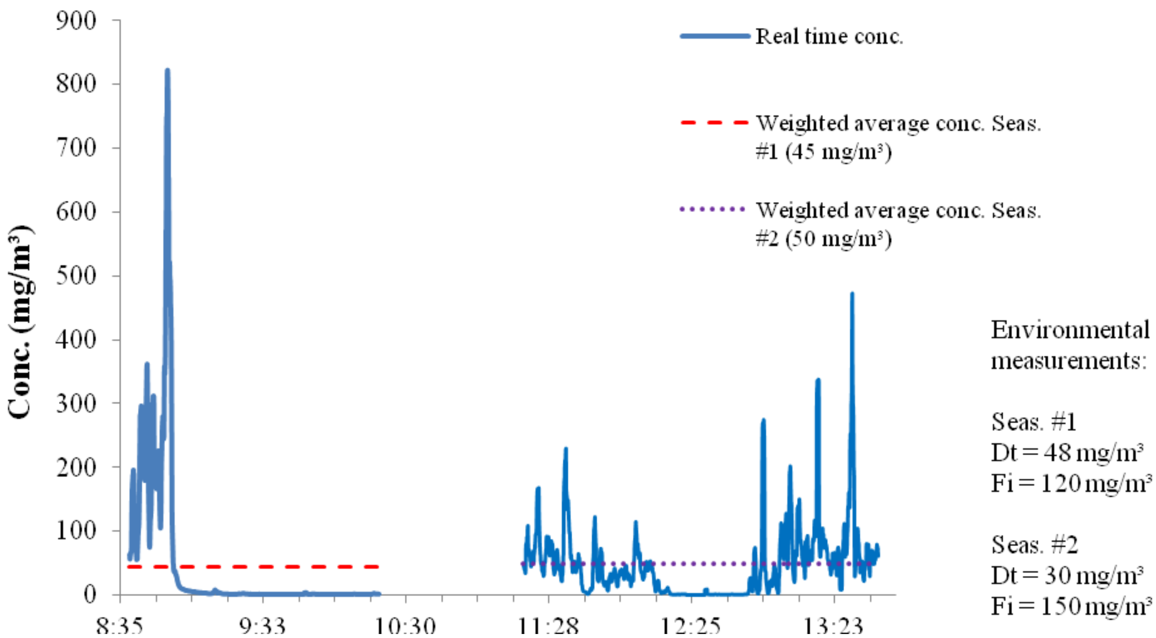


Figure 5.3-3: Concentration read by the GRIMM PAS 1.108 at establishment 3's packaging workstation

5.3.2 Relationship between the inhalable fraction and total dust

The ratios calculated from the results of the IOMs (Fi) and 37-mm cassettes (Dt) are listed by establishment and by workstation in Table 5.3-4. This ratio is obtained by dividing the Fi concentration by Dt. The AM of the ratios is 2.3 (SD: 1.4) and the GM is 2.0 (GSD: 1.6).

Table 5.3-4: Ratio of the inhalable fraction (Fi)/total dust (Dt)

Est	Workstation	Fi/Dt	Fi/Dt Packaging	Fi/Dt Mixing	Fi/Dt Grinding
1	Unloading/mixing	1.4		1.4	
	Automatic packaging	2.0	2.0		
	Manual packaging	2.0	2.0		
2	Manual packaging	2.4	2.4		
	Loading/mixing	1.5		1.5	
	Unloading/mixing Seasoning 1	5.9		5.9	
3	Unloading/grinder	1.7			1.7
	Sifter/mixing	1.6		1.6	
	Automatic packaging Seasoning 1	2.5	2.5		
	Automatic packaging Seasoning 2	5.0	5.0		
4	Loading/mixing	1.3		1.3	
	Unloading/mixing	1.7		1.7	
	Grinding Seasoning 1	1.8			1.8
	Grinding Seasoning 2	1.2			1.2
	Median	1.8			

5.4 Dust characterization - Particle size distribution

5.4.1 Impactors

Five samples were collected in mixing (1 at the loading/mixing workstation, 1 at sifting/mixing, 3 at unloading/mixing), three at packaging, and two at grinding. The mass median aerodynamic diameter (MMAD) and the GSD are presented in Table 5.4-1, by establishment and by workstation.

