GreenFooDec

Development of novel and advanced decontamination sustainable technologies for the production of high quality dried herbs and spices

Research for the benefit of specific groups
Research for SME associations/groupings

Grant Agreement Number 285838
FP7-SME-2011

Attachment to the final Publishable Summary Report

Table of content

1 Quality requirements, product specifications.

Quality requirements have been collected for paprika, pepper and oregano. The objective was to get an overview of actual figures for these quality parameters, but also to make variations and similarities visible between different recommendations, countries and companies. The results are summarized in the following specification sheets.

Table 1. Specification sheet of Paprika.

Specification Sheet	Product	**Paprika**

1. Product description	
Product name	Paprika –*Capsicum annuum*
Origin	Hungary, Spain, South America, United States, Asia
Application	Ingredient in a broad variety of dishes, to season and color rice, stews, and soups, in the preparation of sausages, as a garnish; used in cosmetics; for the production of oleoresin.

2. Quality requirements

2.1 Physico chemical parameters

Reference	*ESA*[1]	ISO[2]				*TSE*[3]				TFC[4]		*JJA*[5]
Category		*I*	*II*	*III*	*IV*	*I**	*II**	*I***	*II***	*	**	
Moisture (%), *by mass, max*	11	11	11	11	11	11	11	11	11	11	11	
Water activity (a_w), *max*	0,65											0,59
Volatile oil (ml/100 g), *on dry basis, min*						0,5	0,2	0,4	0,2	0.2	0.2	
Total ash (%), *by mass on dry basis, max*	10	8	8	8,5	10	6,5	8	7	8	8	9	
Acid insoluble ash (%), *by mass on dry basis, max*	2	0,6	0,7	0,9	1	0,5	1,0	1,0	1,5	1	1.5	
Particle/Mesh size (µm) *max*										560	560	850
Cellulose by mass on dry basis, *max* (%, m/m)										25	25	
Nonvolatile ether extract (%), *on dry basis, mass fraction, (max value[a], min value[b])*		17[a]	17[a]	20[a]	25[a]	12[b]	12[b]	12[b]	12[b]	12[b]	12[b]	
Capsaicin content (µg/g), *max*		30	30	30	30							
Cellulose (% m/m), *dry matter, max*						25	25	25	25	25	25	

**Sweet, **Hot*

2.2 Sensorical parameters

Reference	*ISO*[2]	
Appearance	-	Fine powder
Colour	From vivid brilliant red through yellowish and brownish-red to pale reddish-brown	Reddish
Aroma	Pungent or free from pungency, pleasantly aromatic	Aromatic, slightly spicy and sweet
Texture	-	Fine powder

Note: There are different colour requirements depending on the product according to ASTA (American Spice Trade Association) values

3. Microbiological limits

	Max count (CFU/g)			
Reference	*DGHM*[6]	*2004/24/EC*[7]	*R.D.2242/1984*[8]	*JJA*[5]
Salmonella spp in 25 g	Not detected	Not detected	Not detected	
Yeasts and Moulds (all together)	1,00E+05			1,00E+003
Enterobacteriaceae		1,00E+02		100
E.coli	1,00E+04		10	10
B. cereus	*1,00E+04	1,00E+04		*100
Clostridium perfringens		1,00E+03		100
Clostridium sulf-red anaerobes			1,00E+03	100
Spores of sulphite reducing clostridium	1,00E+04			
Total plate count				1,00E+005
Listeria monocytogenes	No reference limits according to ASTA[9]			
Staphylococcus aureus	No reference limits according to ASTA[9]			

**Presumptive B.cereus*

4. Contaminants

4.1 Mycotoxins

Reference	*Reg 1881/2006*[10]	*Reg 105/2010*[11]	*EC1*[12]	*EC2*[13]	*TFC*[4]	*JJA*[5]
Aflatoxin B_1	5 ppb		5 ppb		5 ppb	
Aflatoxin Tot	10 ppb		10 ppb		10 ppb	
Ochratoxin A		30 µg/kg		*15 µg/kg	*15 µg/kg	**30 µg/kg

