

1st Trimester National Microbiological Survey 2006 (06NS1):

Microbiological Safety/Quality of Raw Mushrooms

Table of Contents

Executive Summary	3
1. Introduction	4
2. Specific Objectives	5
3. Method	5
3.1 Sample source	5
3.2 Sample description	5
3.3 Sample collection	5
3.4 Sample analysis & reporting of results	6
3.5 Assessment of results	6
3.6 Follow-up/enforcement action	7
3.7 Questionnaire data	7
3.8 Statistical analysis	7
4. Results and Discussion	8
4.1 Microbiological results	8
4.1.1 <i>Salmonella</i> spp.	8
4.1.2 <i>Listeria monocytogenes</i>	10
4.1.3 <i>Staphylococcus aureus</i>	12
4.1.4 <i>Escherichia coli</i>	13
4.2 Questionnaire data	14
4.2.1 Information on sample source	14
4.2.2 Information on the sample	16
4.2.3 Information on storage conditions	18
5. Conclusions	20
6. Bibliography	21
7. Appendices	23

Executive Summary

This survey investigated the microbiological safety (*Salmonella* spp., *Listeria monocytogenes* and *Staphylococcus aureus*) and the microbiological quality (*Escherichia coli*) of raw mushrooms on retail sale in the Republic of Ireland.

Harmonised microbiological criteria are laid down in Commission Regulation (EC) No 2073/2005 for some food/pathogen combinations. Where applicable, the results of this survey were assessed against these criteria. Otherwise, the results were assessed against the national microbiological guidelines for ready-to-eat foods sampled at the point of sale (Food Safety Authority of Ireland, Guidance Note No. 3). The following were the main findings:

- *Salmonella* spp. were not detected in any sample, thus:
 - ❖ all sliced mushrooms were classified as satisfactory for *Salmonella* spp. when assessed against the microbiological criterion specified in Commission Regulation (EC) No 2073/2005 and
 - ❖ all whole mushrooms were classified as satisfactory for *Salmonella* spp. when assessed against the national microbiological guidelines.
- *L. monocytogenes* was detected in 1.1% (8/727) of samples but was not quantified at levels >100 cfu/g in any sample. Therefore, all samples were classified as satisfactory for *L. monocytogenes* when assessed against the microbiological criterion specified in Commission Regulation (EC) No 2073/2005.
- 99.2% of samples were classified as satisfactory when assessed against the national microbiological guidelines for *S. aureus*.
- all samples were classified as satisfactory when assessed against the national microbiological guidelines for *E. coli*.

1. Introduction

Mushrooms are the edible fleshy fruiting bodies of certain fungi. The most commonly cultivated mushroom species is *Agaricus bisporus*, although many other species are now gaining importance.

Mushroom compost (i.e. a pasteurised mixture of wheat straw, poultry/horse manure, gypsum and water) inoculated with mushroom spawn (i.e. grain colonised with mushroom mycelium) is the starting material for mushroom cultivation and is produced by dedicated composting companies. Once colonised with mushroom mycelium, the compost is covered with a layer of casing soil (mixture of peat and limestone). The environmental conditions within the climate controlled tunnels are then manipulated firstly to encourage colonisation of the casing layer and secondly to initiate mushroom pinning (growth). The mushroom crop grows in repeating 3 to 5-day cycles called "flushes". Mushrooms are generally harvested by hand from 4 to 5 flushes.

The mushroom industry has been one of the big success stories of the Irish food industry. One of the key success factors has been the development of the satellite mushroom growing system. Under this system, a centralised compost/marketing company supplies compost to the grower who cultivates the mushrooms. The mushrooms are then supplied back to the centralised compost/marketing company for marketing ⁽¹⁾. The UK retail multiples and the home market are the most important outlets for Irish mushrooms. Output from the Republic of Ireland is currently valued at over €115m ⁽²⁾.

Despite its success, the Irish mushroom industry has experienced problems in recent years including increased production costs (e.g. labour, packaging & insurance), downward price pressures, investment issues and environmental issues ^(3,4). To secure the future viability of this sector, The Mushroom Task Force which was set up by the Minister of State, Mr. Noel Tracey TD devised an action plan to address these issues ⁽⁴⁾.

The future viability of this sector depends not only on commercial/economical issues but also on the safety of Irish mushrooms. Mushrooms (like many fruit and vegetables) are eaten in their raw and cooked form and therefore it is important that they are free from contamination (both microbiological and chemical). In 2001, the viability of the Irish mushroom industry was threatened when *Salmonella* Kedougou (an uncommon serovar of *Salmonella* spp.) was isolated from Irish commercially grown mushrooms on sale in the United Kingdom ⁽⁵⁾. Investigations revealed that the contamination originated from sugar beet lime, an alkaline material used in the casing soil. To address the problem all casing manufacturing sites underwent a thorough sanitisation program and a code of practice was developed for casing manufacturers. In addition, the Food Safety Authority of Ireland (FSAI) issued advice to commercial caterers and consumers to cook all mushrooms ⁽⁶⁾. These activities resulted in the elimination of the contamination and the absence of human salmonellosis ⁽⁷⁾. It is now timely to re-examine this advice and to assess the microbiological quality and safety of mushrooms on retail sale in Ireland.

2. Specific Objectives

The aim of this study was to investigate the microbiological safety (*Salmonella* spp., *Listeria monocytogenes* and *Staphylococcus aureus*) and the microbiological quality (*Escherichia coli*) of raw mushrooms on retail sale in the Republic of Ireland.