Table 5.4-1: Particle size distribution by establishment and by workstation

Est	Workstation	MMAD (µm)	GSD
1	Unloading/mixing	**20.2 ***	**2.0**
	Automatic packaging	**25.1 ***	**2.4**
2	Manual packaging	26.9	1.8
	Loading/mixing	21.7	2.1
	Unloading/mixing Seasoning 1	31.7	1.9
3	Unloading/grinder	**18.2 ***	**2.5**
	Sifting/mixing	**18.1 ***	**1.9**
	Automatic packaging Seasoning 1	25.8	2.0
4	Unloading mixing	22.3	2.4
	Grinding Seasoning 1	**15.3 ***	**3.9**

***: Possible bimodal distribution**

The main descriptive statistical data of the particle size distribution results obtained by impactor when grouped according to three processes are summarized in Table 5.4-2.

Table 5.4-2: Descriptive statistics of the MMAD by process

	Packaging	Mixing	Grinding
n	3	5	2
Average (µm)	25.9	22.8	16.8
Standard deviation (µm)	0.9	5.2	2.1
Median (µm)	25.8	21.7	16.8
GM (µm)	25.9	22.4	16.7
GSD	1.0	1.2	1.1
Range (µm)	25.1-26.9	18.1-31.7	15.3-18.2
LCL-UCL 95% (µm)	[23.7-28.2]	[16.3-29.3]	[0-35.2]

n: Number of samples GM: Geometric mean GSD: Geometric standard deviation
LCL-UCL 95%: 95% lower-upper confidence limit

The uncorrected results and the normalized histograms of the mass fractions for each of the sampling stations by establishment are represented in the tables and figures in Appendix 1. The concentrations calculated from the masses collected by the impactor are grouped as Dti, Fii and Fri of the dusts and presented in Table 5.4-3. All of the results are grouped in the table in Appendix 2.

Table 5.4-3: Concentration calculated from the masses collected by the impactor

Est	Workstation	Corrected concentration (mg/m^3)		
		Dti	Fii	Fri
1	Unloading/mixing	**8.7***	**12 ***	**0.6 ***
	Automatic packaging	**6.6***	**9.6 ***	**0.5 ***
2	Manual packaging	3.4	5.1	0.1
	Loading/mixing	5.1	7.1	0.3
	Unloading/mixing: Seasoning 1	4.8	7.6	0.1
3	Unloading/grinder	**1.4***	**1.9 ***	**0.2 ***
	Sifting/mixing	**2.4***	**3.3 ***	**0.2 ***
	Automatic packaging: Seasoning 1	56	83	1.7
4	Unloading/mixing	2.0	2.8	0.2
	Grinding Seasoning 1	**12***	**16***	**3.8 ***

***: Possible bimodal distributions**

5.4.2 Direct-reading instrument

The mass percentage read by the GRIMM PAS 1.108 by particle size fraction is summarized by establishment and by workstation in Table 5.4-4 and illustrated in Figure 5.4-1.

Table 5.4-4: Mass percentage read by GRIMM PAS 1.108 by particle size fraction

Est	Workstation	Mass percentage read by the DRI (%)			
		0.23-4 µm	4-10 µm	10-20 µm	> 20 µm
1	Automatic packaging	7.2	32	40	21
2	Unloading/mixing	8.0	27	38	27
3	Automatic packaging	6.1	23	34	37