From 1.7.2012 (30 µg/kg from 1.7.2010 until 30.06.2012)* ***NOTE!* *The limit 30 µg/kg will be extended until 31.12.2014 (publication pending).*

***From 1.7.2010 until 31.12.2014 (publication pending)*

References

1	ESA	European Spice Association Quality Minima Document. Applies to "buisness to buisness" and not for direct sale to consumers
2	ISO	ISO 7540-2006 Ground paprika (Capsicum annuum L.) –Specification
3	TSE	Turkish standard TS 2419 –Red pepper (Capsicum annuum L.) –Ground (powdered)
4	TFC	Turkish Food Codex
5	JJA	Juan José Albarracín, S.A. (SMEs)
6	DGHM	Deutsche Gesellschaft für Hygiene und Mikrobiologie (2010). Includes both warning and guideline values for products out to consumer.
7	2004/24/EC	Commission Recommendation (Dec, 2003). Official control of foodstuffs for 2004. Production and retail premises.
8	R.D.2242/1984	R.D.2242/1984. Condimentos y especias: Reglamentación Técnico-Sanitaria para elaboración, circulación y comercio. (Repealed legislation, only as a technical reference)
9	ASTA	Guidance from the American Spice Trade Association
10	Reg 1881/2006	Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs
11	Reg 105/2010	Regulation (EU) No 105/2010 of 5 February 2010 amending Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs as regards ochratoxin A
12	EC1	COMMISSION REGULATION (EC) No 1881/2006 Setting maximum levels for certain contaminants in foodstuffs
13	EC2	COMMISSION REGULATION (EC) No 105/2010 Amending Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs as regards ochratoxin A

Table 2. Specification sheet of Oregano.

Specification Sheet	Product	**Oregano**

1. Product description	
Product name	Oregano -Commercially divided into Mediterranean Oregano (e. g. *Oregano vulgare*) and Mexican Oregano (e. g. *Lippiagraveolens, Lippiaberlandiori*). Totally 6 families in the market: *Lamiaceae* (Turkish and Greek types), *Verbenaceae* family, *Rubiaceae*, *Scrophulariaceae, Apiaceae* and *Asceraceae*.
Origin	Mediterranean countries (Turkey, Italy, Greece, Libya, Morocco, Israel, France), Southwest Asia, United States and Mexico.
Application	Ingredient in several different dishes; tomato-based sauces, lamb, seafood, pizza, salads etc. Used in processed foods (e.g. meat products). Oregano oil is used in alcoholic beverages, baked goods, meats and meat products, condiments and relishes, milk products, processed vegetables, snack foods, fats and oils.

2. Quality requirements

2.1 Physico chemical parameters

Reference	*ESA*[1]	*ISO*[2]			*TSE*[3]			*AEGEAN*[4]	TFC[5]
		P*	SP**	Ground (powdered)	P*	SP**	Ground (powdered)		
Moisture (%), *by mass, max*	12	12	12	12	12	12	12		12
Water activity (a_w), *max*	0,65	-	-		-	-			
Volatile oil (ml/100 g), *on dry basis, min*	1,5	1,8	1,5	1.5	1	1	1		1
Total ash (%), *by mass on dry basis, max*	10	10	12	12	12	14	12		14
Acid insoluble ash (%), *by mass on dry basis, max*	2	2	2	2	3	5	3		5
Mesh size (mm)								1-4	
Extraneous matter (% m/m), *max*									2

**Processed, **Semi-processed*

2.2 Sensorical parameters

Reference	*ISO*[2]
Appearance	-
Colour	Greyish green to olive green for dried leaves
Aroma	Fragrant, warm, pungent and bitter flavour
Texture	-