3. Method

3.1 Sample source

Environmental Health Officers (EHOs) were requested to sample raw mushrooms from the following premises:

- Retail premises (including supermarkets, corner shops, fruit & vegetable shops, fruit & vegetable stalls)
- Catering premises (particularly catering premises where mushrooms were supplied direct from the primary producer)
- Distributors/packers (including central distribution centres, wholesalers, importers and packers)

3.2 Sample description

Raw mushrooms were sampled. Samples included:

- Whole and sliced mushrooms
- Loose and pre-packed mushrooms
- All varieties of mushrooms, i.e. white, brown and exotic mushrooms (e.g. shiitake, oyster, chanterelle etc)
- All sizes of mushrooms, i.e. buttons, cups and flats
- All qualities of mushrooms, i.e. value packs, prime mushrooms, etc.
- Washed and unwashed mushrooms
- Irish and imported mushrooms

The following mushrooms were specifically excluded from this survey:

- Tinned mushrooms
- Value added mushrooms (e.g. garlic mushrooms)
- Dried mushrooms
- Cooked mushrooms

3.3 Sample collection

Sampling was undertaken by EHOs from the Health Service Executive (HSE) during January, February & March 2006. In every premises, only one sample of each type of mushroom was obtained for each producer/supplier (sample weight = 200g). Loose mushrooms were obtained in a manner similar to that which would be used to serve customers.

Sample temperature was measured at the time of sampling as follows:

- Loose samples: The core temperature of the sample was measured using an insertion probe taking care not to damage the mushrooms.

- Pre-packed samples: Two pre-packed samples were pressed together and the temperature between the packs was measured (the two packs were from the same production batch and were stored under identical conditions).

Sample temperatures, storage conditions, premises information and sample information were recorded on the questionnaire provided (Appendix 1) at the time of sampling.

3.4 Sample analysis & reporting of results

Analysis was undertaken in the HSE Official Food Microbiology Laboratories (OFMLs). Samples were analysed for:

- *Salmonella* spp.
- *Listeria monocytogenes* (both qualitative and quantitative)
- *Staphylococcus aureus* and
- *Escherichia coli*

The OFMLs reported the microbiological results to the FSAI and the relevant EHO.

3.5 Assessment of results

The microbiological results were assessed against:

- i) the microbiological criteria laid down in *Commission Regulation No. 2073/2005 on Microbiological Criteria for Foodstuffs* ⁽⁸⁾ or
- ii) the 2001 national microbiological guidelines ‘*Guidelines for the Interpretation of Results of Microbiological Analysis of Some Ready-To-Eat Foods Sampled at Point of Sale*’ (FSAI Guidance Note No.3) ⁽⁹⁾

(Note: Where a microbiological criterion is laid down in legislation it takes precedence over a microbiological guideline)

i) Commission Regulation (EC) No 2073/2005

Harmonised European microbiological criteria are laid down in Commission Regulation (EC) No 2073/2005. Although this Regulation does not lay down criteria specifically for raw mushrooms, it lays down:

- a food safety criterion for *Salmonella* spp. in pre-cut fruit and vegetables and
- a food safety criterion for *L. monocytogenes* in ready-to-eat (RTE) food.

These criteria are applicable to raw mushrooms sampled at retail level and are summarised in Table 1.

Table 1: Food safety criteria laid down in Commission Regulation 2073/2005 which are applicable to raw mushrooms

Food category	Micro-organism	Satisfactory
Pre-cut fruit and vegetables	<i>Salmonella</i> spp.	Absence in 25g
Ready-to-eat foods*	<i>Listeria monocytogenes</i>	≤100cfu/g

* Raw mushrooms were considered RTE foods

Thus:

- pre-cut mushrooms (i.e. sliced mushrooms) were assessed against the food safety criterion for *Salmonella* spp.
- all mushrooms (i.e. whole & sliced mushrooms) were assessed against the food safety criterion for *L. monocytogenes*.

ii) National microbiological guidelines (FSAI Guidance Note No. 3)

Where harmonised European microbiological criteria do not exist, the results were assessed against the national microbiological guidelines, i.e:

- Whole mushrooms were assessed against the guideline for *Salmonella* spp.
- All mushrooms (i.e. whole & sliced mushrooms) were assessed against the guideline for *S. aureus* &
- All mushrooms (i.e. whole & sliced mushrooms) were assessed against the guideline for *E. coli*

These guidelines are outlined in Table 2:

Table 2: Microbiological guidelines for RTE foods[¥] sampled at the point of sale

Type of parameter	Parameter	Microbiological safety/quality (cfu/g)			
		Satisfactory	Acceptable	Unsatisfactory	Unacceptable/ Potentially hazardous
Pathogen	<i>Salmonella</i> spp.	Not detected in 25g	N/A	N/A	Detected in 25g
	<i>Staphylococcus aureus</i>	<20	20 to <100	100 to <10 ⁴	≥10 ⁴
Indicator	<i>Escherichia coli</i>	<20	20 to <100	≥100	N/A

[¥] Raw mushrooms were considered RTE foods

N/A: Not Applicable

3.6 Follow-up/enforcement action

EHOs were advised to undertake follow-up action on samples categorised as unsatisfactory or unacceptable/potentially hazardous.

3.7 Questionnaire data

Upon receipt of the laboratory results, EHOs completed the questionnaire (Appendix 1) and returned it to the FSAI within 2 months of the survey completion date.

3.8 Statistical analysis

Results were analysed at a 95% confidence interval using the Z-test for two proportions.

4. Results and Discussion

4.1 Microbiological results

A total of 727 samples submitted from the 10 HSE areas (Appendix 2) were analysed in the 7 OFMLs (Appendix 3).

4.1.1 *Salmonella* spp.

Salmonellae are pathogens which are one of the most common causes of bacterial food poisoning. Salmonellosis (i.e. the disease caused by *Salmonella enterica*) is principally a food borne disease, although other possible routes of transmission include contact with infected animals or their faecal material, person to person spread and nosocomial infection. In Ireland, 357 clinical isolates of *S. enterica* were referred to the National Salmonella Reference Laboratory in 2005 (crude incidence rate of 8.9 cases per 100,000 population)⁽¹⁰⁾.

Salmonellae reside in the intestinal tract of infected animals and humans and are shed in the faeces. Foods subject to faecal contamination (e.g. agricultural products, meat) are among those which have been implicated as vehicles in the transmission of this pathogen to humans⁽¹¹⁾. Contamination of agricultural products can occur at any stage during cultivation, harvest or post harvest.