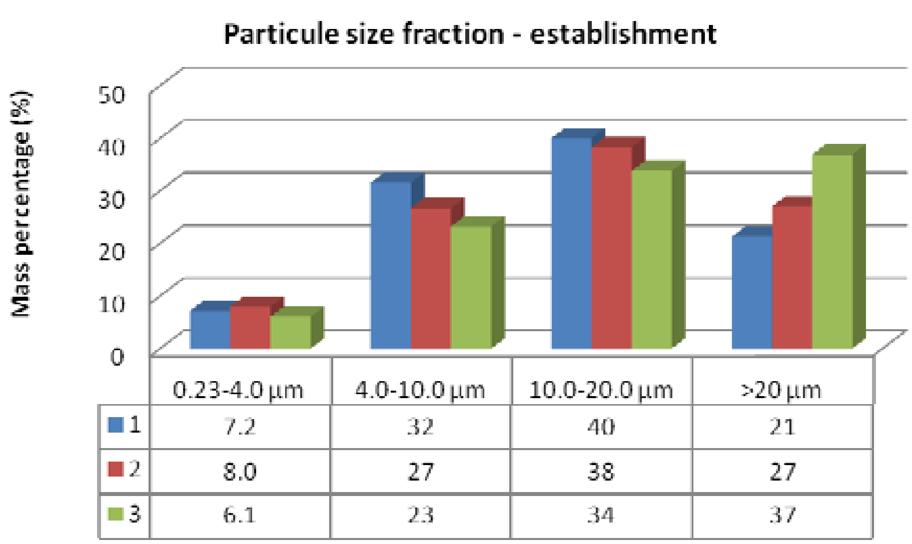


Figure: 5.4-1: Mass percentage read by the GRIMM PAS 1.108 by particle size fraction

6. DISCUSSION

6.1 Dust characterization – Environmental results

This section deals with the concentrations measured with the different samplers, comparison of the Dt and Fi concentrations, as well as an evaluation of the dust exposure at the workstations studied.

6.1.1 Dt, Fi and Fr concentrations

Despite the fact that there is no statistically significant difference, it is seen in Table 5.3-1 that the 95% confidence interval of the average of the differences is considerable for pairs of Fi and Dt samplers, which also explains the average relative difference. Fr also shows a high average difference, but this is mainly due to the low measured concentrations. The rather small number of samples could partly explain these results. Another explanation would be the much more significant dust projection that was observed during the intervention during the bag packaging process. In fact, the rapid evacuation of the air from the head space of the just-filled bags resulted in significant dust projection that would contribute to differences between the duplicates due to their directional nature.

Rather low Fr levels in the order of 0.5 mg/m³ were observed for all of the studied workstations. This observation is confirmed by the masses collected by the impactors. The median levels observed for Dt and Fi were 6 mg/m³ and 12 mg/m³ respectively. The higher levels observed for the IOM sampler (Fi) were expected because of the reduced efficiency of the 37-mm closed cassette compared to the efficiency of the IOM sampler. The highest dust levels were observed for packaging-related operations. However, these levels were approximately 6 mg/m³ for Dt for packaging and grinding operations, and around 3 mg/m³ for mixing-related operations.

6.1.2 Relationship between the inhalable fraction and total dust

The median concentrations of Dt (Table 5.3-3) were less than the median concentrations of Fi. The Wilcoxon signed rank test applied to Fi and Dt ($Z = 3.41$ and $P = 0.0007$) allowed the null hypothesis to be rejected (Fi-Dt = 0) since there was no significant difference between the two fractions. The values of the Fi/Dt ratio (Table 5.3-4) show that the relationship is different depending on the workstation. This could be explained by the respective efficiency of the samplers. In fact, the IOM sampler is more efficient for sampling larger sized particles. However, it can overestimate the portion of larger sized particles, while the 37-mm closed cassette is known for underestimating exposure to particles with an aerodynamic diameter greater than 20 µm (Vincent 2007).