3. Microbiological limits				
Reference	*DGHM*[6]		*2004/24/EC*[7]	*TFMC*[8]
	Warning	*Guideline*		
Salmonella spp in 25 g	Not detected		Absent	Absent
Yeasts and Moulds (all together)		1×10^3		
Enterobacteriaceae			< 10 (Satisfactory) $\geq 10^2$ (Unsatisfactory)	
E.coli	1×10^4	1×10^3		
B. cereus	*1×10^4	*1×10^3	$< 10^3$ (Satisfactory) $\geq 10^4$ (Unsatisfactory)	$< 10^3$(Satisfactory) $\geq 10^4$ (Unsatisfactory)
Clostridium perfringens			$< 10^2$ (Satisfactory) $\geq 10^3$ (Unsatisfactory)	
Spores of sulphite reducing clostridium	1×10^4	1×10^3		
Coagulase positive Staphylococcus				$<10^3$ (Satisfactory) $\geq 10^4$ (Unsatisfactory)
**Presumptive B.cereus*				

4. Contaminants	
4.1 Mycotoxins	
Reference	
Aflatoxin B_1	No maximum limit specified for Oregano according to EC legislation
Aflatoxin Tot	No maximum limit specified for Oregano according to EC legislation
Ochratoxin A	No maximum limit specified for Oregano according to EC legislation

References		
1	ESA	European Spice Association Quality Minima Document. Applies to "buisness to buisness" and not for direct sale to consumers
2	ISO	ISO 7925: 1999 Dried Oregano (*Origanum Vulgare L.*) –Whole and ground leaves –Specification
3	TSE	Turkish standard TS 3786: 2003 Tyme, oregano and marjoram
4	AEGEAN	Aegean Exporters' Associations
5	TFC	Turkish Food Codex
6	DGHM	Deutschen Gesellschaft für Hygieneund Mikrobiologie. Includes both warning and guideline values for products out to consumer.
7	2004/24/EC	Commission Recommendation (Dec, 2003) 2004/24/EC. Official control of foodstuffs for 2004. Production and retail premises
8	TFMC	Turkish Food Microbiological Codex

Table 3. Specification sheet of pepper.

Specification Sheet	Product	**Pepper**

1. Product description	
Product name	Pepper –*Piper nigrum*
Origin	Indonesia, Vietnam, Brazil, China etc.
Application	Sold for consumers, used by the food industry as a condiment for food products and as a food preservative

2. Quality requirements

2.1 Physico chemical parameters

Reference	*ESA*[1]		*ISO*[2]			*ISO*[3]			*TSE*[4]			*TSE*[5]			*TSE*[6]	
	Black	*White*	*Black*			*White*			*Black*			*White*			*Black*	*White*
			NP or SP	P	G	SP	P	G	NP or SP	P	G	SP	P	G		
Moisture (%), *by mass, max*	12	12	13	13	13	14	14	14	13	13	13	14	14	14	12	14
Water activity (a_w), *max*	0,65	0,65														
Volatile oil (ml/100 g), *on dry basis, min*	2	1,5	2	2	1*	1	1	0.7	2	2	1*	1	1	0.7	2	1
Total ash (%), *by mass on dry basis, max*	7	3,5	7	6	6	3.5	3.5	3.5	7	6	6	2	2	2	8	2
Acid insoluble ash (%), *by mass on dry basis, max*	1,5	0,3			1.2			0.3			1.2	0.3	0.3	0.3	1	0.3
Non-volatile ether extract % (m/m), *min, on dry basis*			6	6	6	6.5	6.5	6.5	6	6	6	6.5	6.5	6.5	6	6.5
Piperine content % (m/m), *min, on dry basis*			4	4	4	4	4	4	4	4	4	4	4	4		
Crude fibre, insoluble index,					17.5						17.5				18**	6**

% (m/m), *max, on dry basis*																
Extraneous matter, % (m/m), *max*			2.5	1.5		1	0.8		2.5	1.5		0.5	0.8		1	0.5
Light berries, % (m/m) *max*			10	5					10	5					10	
Pinheads or broken berries, % (m/m), *max*			7	4					7	4						
Broken berries, % (m/m), *max*						4	3					3	3			3
Black berries, % (m/m), *max*						15	10					15	10			10
Bulk density, (g/l), *min*			450	490		600	600		450	490		600	600			

NP: Unprocessed, SP: Semi-processed, P:Processed, G:Ground
*The volatile oil content should be determined immediately after grinding.
**Cellulose, on dry basis, max (%m/m)