Mushrooms have been linked with salmonella contamination. In 2001, *Salmonella* Kedougou (an uncommon serovar of *Salmonella* spp.) was isolated from Irish commercially grown mushrooms on sale in the UK but fortunately there were no associated human cases of infection. In 2003, an outbreak of *Salmonella* Heidelberg in the USA was linked to mushrooms. In that outbreak 65 cases of salmonellosis were identified and 39 were laboratory confirmed⁽¹²⁾.

In this survey, 727 samples were tested for *Salmonella* spp. This pathogen was not detected in any sample (Table 3 & Appendix 4).

Table 3: Results for *Salmonella* spp. (presence/absence) in raw mushrooms

No. of samples (%)		
<i>Salmonella</i> spp. present in 25g	<i>Salmonella</i> spp. absent in 25g	Total
0 (0%)	727 (100%)	727 (100%)

The samples analysed consisted of both sliced (n=51) and whole (n=538) mushrooms. Both were classified as satisfactory when assessed against the relevant criterion or guideline (see section 3.5). The remaining 138 samples could not be assessed as the nature of these samples (i.e. sliced/whole) was unreported (Table 4).

Table 4: Classification of samples based on salmonella results

Nature of sample	No. of samples	Classification of samples based on food safety criteria specified in Regulation 2073/2005		Classification of samples based on the national microbiological guidelines	
		Satisfactory	Unsatisfactory	Satisfactory	Unacceptable/potentially hazardous
Sliced	51	51 (100%)	0 (0%)	N/A	N/A
Whole	538	N/A	N/A	538 (100%)	0 (0%)
Unreported	138	N/A	N/A	N/A	N/A

The findings of this national survey are significantly different ($p < 0.05$) to the findings of a US study⁽¹³⁾, where salmonella was detected in 5% (5/100) of mushroom samples.

4.1.2 *Listeria monocytogenes*

L. monocytogenes is ubiquitous in the environment and is present in many raw foods including fruit and vegetables. The presence of this pathogen in ready-to-eat (RTE) foods raises concern as it is capable of proliferating under refrigerated temperatures. Levels of *L. monocytogenes* >100cfu/g at the point of consumption is considered to represent a risk to consumers ⁽¹⁴⁾ (i.e. it can cause listeriosis[‡] in susceptible members of the population).

In this survey, 727 mushroom samples were analysed qualitatively (i.e. presence/absence test) for *L. monocytogenes* (Table 5 & Appendix 5). *L. monocytogenes* was detected in 1.1% (8/727) of samples.

Table 5: Qualitative results for *L. monocytogenes* (i.e. presence/absence) in pre-packaged mixed salad

Number of samples (%)		
<i>L. monocytogenes</i> present in 25g	<i>L. monocytogenes</i> absent in 25g	Total
8 (1.1%)*	719 (98.9%)	727 (100%)

* Sample information was available for 6 of the 8 samples in which *L. monocytogenes* was detected. The pathogen was detected in both loose and pre-packed mushrooms; buttons, cups & flats; white/brown and exotic mushrooms.

The findings of other surveys are summarised in Table 6. There is no significant difference (p=0.05) in the prevalence of positive samples between these surveys and this Irish survey.

[‡] Listeriosis is the disease caused by *L. monocytogenes*.

Table 6: *L. monocytogenes* in raw mushrooms – A comparison with other surveys

Reference	Location of study	Period of study	No. of samples	No. of samples positive for <i>L. monocytogenes</i>
13	US	2006*	100	1 (1.0%)
15	US	Oct '87-Aug '88	92	0 (0%)
16	Norway	May '99 to Feb '00 & April '00 – Jan '01	156	1 (0.6%)
This study	Ireland	Jan '06 – March '06	727	8 (1.1%)

* This is the publication date of the article, the date of the study was not provided

In this survey, quantitative analysis (Table 7 & Appendix 5) was carried out on 722 samples (this included the 8 samples in which *L. monocytogenes* was detected qualitatively). The results were assessed against the microbiological criteria laid down in *Commission Regulation No. 2073/2005 on Microbiological Criteria for Foodstuffs* (see section 3.5). *L. monocytogenes* was not detected at levels >20cfu/g in any sample, therefore, all samples were classified as satisfactory.

Table 7: Microbiological safety of raw mushroom samples based on *L. monocytogenes* count

No. of samples tested	Classification of samples based on the food safety criterion for <i>L. monocytogenes</i> in RTE foods specified in Regulation 2073/2005	
	Satisfactory (i.e. <100cfu/g)	Unsatisfactory (i.e. >100cfu/g)
722*	722 (100%)	0 (0%)

*A total of 727 samples were submitted for analysis; however, 5 samples submitted from the Midlands Area were not tested quantitatively for *L. monocytogenes*. These 5 samples were tested qualitatively and *L. monocytogenes* was not detected in any sample.

4.1.3 *Staphylococcus aureus*

S. aureus is a pathogenic bacterium which is a common cause of food poisoning. Staphylococcal food poisoning is caused by ingestion of a heat stable toxin formed by *S. aureus* in the food (the bacterium must grow to levels $>10^5$ cells/g before producing sufficient quantities of the heat-stable staphylococcal toxin to cause illness ⁽¹⁷⁾). Both the onset and the severity of the symptoms depend on the susceptibility of the person and the amount of toxin consumed. The main symptoms include abdominal cramps, vomiting and diarrhoea ⁽¹⁸⁾. In Ireland, 6 notifications of staphylococcal food poisoning were reported to the Health Protection Surveillance Centre (HPSC) in 2005 ⁽¹⁰⁾.

Food handlers are commonly implicated in the transmission of this pathogen to food (it is estimated that up to 50% of humans are carriers of this bacterium on their skin, nose and throat ⁽¹⁸⁾). As raw mushrooms undergo considerable handling during harvesting and packing, it was considered important to investigate the incidence of *S. aureus* in this commodity.

A total of 727 samples were tested for *S. aureus*. There is no microbiological criterion specified in legislation for this pathogen/food combination; therefore, the results were assessed against the 2001 national microbiological guidelines (see section 3.5). 99.2% (721/727) of samples were classified as satisfactory for this pathogen; 0.5% (4/727) were classified as acceptable and 0.3% (2/727) were classified as unsatisfactory. No sample was classified as unacceptable/potentially hazardous (Table 8 & Appendix 6).