The study by Perrault *et al*. (1999) reported that the Fi concentrations were approximately 2.1 times greater than the Dt concentrations, in the workers' breathing zones as well as for stationary sampling for the establishments visited in their study. The difference between the ratios obtained could be due to the different particle size distribution, as mentioned by Perrault *et al*. (1999). The dusts in this latter study are different from those in our project. The ratio can vary with the particle size distribution of the dusts present.

6.1.3 Evaluation of dust exposure

The median concentrations expressed as Dt (Table 5.3-3) are above the SSA recommendation of 3 mg/m³ and below the ROHS PEV of 10 mg/m³.

Figures 5.3-1 to 5.3-3 show significant variations in the dust concentration over time, with maximum concentrations reaching levels 30 times higher than the weighted average of 10 mg/m³. Despite the limitations of the GRIMM PAS 1.108, comparison of its results to the corresponding environmental results suggests a strong possibility of exceedence of the excursion limits as defined in Schedule I of the ROHS. This observation supports the importance of controlling exposure at source, and underlines the importance of using a DRI for occupational hygiene interventions.

Dust contamination was observed during loading of a mixer, despite the presence of a local ventilation system. The average concentration measured for 62 minutes (Dt) during unloading of seasoning 1 (into 2.5-kg containers) was 7.9 mg/m³, while that for containers larger than 500 kg was below the MRV (< 0.4 mg/m³, Table 5.3-2). The duration of this latter sample was short, namely 29 minutes.

According to the results obtained in the establishments and with respect to the median concentrations, the tasks related to automatic packaging would constitute higher risk (see equation 6.1-a). However, the risk depends mainly on the seasoning's ingredients (the particle size distribution, how easily airborne, etc.), the packaging format, the work methods and pace, etc. The limited number of samples does not allow us to arrive at a conclusion about several determinants, including the work methods.

Considering the small number of data (< 6), these can be analyzed by workstation (Table 5.3-3) according to the simplified probabilistic approach of the INRS as described in Drolet *et al.* (2010). The value of exceedence (U) of the PEV[4] is calculated from the GM and the GSD of the collected samples according to the following equation:

$$U = \frac{\mathrm{Ln}\,(PEV) - \mathrm{Ln}\,(GM)}{\mathrm{Ln}\,(GSD)} \qquad \text{equation 6.1-a}$$

Where: $U < 1.645$ the PEV is exceeded ($5\% < P$);
$1.645 < U < 3.1$ non-exceedence is uncertain;
$U > 3.1$ the PEV is not exceeded ($P < 0.1\%$).

This diagnosis is based on the probability of exceedence of the selected PEV. For the stationary samples, we obtain an exceedence value of 0.11 in packaging, of 1.18 in mixing, and 0.61 in grinding. Considering that the calculated value of U is less than 1.645 and that this approach is for personal sampling, this approach predicts exceedence of the PEV for each of the studied workstations.

[4] PEV: PNOC – 10 mg/m³ Expressed in total dusts.

6.2 Dust characterization - Particle size distribution

6.2.1 Particle size distribution profile

Variability is observed between the histograms of the collected masses (see Appendix 1). This is due to the very large diversity in the ingredients handled. In general, and even if the presence of a very small proportion of small particles is observed in several histograms, the mass median aerodynamic diameter was between 18 and 32 µm for most of the operations, except for grinding operations where it was between 15 and 18 µm. The histogram for the grinder in establishment 4 is different from the others and shows a slightly larger percentage of small particles (grinding). It is important to mention that these conclusions are based on a very small number of samples, on very variable processes, and for very different dusts.

6.2.2 Direct-reading instrument

The mass percentages read by the GRIMM PAS 1.108, reported in Table 5.4-4, show, for the three establishments, that the mass median diameters are situated in the 10–20 µm interval. This value, without being identical, is close to that of the MMAD obtained by the impactors. It is normal to observe a difference between the optical diameter measured by an optical counter (GRIMM PAS 1.108) and the aerodynamic diameter obtained by impactor (see section 4.1). In addition, by assuming that the optical diameter is close to the geometric diameter and that the density of the particles is greater than 1.0, it is normal for the geometric diameter to correspond to a larger aerodynamic diameter.