2.2 Sensorical parameters

Reference	*McCormick*[7]		
	Black	*White*	
Appearance	Dried berry	Dried seed	
Colour	Brownish black	Light brown	
Aroma	Spicy hot, woody, pungent	Spicy hot, musty	
Texture	Whole, crushed or ground to powder	Whole, ground to powder	

3. Microbiological limits

Reference	*DGHM*[8]		*2004/24/EC*[9]	TFMC[10]
	Warning	*Guideline*		
Salmonella spp in 25 g	Not detected		Absent	Absent
Yeasts and Moulds (all together)		1×10^3		
Enterobacteriaceae			< 10 (Satisfactory) $\geq 10^2$ (Unsatisfactory)	
E.coli	1×10^4	1×10^3		
B. cereus	*1×10^4	*1×10^3	$< 10^3$ (Satisfactory) $\geq 10^4$ (Unsatisfactory)	$<10^3$ (Satisfactory) $\geq 10^4$ (Unsatisfactory)
Clostridium perfringens			$< 10^2$ (Satisfactory) $\geq 10^3$ (Unsatisfactory)	
Spores of sulphite reducing clostridium	1×10^4	1×10^3		
Coagulase positive Staphylococcus				$<10^3$ (Satisfactory) $\geq 10^4$ (Unsatisfactory)

**Presumptive B. cereus*

4. Contaminants

4.1 Mycotoxins

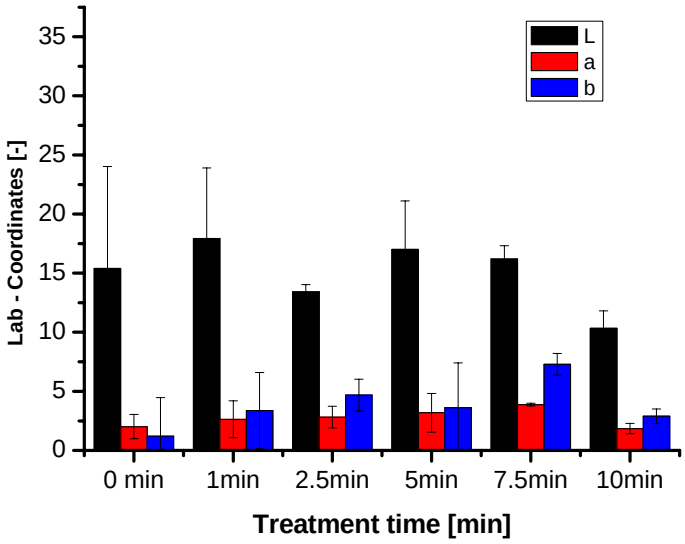
Reference	*EC1*[11]	*EC2*[12]	TFC[12]
Aflatoxin B_1	5 ppb		5 ppb
Aflatoxin Tot	10 ppb		10 ppb
Ochratoxin A		*15 µg/kg	*15 µg/kg

From 1.7.2012 (30 µg/kg from 1.7.2010 until 30.6.2012)* ***NOTE!* *The limit 30 µg/kg will be extended until 31.12.2014 (publication pending).*

References		
1	ESA	European Spice Association Quality Minima Document. Applies to "buisness to buisness" and not for direct sale to consumers
2	ISO	ISO 959-1:1998 Pepper (Piper nigrum L.), whole or ground-Specification Part 1 Black pepper
3	ISO	ISO 959-2:1998 Pepper (Piper nigrum L.), whole or ground-Specification Part 2 White pepper
4	TSE	Turkish standard TS 2290: 2000 Pepper (Piper nigrum L.)- whole or ground-Specification Part 1 Black pepper
5	TSE	Turkish standard TS 5103: 2003 Pepper (Piper nigrum L.)- whole or ground-Specification Part 1 Black pepper
6	TFC	Turkish Food Codex
7	McCormick	US company that manufactures spices, herbs and flavouring for retail, commercial and industrial markets.
8	DGHM	Deutschen Gesellschaft für Hygiene und Mikrobiologie (2010). Includes both warning and guideline values for products out to consumer.
9	2004/24/EC	Commission Recommendation (Dec, 2003) 2004/24/EC. Official control of foodstuffs for 2004. Production and retail premises
10	TFMC	Turkish Food Microbiological Codex
11	EC1	COMMISSION REGULATION (EC) No 1881/2006 Setting maximum levels for certain contaminants in foodstuffs
12	EC2	COMMISSION REGULATION (EC) No 105/2010 Amending Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs as regards ochratoxin A

2 Prototype samples obtained during the project.

Here are presented some prototype samples obtained during the development of the project.