Table 8: Microbiological safety of raw mushroom samples based on *S. aureus* count

Total no. of samples tested	Microbiological safety			
	Satisfactory	Acceptable	Unsatisfactory	Unacceptable/ Potentially hazardous
727 (100%)	721 (99.2%)	4 (0.5%)	2 (0.3%)	0 (0%)

Details of the two samples classified as unsatisfactory for *S. aureus* are outlined in Table 9.

Table 9: Details of samples (n=2) classified as unsatisfactory for *S. aureus*

Detail	Sample 1	Sample 2
<i>S. aureus</i> count	200 cfu/g	6500 cfu/g
Sample source	Fruit & vegetable shop	Central distribution centre
Whole/sliced mushrooms	Whole	Whole
Type of packaging	Loose	Pre-packed
Mushroom size	Cups	Cups
Variety of mushroom	White/brown mushrooms	White/brown mushrooms
Mushroom quality	Prime	Value-pack
Washed/Unwashed	Unwashed	Washed
Storage conditions	Ambient	Ambient
Sample temperature	8.8°C (core temp. of loose mushrooms)	4°C (between pack temp. measurement)

Follow-up action was taken on both unsatisfactory samples by the relevant EHO. In both cases written advice was issued to the proprietors of the premises where the mushrooms were sampled. In addition, a repeat sample of sample 2 was submitted for analysis. This repeat sample was satisfactory for *S. aureus*.

4.1.4 *Escherichia coli*

E. coli is an enteric organism. Most strains of *E. coli* are harmless; however, several are known to be pathogenic. The pathogenic strains may be categorised based on the mechanism underlying the illness. Currently four categories of pathogenic *E. coli* have been associated with foodborne illness: Enteropathogenic (EPEC), Enterotoxigenic (ETEC), Enteroinvasive (EIEC) and Enterohaemorrhagic (EHEC) *E. coli* ⁽¹⁹⁾.

E. coli is often used as an indicator of faecal contamination in food.

In this study, a total of 727 samples were tested for *E. coli*. There is no microbiological criterion specified in legislation for this pathogen/food combination; therefore, the results were assessed against the 2001 national microbiological guidelines (see section 3.5). All samples were classified as satisfactory for this organism (Table 10 & Appendix 7).

Table 10: Microbiological quality of raw mushroom samples based on *E. coli* count

Total no. of samples tested	Microbiological quality		
	Satisfactory	Acceptable	Unsatisfactory
727 (100%)	727 (100%)	0 (0%)	0 (0%)

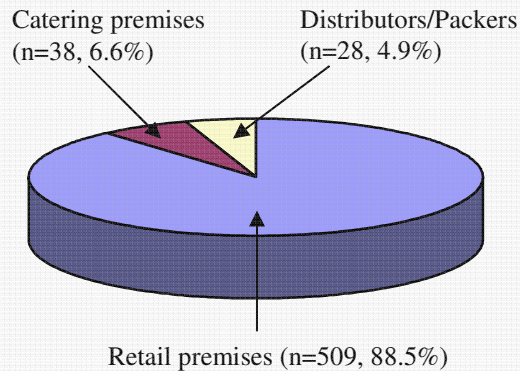
4.2 Questionnaire data

Information on 1) the sample source, 2) the sample and 3) the storage conditions was captured by means of a questionnaire (Appendix 1). Questionnaires were returned for 607 samples, i.e. 83.5% (607/727) response rate. This section of the report summarises the data captured via the questionnaires.

4.2.1 Information on sample source

Information on sample source was available for 575 samples. The majority of samples (88.5%, 509/575) were obtained from retail premises. The remainder of samples were obtained from catering premises and distributors/packers (Figure 1).

Figure 1: Sample source (n=575*)



* Questionnaires were returned for 607 samples; however, information regarding sample source was not provided for 4 samples and this information could not be elucidated from the questionnaires for a further 28 samples.

Further detail on the sample source is provided in Table 11.

Table 11: Further detail on the sample source

Type of premises	Details regarding premises	Number of premises
Retail premises	Supermarket	369 (72.5%)
	Fruit & vegetable shop	77 (15.1%)
	Corner shop	44 (8.6%)
	Other	19 (3.7%)
	Total retail premises	509 (100%)
Catering premises	Restaurant	21 (55.3%)
	Hotel	3 (7.9%)
	Other	14 (36.8%)
	Total catering premises	38 (100%)
Distributor/Packer	Wholesalers	18 (64.3%)
	Central distribution centres	6 (21.4%)
	Importers	1 (3.6%)
	Packers	3 (10.7%)
	Total distributors/packers	28 (100%)

4.2.2 Information on the sample

Information was captured on the:

- Nature of the mushrooms (i.e. whole or sliced)
- Type of packaging (i.e. loose or pre-packed)
- Mushroom size (i.e. buttons, cups, flats or mixed)
- Mushroom variety (i.e. white/brown or exotic)
- Mushroom quality (i.e. prime, value-pack etc)
- Cleanliness of the mushrooms (i.e. whether they had been washed or not)

These data are presented in Figures 2 to 7.

The majority of samples were whole (88.6%, 538/607), pre-packed (55.5%, 337/607) mushrooms (Figures 2 & 3).

The three main categories of mushrooms, i.e. buttons, cups and flats were sampled in this survey. Each category represents a different stage of maturity. Buttons are small unopened mushrooms, cups are older buttons where the cap has begun to open and flats (often referred to as breakfast flats or portobello mushrooms) are cups that have fully expanded to expose all of the gills. Mushrooms may be picked at the button, cup or flat stage depending on market requirements. In this survey buttons and cups accounted for 85.9% (521/607) of all samples (Figure 4).