6.3 Relationship between the fractions (Fi, Fr and Dt) collected by the samplers and those calculated from the impactor data

The results of the inhalable fractions (Fii) obtained by multiplying an IOM sampler's theoretical efficiency curve by the impactor data are less than those obtained from the IOM samplers. The latter collect, based on the median of the corrected results, 1.4 times more dust (Table 6.3-1, Appendix 3). This could be due to the corrections applied according to the manufacturer's curves which are limited to a diameter of 30 µm, but also to the fact that the IOM samplers can overevaluate the Fi (Vincent 2007).

Table 6.3-1: Relationship between the environmental results and the impactor results

Est	Workstation	Fi/Fii
1	Unloading/mixing	1.2
	Automatic packaging	1.3
2	Manual packaging	1.3
	Loading/mixing	1.6
	Unloading/ mixing Seasoning 1	2.1
3	Unloading/grinder	1.0
	Sifting/mixing	1.4
	Automatic packaging Seasoning 1	1.4
4	Unloading/mixing	1.5
	Grinding Seasoning 1	1.4
	Median	**1.4**

The 37-mm closed cassettes (Dt) collected an amount equivalent to those evaluated by the impactors (Dti) (Appendix 3). This seems to confirm that the curve used and traced using the results in the literature (Figure 4.3-1) is a good indicator of the equivalent fraction for the 37-mm closed cassettes.

The results for the Fr collected using cyclones are substantially lower than those obtained using the impactors. Based on the medians, this relationship is approximately 0.5 (Appendix 3). It is difficult to come to a conclusion about this relationship because of the small mass collected during sample collection and because several results are below the method's MRV.

The ratio between the fraction of the inhalable fraction that an ideal sampler should collect and that of a 37-mm cassette should be around 1.4 for the dusts studied here and based on the corrected results for the impactors. The ratio measured by the environmental samples (Table 6.3-2) is around 1.8. This higher ratio could be due to overevaluation by the IOM sampler or to variations related to the corrections of the impactor data which are a function of the fine structure of the dusts.

Table 6.3-2: Ratios of the inhalable fractions (Fi and Fii) to the Dt and Dti dusts

Est	Workstation	Fi/Dt	Fii /Dti
1	Unloading/mixing	1.4	**1.4**
	Automatic packaging	2.0	**1.5**
2	Manual packaging	2.4	1.5
	Loading/mixing	1.5	1.4
	Unloading/mixing Seasoning 1	5.9	1.6
3	Unloading/grinder	1.7	**1.4**
	Sifting/mixing	1.6	**1.4**
	Automatic packaging Seasoning 1	2.5	1.5
4	Unloading/mixing	1.7	1.4
	Grinding Seasoning 1	1.8	**1.3**
	Median	**1.8**	**1.4**

6.4 Limitations of the study

This report's results apply to establishments in the food seasonings production industry, namely establishments whose description is similar to those in the study of Chirane *et al*. (2009). Extrapolations to other workplaces producing seasonings must be done with care.

The results correspond to stationary sampling concentration levels and not to personal sampling concentrations. The DAEVs calculated for stationary sampling are not necessarily representative of personal exposures; a major difference may exist between samples at these two sampling stations due to the distance.

Despite the fact that the impactor data are corrected according to the manufacturer's specifications, the impactor concentration ($Conc_i$) is an evaluation of the ambient concentration. Closed cassettes (Dt) sample this concentration more or less efficiently.

Finally, the limited number of samples per workstation and grouping by process as well as the variety of ingredients are factors contributing to the limitations of this project in this sector (food seasonings). This limitation is such that the precision related to sampling and field manipulations in IRSST method 373 (inhalable dusts) could not be appropriately evaluated in this type of environment.

6.5 Recommendations

A larger number of samples would validate this project's conclusions; these conclusions must be considered as preliminary due to the limited number of samples.