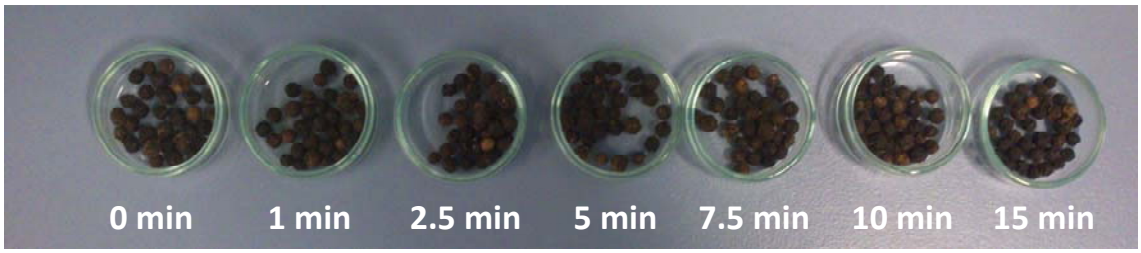


Figure 1. Impact of a direct plasma exposure with a plasma jet on the product colour of black pepper.

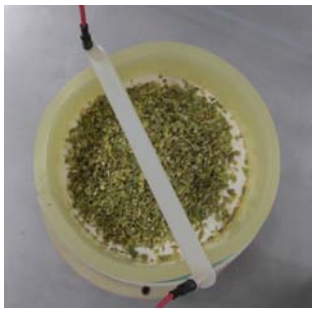


Figure 2. 3g of oregano treated for 10 min in the DBD plasma system.

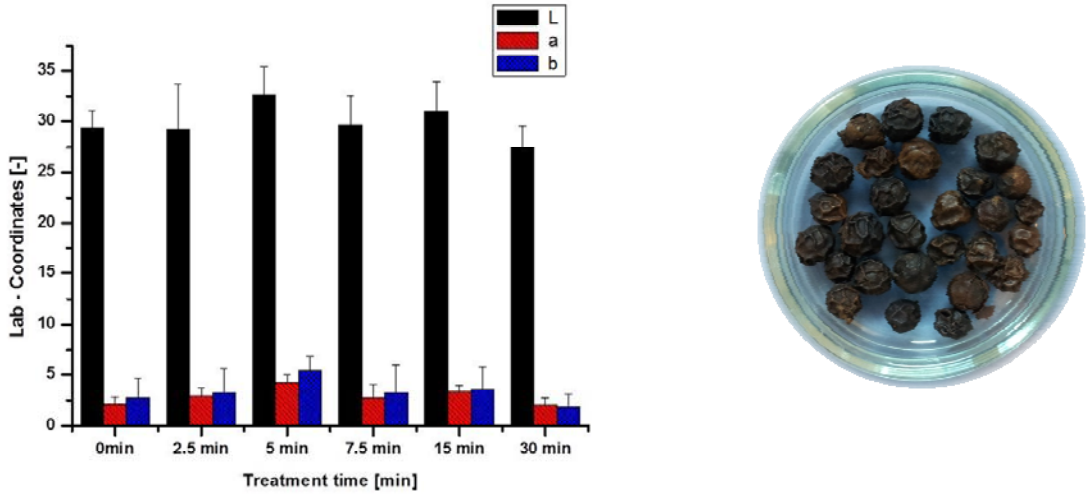


Figure 3. Impact of a direct DBD plasma exposure on the product colour of black pepper. The sample displayed, was treated for 30min.