The vast majority of mushrooms grown for the Irish market are white or brown mushrooms; however, consumer demand had led to an increase in the importation of exotic and minor mushrooms such as shiitake, oyster and chanterelles. A small number of specialist mushroom growers are growing shiitake mushrooms in Ireland. In this survey white/brown mushrooms accounted for 91.1% (553/607) of all samples and exotic mushrooms accounted for 3.6% (22/607) of samples (Figure 5).

Quality standards are often used by mushroom companies as marketing tools (quality standards are defined by a combination of parameters such as mushroom whiteness, texture, length of stalk etc.). Prime/Class 1/Premier are the highest quality mushrooms. Information on mushroom quality was available for 47.1% (286/607) of mushrooms sampled in this survey. 38.2% (232/607) of mushrooms were prime/Class 1 mushrooms while 8.9% (54/607) were value-packs (Figure 6).

Mushrooms are often washed prior to sale to improve appearance and consumer appeal by removing casing residues from the mushroom surface. Washed mushrooms also show less enzymatic browning during the first few days of storage ⁽²⁰⁾. In this study 6.8% (41/607) of mushrooms were washed, 49.4% (300/607) of mushrooms were unwashed and this information was not known or was not provided for the remaining 43.8% (266/607) of samples (Figure 7).

Figure 2: Nature of mushrooms (whole/sliced)

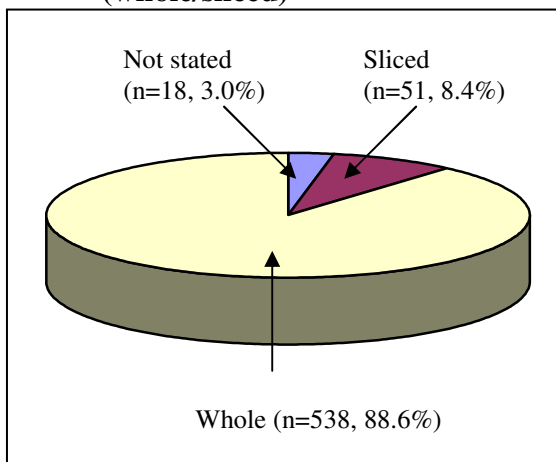


Figure 3: Type of packaging

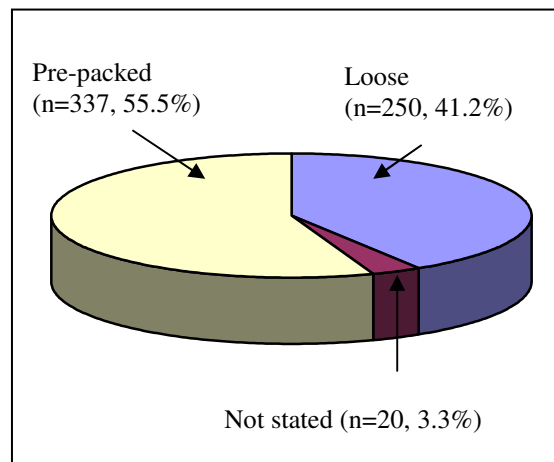


Figure 4: Mushroom size

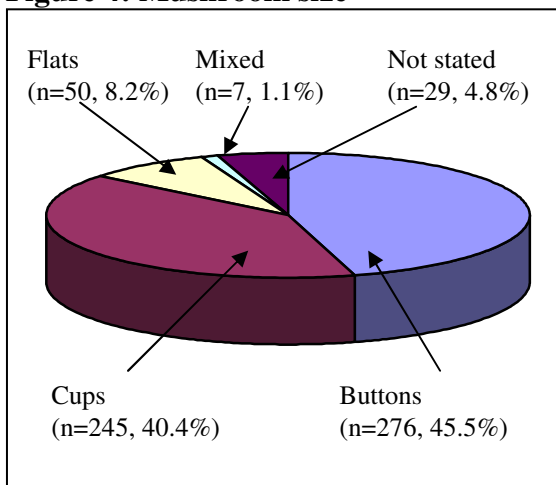


Figure 5: Mushroom variety

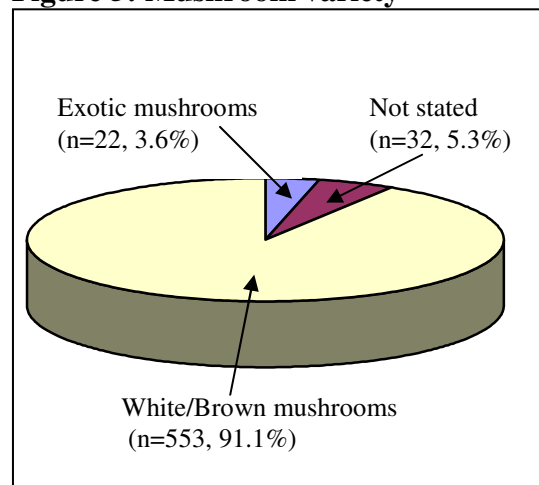


Figure 6: Mushroom quality

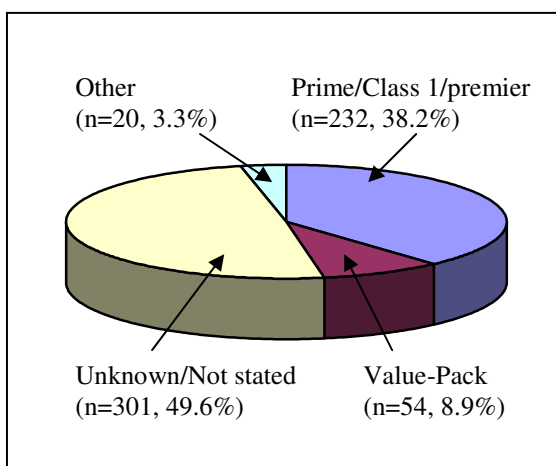
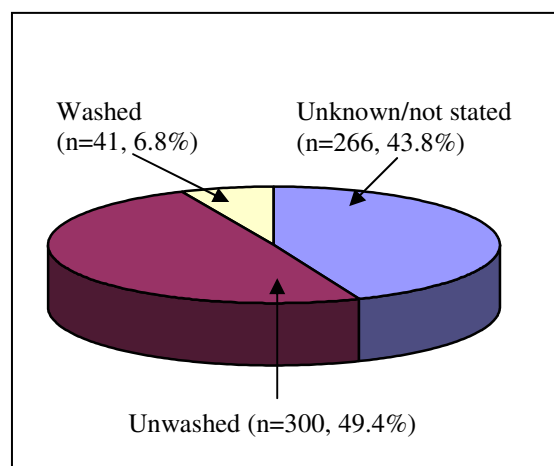