Stationary sampling in parallel with the evaluation of personal exposures would document the exposure of workers in this food industry. In addition, the concept of work practices could be documented more specifically in order to demonstrate the evidence of the link between certain practices and the risk.

7. CONCLUSION

Differences were observed between the results of the Fi duplicates, regardless of the workstation. These prevent us from arriving at a conclusion about the field validation of this method.

A mean ratio around 2.3 and a median of 1.8 were determined between the Fi and Dt. This ratio shows that the IOM sampler collects higher concentrations. An ideal sampler for the inhalable fraction must theoretically collect higher concentrations than a total dust sampler.

Although measured by stationary sampling, the exposure values (DAEV) obtained at the studied workstations are below the Québec permissible exposure value (PEV) of 10 mg/m³, except in packaging in one of the establishments; however, some are above the SSA recommendation of 3 mg/m³.

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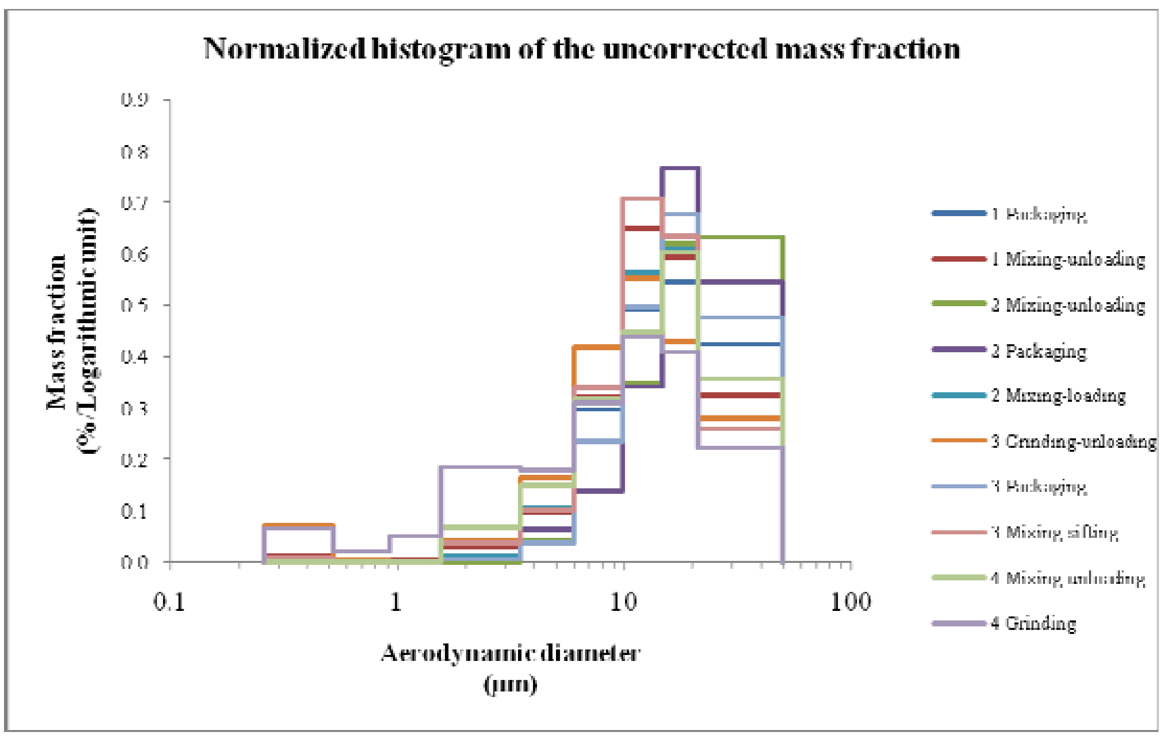
APPENDIX 1: RESULTS AND HISTOGRAMS OF THE MASS FRACTION BY WORKSTATION BY ESTABLISHMENT