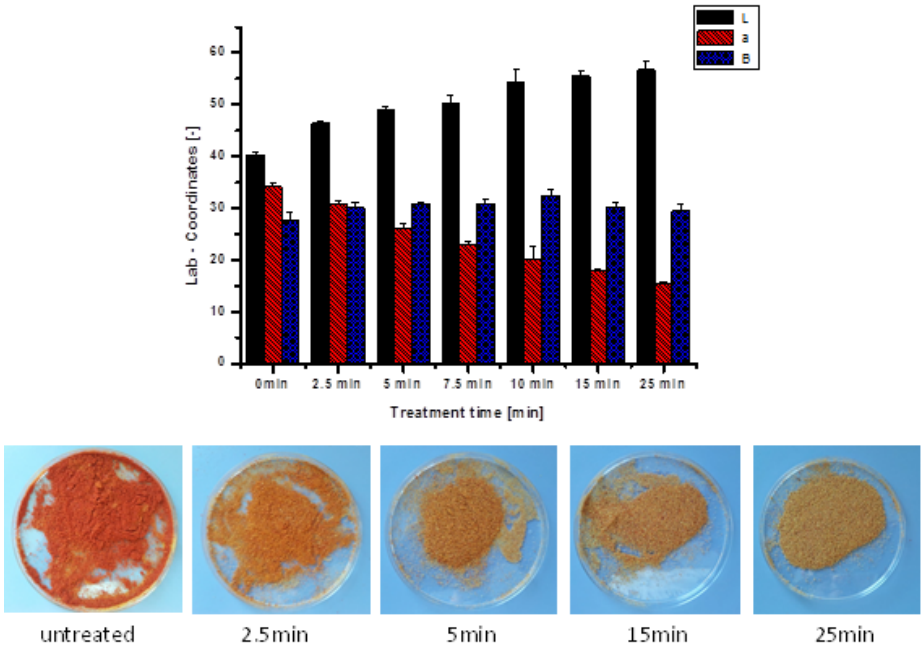


Figure 4. Impact of a direct DBD plasma exposure on the product colour of paprika powder.