Figure 7: Washed/Unwashed status

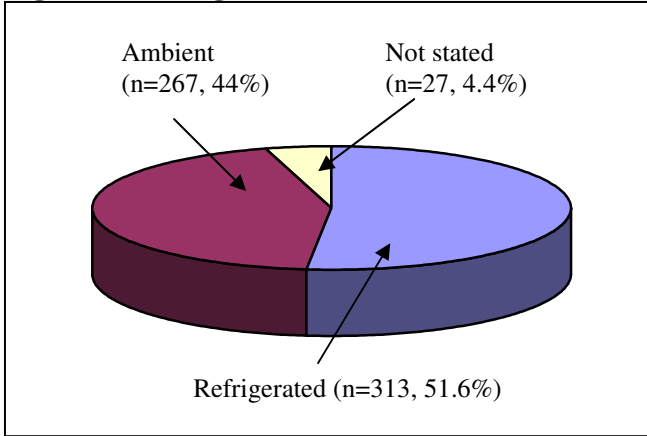


4.2.3 Information on storage conditions

Mushrooms are commonly stored at both ambient and refrigerated conditions. Mushrooms stored at ambient temperature have a short shelf life (1-3 days), while those stored at refrigeration temperature have a longer shelf life (8-10 days) ⁽²¹⁾.

In this study, 44% (267/607) of mushroom samples were stored under ambient conditions and 51.6% (313/607) of samples were stored under refrigerated conditions (Figure 8).

Figure 8: Storage conditions (n=607)



The relationship between storage conditions and sample temperature is outlined in Table 12.

Table 12: Relationship between storage conditions and sample temperature*

Storage conditions	Type of packaging	No. of samples	Temp. measurement	Temp. Range (°C)	No. of samples		
					≤ 5°C	> 5°C	N/S
Refrigerated	Loose	135	Core temperature	0.9-13.5	67	65	3
	Pre-packed	170	Between pack	1-18.2	51	107	12
	Not stated	8	N/A				
Ambient	Loose	103	Core temperature	2.1-22	2	88	13
	Pre-packed	154	Between pack	2.7-20	10	132	12
	Not stated	10	N/A				
Not stated	Loose	12	Core temperature	2.8-11.7	5	6	1
	Pre-packed	13	Between pack	5-17.4	2	8	3
	Not stated	2	N/A				

* The core temperature was measured for the loose mushrooms while the between-pack temperature was measured for the pre-packed mushrooms.

Refrigerated food should be maintained at $\leq 5^{\circ}\text{C}$; however, temperatures $>5^{\circ}\text{C}$ (i.e. either the core temperature or the between pack temperature measurement) were recorded for 54.9% (172/313) of all ‘refrigerated’ samples (Table 12). These findings clearly show that refrigeration is not taking place at the correct temperature.

In this study, the relationship between sample temperature and microbiological quality/safety was not assessed because the majority of samples were of satisfactory quality/safety. However, the sample temperature of 6 of the 8 samples in which *L. monocytogenes* was detected is outlined in Table 13 (this information was not provided for the remaining 2 samples). One sample (16.7%, 1/6) was stored under refrigerated conditions; the remaining 5 samples were stored under ambient conditions. This raises concern, as growth of *L. monocytogenes* increases under ambient conditions and levels $>100\text{cfu/g}$ at the point of consumption represents a risk to consumers.

Table 13: Storage conditions and temperatures of samples contaminated with *L. monocytogenes* (n=6)

Sample no.	Type of packaging (loose/pre-packed)	Storage conditions	Sample temperature	
			Core temperature	Between pack temperature
1	Loose	Ambient	15 °C	N/A
2	Loose	Ambient	9 °C	N/A
3	Loose	Refrigerated	5 °C	N/A
4	Pre-packed	Ambient	N/A	11 °C
5	Pre-packed	Ambient	N/A	12 °C
6	Pre-packed	Ambient	N/A	10 °C

5. Conclusions

The findings of this study are very encouraging, i.e.

- *Salmonella* spp. was not detected in any sample, thus:
 - ❖ all sliced mushrooms were classified as satisfactory for *Salmonella* spp. when assessed against the microbiological criterion specified in Commission Regulation (EC) No 2073/2005 and
 - ❖ all whole mushrooms were classified as satisfactory for *Salmonella* spp. when assessed against the national microbiological guidelines
- *L. monocytogenes* was detected in 1.1% (8/727) of samples but was not quantified at levels >100 cfu/g in any sample. Therefore, all samples were classified as satisfactory for *L. monocytogenes* when assessed against the microbiological criterion specified in Commission Regulation (EC) No 2073/2005.
- 99.2% of samples were classified as satisfactory when assessed against the national microbiological guidelines for *S. aureus*
- all samples were classified as satisfactory when assessed against the national microbiological guidelines for *E. coli*

These findings are very encouraging as mushrooms (like many fruit and vegetables) are eaten both in their raw and cooked form and therefore it is important that they are free from microbial contamination. In light of these findings, the FSAI recommendation to cook all mushrooms prior to consumption (issued in 2001) will be reviewed.

The microbiological quality and safety of mushrooms depends on the implementation of strategies to avoid and control contamination. These strategies must be implemented at all stages of the food chain, i.e. from farm to fork. Some of these strategies are outlined in the Bord Glas Quality Manual for the Irish Mushroom Industry ⁽²²⁾ and in the FSAI Code of Practice for Food Safety in the Fresh Produce Supply Chain in Ireland ⁽²³⁾.