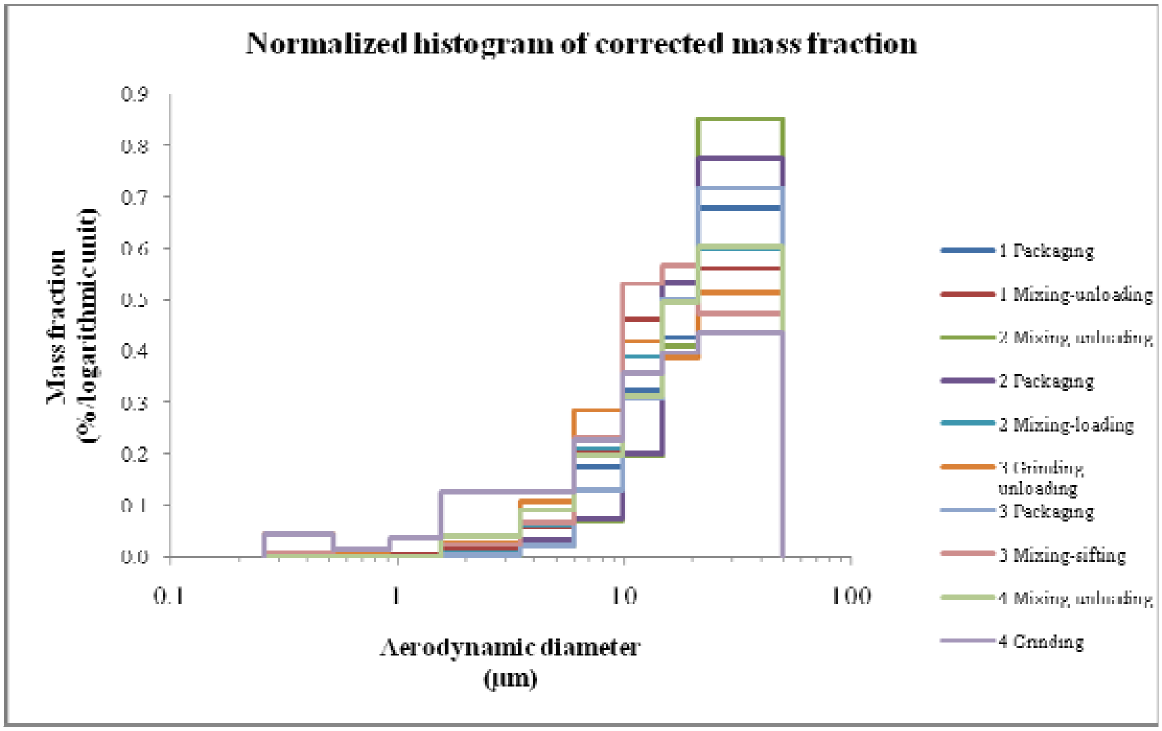
Particle size distribution by establishment and by workstation

Est	Workstation	Uncorrected MMAD	Uncorrected GSD	Corrected MMAD	Corrected GSD
1	Unloading/mixing	**14.9 µm ***	**1.8**	**20.2 µm ***	**2.0**
	Automatic packaging	**16.5 µm ***	**2.1**	**25.1 µm ***	**2.4**
2	Manual packaging	20.8 µm	1.8	26.9 µm	1.8
	Loading/mixing	15.4 µm	1.9	21.7 µm	2.1
	Unloading/mixing Seasoning 1	22.6 µm	1.8	31.7 µm	1.9
3	Unloading/grinder	**12.3 µm ***	**2.1**	**18.2 µm ***	**2.5**
	Sifting/mixing	**14.0 µm***	**1.7**	**18.1 µm ***	**1.9**
	Automatic packaging Seasoning 1	18.5 µm	1.8	25.8 µm	2.0
4	Unloading mixing	14.8 µm	2.2	22.3 µm	2.4
	Grinding Seasoning 1	**9.0 µm ***	**3.1**	**15.3 µm ***	**3.9**