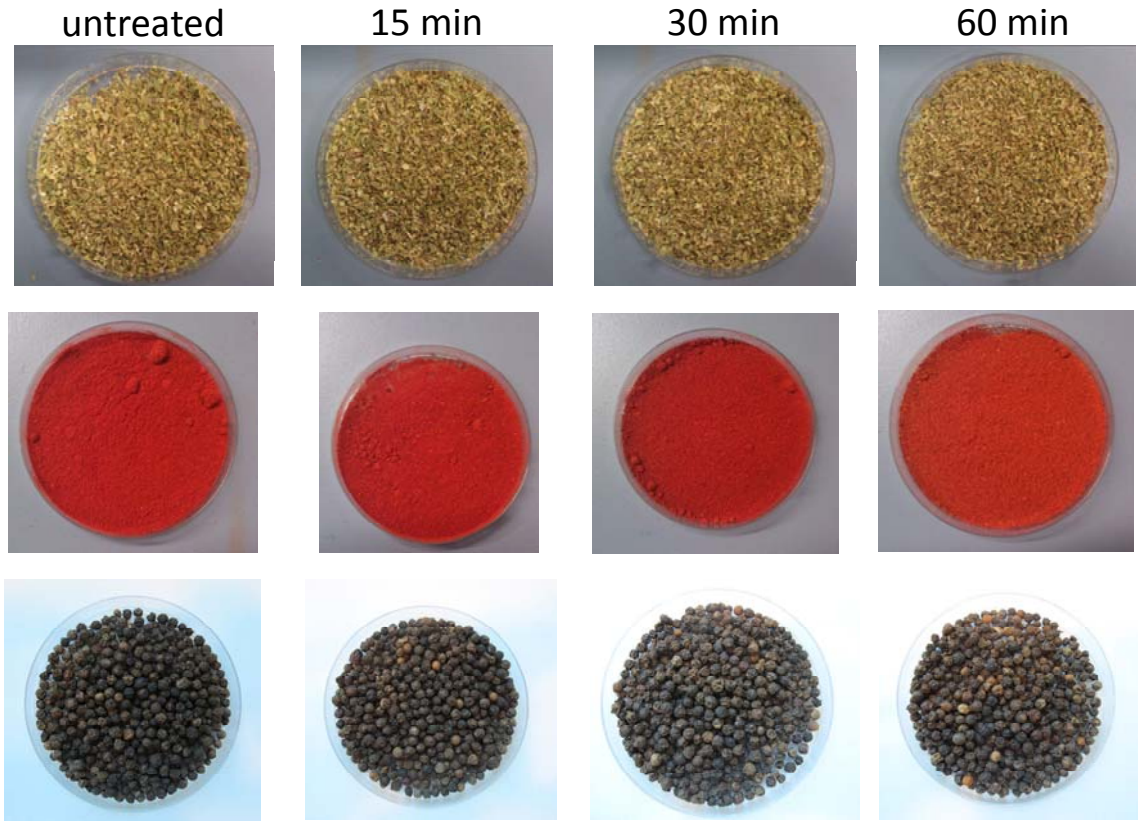


Figure 5. Oregano, paprika and black pepper seeds after various exposure times to indirect plasma.

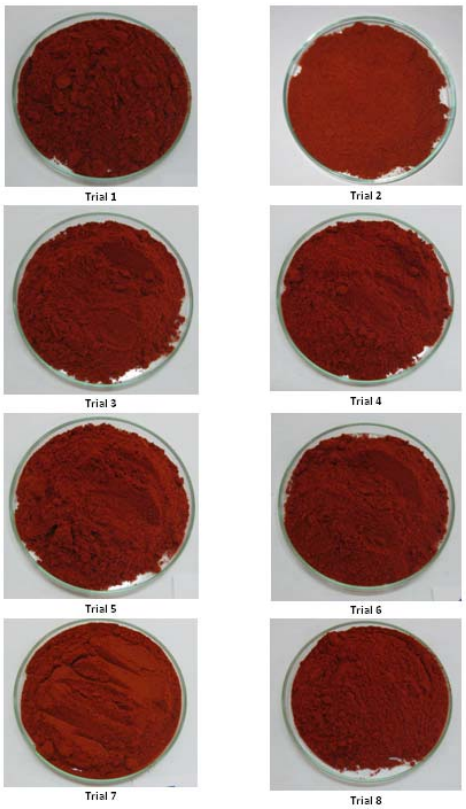


Figure 6.Treated samples from the preliminary trials with HPCD.

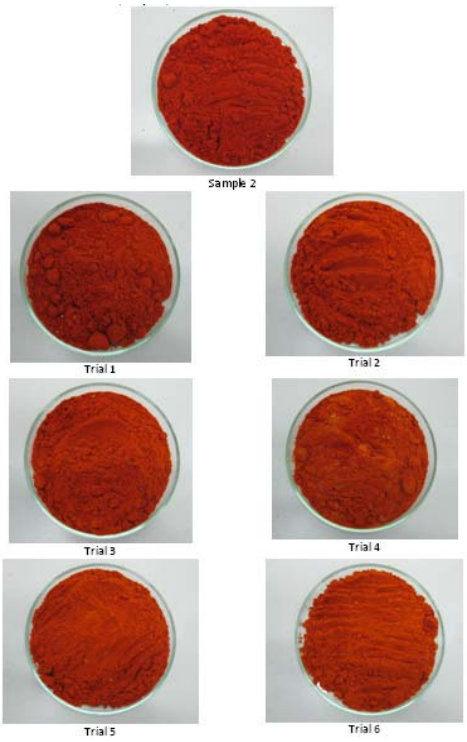


Figure 7. Treated samples from the trials performed with sample 2 with HPCD+US.

Figure 8. Sample 3 before and after treatment with HPCD+US.