6. Bibliography

1. Bord Bia. Mushroom sector.
http://www.bordbia.ie/go/Industry/Sector_Profiles/Horticulture/Sectors/mushrooms.htm
2. Bord Bia. 2005. Annual report 2005. <http://www.bordbia.ie/Corporate/Publications>
3. Neary, M. 2003. Challenging times for Irish mushrooms. Agriculture-New challenges, new opportunities. <http://www.farmersjournal.ie/indsup2003/mushrooms.pdf>
4. Department of Agriculture and Food. 2004. Report of the Mushroom Taskforce. http://agriculture.gov.ie/publicat/mush_taskforce_rep.pdf
5. Food law news. 2001. Food Poisoning-Food standards Agency acts on salmonella in mushrooms. <http://www.foodlaw.rdg.ac.uk/news/uk-01-28.htm>
6. Food Safety Authority of Ireland. 2001. Press releases 12th April & 21st May 2001: http://www.fsai.ie/news/press/pr_01/pr20010412.asp,
http://www.fsai.ie/news/press/pr_01/pr20010521.asp
7. Doran, G, Sheridan, F., De Lappe, N., O'Hare, C., Anderson, W., Corbett-Feeney, G., and M Cormican. 2005. *Salmonella enterica* serovar Kedougou contamination of commercially grown mushrooms. *Diag. Microbiol. and Infectious Disease*. **51**, 1, 3-76
8. Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs (OJ L338, p1, 22/12/2005).
http://www.fsai.ie/legislation/food/eu_docs/Food_hygiene/Reg2073_2005.pdf
9. Food Safety Authority of Ireland. 2001. Guidance Note No. 3. Guidance Note on the Interpretation of Results of Microbiological Analysis of Some Ready-To-eat Foods Sampled at the Point of Sale. http://www.fsai.ie/publications/guidance_notes/gn3.pdf
10. Health Protection Surveillance Centre. 2005. Annual report of the HPSC 2005. <http://www.ndsc.ie/hpsc/AboutHPSC/AnnualReports/File,2141,en.pdf>
11. International Commission on Microbiological Specifications for Foods. 1996. *Salmonellae*. p 217-264. In *Micro-Organisms in Foods. 5. Characteristics of Microbial Pathogens*. Roberts, T.A., Baird Parker, A.C. and Tompkin, R.B. eds. Published by Blackie Academic & Professional, London.
12. Weidenbach-K-N, Seys-S-A, Cassady-J-D, Finkenbinder-D-L, Bloomenrader-N, Heryford-A-G, Manley-W-A, Walford-J-R, Buxman-J-E. 2006. Restaurant-associated outbreak of *Salmonella* serotype Heidelberg linked to improperly handled mushrooms, Wyoming, 2003. *Food Protection Trends*, **26**, 3, 150-157.
13. Samadpour-M, Barbour-M-W, Nguyen-T, Cao-T-M, Buck-F, Depavia-G-A, Mazengia-E, Yang-P, Alfi-D, Lopes-M, Stopforth-J-D. 2006. Incidence of enterohemorrhagic *Escherichia coli*, *Escherichia coli* O157, *Salmonella*, and *Listeria monocytogenes* in retail fresh ground beef, sprouts, and mushrooms. *Journal of Food Protection*, 2006, **69**, 2, 441-443
14. European Commission. 1999. Opinion of the Scientific Committee on Veterinary Measures Relating to Public Health on *Listeria monocytogenes*. http://europa.eu.int/comm/food/fs/sc/scv/out25_en.html
15. Heisick-J-E, Wagner-D-E, Nierman-M-L, Peeler-J-T. 1989. *Listeria* spp. found on fresh market produce. *Applied and Environmental Microbiology*, **55**, 1925-1927
16. Johannessen-G-S, Loncarevic-S, Kruse-H. 2002. Bacteriological analysis of fresh produce in Norway. *International Journal of Food Microbiology*. **77**, 199-204

17. Scientific Committee on Veterinary Measures Relating to Public Health. Opinion on staphylococcal enterotoxins in milk products, particularly cheeses. http://ec.europa.eu/food/fs/sc/scv/out61_en.pdf
18. International Commission on Microbiological Specifications for Foods. 1996. *Staphylococcus aureus*. p 299-333. In *Micro-Organisms in Foods. 5. Characteristics of Microbial Pathogens*. Roberts, T.A., Baird Parker, A.C. and Tompkin, R.B. eds. Blackie Academic & Professional, London.
19. International Commission on Microbiological Specifications for Foods. 1996. Intestinally pathogenic *Escherichia coli*. p 126-140. In *Micro-Organisms in Foods. 5. Characteristics of Microbial Pathogens*. Roberts, T.A., Baird Parker, A.C. and Tompkin, R.B. eds. Blackie Academic & Professional, London.
20. *Sapers et al., 1994 cited by Sang W. Choi and Gerald M. Sapers. 1994. Effects of Washing on Polyphenols and Polyphenol Oxidase in Commercial Mushrooms (Agaricus bisporus)*. J. Agric. Food Chem. **42**, 2286-2290
21. Burton K.S. 1989. The quality and storage life of *Agaricus bisporus*. Mushroom Science XII. Proceedings of the 12th International Congress on the Science and Cultivation of edible fungi. Braunschwey, Germany, pp638-688.
22. Bord Glas. Quality manual for the Irish Mushroom Industry
23. FSAI. 2001. Code of Practice No. 4 'Code of Practice for Food Safety in the Fresh produce Supply Chain in Ireland' <http://www.fsai.ie/publications/codes/cop4.pdf>

7. APPENDICES
APPENDIX 1
Questionnaire 06NS1
Microbiological Safety/Quality of Raw Mushrooms

General Information:

- * EHO Name: _____
- * EHO Sample Reference Number (i.e. EHO's own personal reference number for the sample) _____
- * Laboratory Reference Number (upon receipt of lab report) _____

Premises Information (See section 4 of Protocol):

- Retail premises:** Supermarket ; Corner shop ; Fruit & Veg shop ; Fruit & Veg stall ; Other *Please specify* _____
- Catering premises:** Hotel ; Restaurant ; Other *Please specify* _____
- Distributor/Packer:** Central distribution centres ; Wholesalers ; Importers ; Packers ; Others *Please specify* _____