***:** **Possible bimodal distribution**

Histograms for all the workstations in the visited establishments




Normalized histogram of corrected mass fraction
Mass fraction
(%/logarithmic unit)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.1
1
10
100
Aerodynamic diameter
(µm)
1 Packaging
1 Mixing-unloading
2 Mixing, unloading
2 Packaging
2 Mixing-loading
3 Grinding, unloading
3 Packaging
3 Mixing-sifting
4 Mixing, unloading
4 Grinding

APPENDIX 2: CONCENTRATIONS CALCULATED FROM THE MASSES COLLECTED BY THE IMPACTOR AND BASED ON THE EFFICIENCY CURVE

		Concentration (mg/m³)							
		Uncorrected				Corrected			
Est	Workstation	$Conc_i$	Dti	Fii	Fri	$Conc_i$	Dti	Fii	Fri
1	Unloading/mixing	**10.8 ***	**5.8***	**7.6 ***	**0.6 ***	**18.6 ***	**8.7***	**12.2 ***	**0.6 ***
	Automatic packaging	**8.0 ***	**4.1***	**5.5 ***	**0.5 ***	**15.0 ***	**6.6***	**9.6 ***	**0.5 ***
2	Manual packaging	4.0	1.8	2.6	0.1	8.3	3.4	5.1	0.1
	Loading/mixing	6.2	3.2	4.3	0.3	10.9	5.1	7.1	0.3
	Unloading/mixing: Seasoning 1	5.7	2.5	3.6	0.1	12.5	4.8	7.6	0.1
3	Unloading/grinder	**1.7 ***	**1.0***	**1.3 ***	**0.2 ***	**2.8 ***	**1.4***	**1.9 ***	**0.2 ***
	Sifting/mixing	**3.0 ***	**1.7***	**2.2 ***	**0.2 ***	**4.9 ***	**2.4***	**3.3 ***	**0.2 ***
	Automatic packaging: Seasoning 1	67.3	32.4*	44.8	1.6	132.4	55.7	83.2	1.7
4	Unloading/mixing	2.4	1.3	1.7	0.2	4.3	2.0	2.8	0.2
	Grinding Seasoning 1	**14.7 ***	**7.1***	**11.3 ***	**3.7 ***	**22.0 ***	**12.3***	**15.7 ***	**3.8 ***

***: Two possible modes**

APPENDIX 3: RATIO OF THE ENVIRONMENTAL RESULTS TO THE IMPACTOR'S UNCORRECTED AND CORRECTED RESULTS

Est	Workstation	Environmental /impactor results ratio					
		Uncorrected impactor			Corrected impactor		
		Dt /Dti	Fi/Fii	Fr/Fri	Dt /Dti	Fi/Fii	Fr/Fri
1	Unloading/mixing	**1.9**	**2.0**	**0.8**	**1.3**	**1.2**	**0.8**
	Automatic packaging	**1.4**	**2.2**	**1.2**	**0.9**	**1.3**	**1.2**
2	Manual packaging	1.6	2.6		0.8	1.3	
	Loading/mixing	2.5	2.7		1.5	1.6	
	Unloading/ mixing Seasoning 1	1.1	4.4		0.6	2.1	
3	Unloading/grinder	**1.1**	**1.5**	**0.5**	**0.8**	**1.0**	**0.5**
	Sifting/mixing	**1.8**	**2.1**	**0.5**	**1.3**	**1.4**	**0.5**
	Automatic packaging Seasoning 1	1.5	2.7	0.4	0.9	1.4	0.4
4	Unloading/mixing	1.9	2.5	1.0	1.3	1.5	1.0
	Grinding Seasoning 1	**1.7**	**1.9**	**0.3**	**1.0**	**1.4**	**0.3**
	Median	**1.6**	**2.3**	**0.5**	**0.9**	**1.4**	**0.5**