Sample Information (See section 3 of protocol) :

- Mushroom producer/supplier:** Name & address _____
- Batch Number:** _____
- Nature of mushroom:** Whole or Sliced
- Type of packaging:** Pre-packed or Loose
- Mushroom size:** Buttons ; Cups Flats (often referred to as breakfast flats or portobello mushrooms) or Mixed
- Mushroom variety:** White/Brown or Exotic (if exotic please provide details of species: _____)
- Mushroom quality:** Value Pack ; Prime ; Unknown or Other (if other please provide details: _____)
- Info on washing:** Washed ; Unwashed or Unknown

Temperature Information (see section 6.4 & 6.5 of protocol):

- Temperature of sample:**
- Core temperature of loose mushrooms: _____ °C
- Between pack temperature of pre-packed mushrooms: _____ °C
- Storage conditions:**
- Ambient ; Refrigerated ; Other (please provide details of other storage conditions: _____)

Microbiological status (see section 8 of protocol):

	S	A	U	U/PH
<i>Salmonella</i> spp.	<input type="checkbox"/>	N/A	N/A	<input type="checkbox"/>
<i>S. aureus</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>L. monocytogenes</i>	<input type="checkbox"/>	<input type="checkbox"/>	N/A	<input type="checkbox"/>
<i>E. coli</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	N/A

S=Satisfactory, A=Acceptable, U=Unsatisfactory, U/PH=Unacc./Potentially hazardous,

Follow-up action (see section 10 of protocol) (Please tick as many boxes as necessary):

- Repeat sample (Please record lab no. of repeat sample: _____); Verbal advice ; Written advice ; Product withdrawal ; Product recall ; Other (Please specify): _____

APPENDIX 2

No. of samples submitted from each Health Service Executive (HSE) Region & Area

HSE Region	HSE Area	Number of samples submitted
HSEDMLR	East Coast Area	40
	Midlands Area	43
	South Western Area	57
HSEDNER	North Eastern Area	50
	Northern Area	41
HSESR	South Eastern Area	181
	Southern Area	104
HSEWR	Mid-Western Area	85
	North Western Area	60
	Western Area	66
Total		727

APPENDIX 3

No. of samples analysed in each Official Food Microbiology Laboratory (OFML)

OFML	No. of samples analysed in each OFML
Cherry Orchard	138
Cork	104
Galway	66
Limerick	85
Sligo	60
SPD	93
Waterford	181
Total	727

APPENDIX 4
***Salmonella* spp. results by HSE Area**

HSE Area	Presence/absence of <i>Salmonella</i> spp. in 25g sample		
	Present in 25g	Absent in 25g	Total
East Coast Area	0	40	40
Midlands Area	0	43	43
Mid-Western Area	0	85	85
North Eastern Area	0	50	50
North Western Area	0	60	60
Northern Area	0	41	41
South Eastern Area	0	181	181
South Western Area	0	57	57
Southern Area	0	104	104
Western Area	0	66	66
Total	0 (0%)	727 (100%)	727 (100%)

APPENDIX 5
Listeria monocytogenes results by HSE Area

Qualitative results – *L. monocytogenes*

HSE Area	Number of samples		
	<i>L. monocytogenes</i> present	<i>L. monocytogenes</i> absent	Total
East Coast Area	0	40	40
Midlands Area	0	43	43
Mid-Western Area	1	84	85
North Eastern Area	0	50	50
North Western Area	2	58	60
Northern Area	0	41	41
South Eastern Area	2	179	181
South Western Area	1	56	57
Southern Area	1	103	104
Western Area	1	65	66
Total	8 (1.1%)	719 (98.9%)	727 (100%)

Quantitative results – *L. monocytogenes*

HSE Area	<i>L. monocytogenes</i> count <20 cfu/g	Total
East Coast Area	40	40
Midlands Area*	38	38
Mid-Western Area	85	85
North Eastern Area	50	50
North Western Area	60	60
Northern Area	41	41
South Eastern Area	181	181
South Western Area	57	57
Southern Area	104	104
Western Area	66	66
Total	722 (100%)	722 (100%)

*A total of 43 samples were submitted for analysis from the Midlands area; however, 5 of these were not tested quantitatively for *L. monocytogenes*. These 5 samples were tested qualitatively and *L. monocytogenes* was not detected in any sample.

APPENDIX 6
***Staphylococcus aureus* results by HSE Area**

HSE Area	Microbiological safety* of samples based on <i>Staphylococcus aureus</i> count				
	S	A	U	U/PH	Total
East Coast Area	40	0	0	0	40
Midlands Area	43	0	0	0	43
Mid-Western Area	84	0	1	0	85
North Eastern Area	50	0	0	0	50
North Western Area	60	0	0	0	60
Northern Area	41	0	0	0	41
South Eastern Area	177	4	0	0	181
South Western Area	57	0	0	0	57
Southern Area	103	0	1	0	104
Western Area	66	0	0	0	66
Total	721 (99.2%)	4 (0.5%)	2 (0.3%)	0 (0%)	727 (100%)

* Microbiological safety was assessed using the national microbiological guidelines (section 3.5)
S=Satisfactory, A=Acceptable, U=Unsatisfactory, U/PH=Unacceptable/potentially hazardous

APPENDIX 7
***Escherichia coli* results by HSE Area**

HSE Area	Microbiological safety of samples based on <i>Escherichia coli</i> count			
	S	A	U	Total
East Coast Area	40	0	0	40
Midlands Area	43	0	0	43
Mid-Western Area	85	0	0	85
North Eastern Area	50	0	0	50
North Western Area	60	0	0	60
Northern Area	41	0	0	41
South Eastern Area	181	0	0	181
South Western Area	57	0	0	57
Southern Area	104	0	0	104
Western Area	66	0	0	66
Total	727 (100%)	0 (0%)	0 (0%)	727 (100%)

* Microbiological safety was assessed using the national microbiological guidelines (section 3.5)
S=Satisfactory, A=Acceptable, U=Unsatisfactory