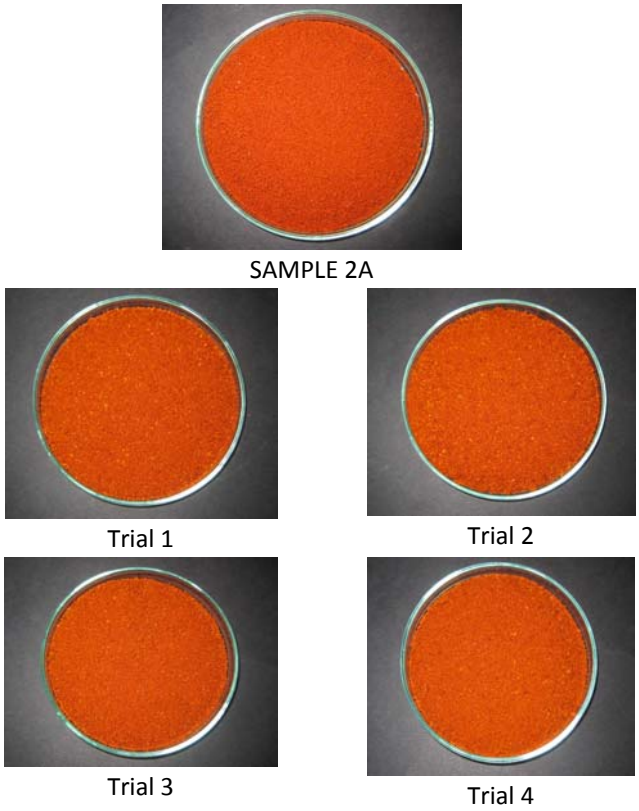


Figure 9. Sample 2A before and after treatment with HPCD+US.

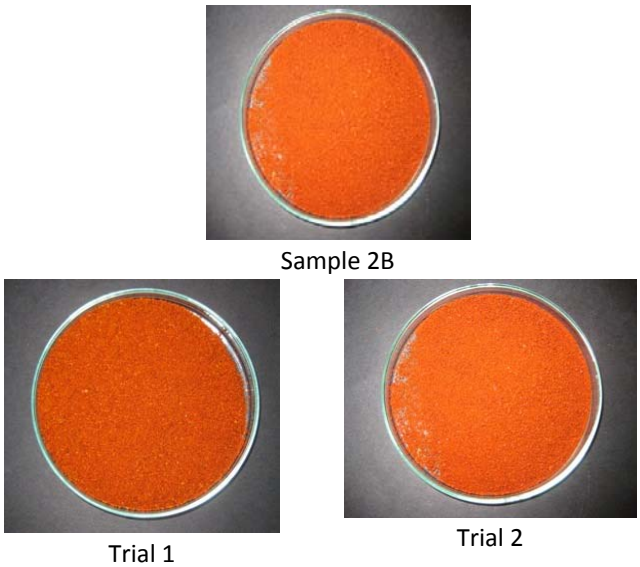


Figure 10. Sample 2B before and after treatment with HPCD+US.

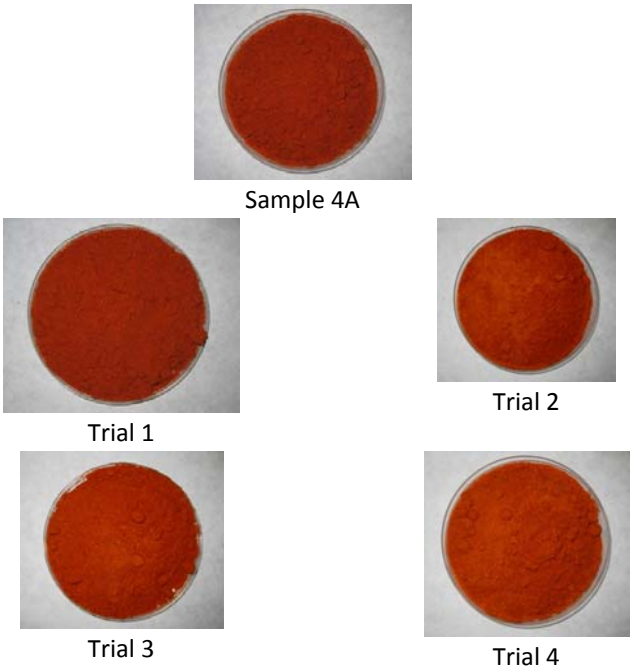


Figure 11. Sample 4A before and after treatment with HPCD+US.

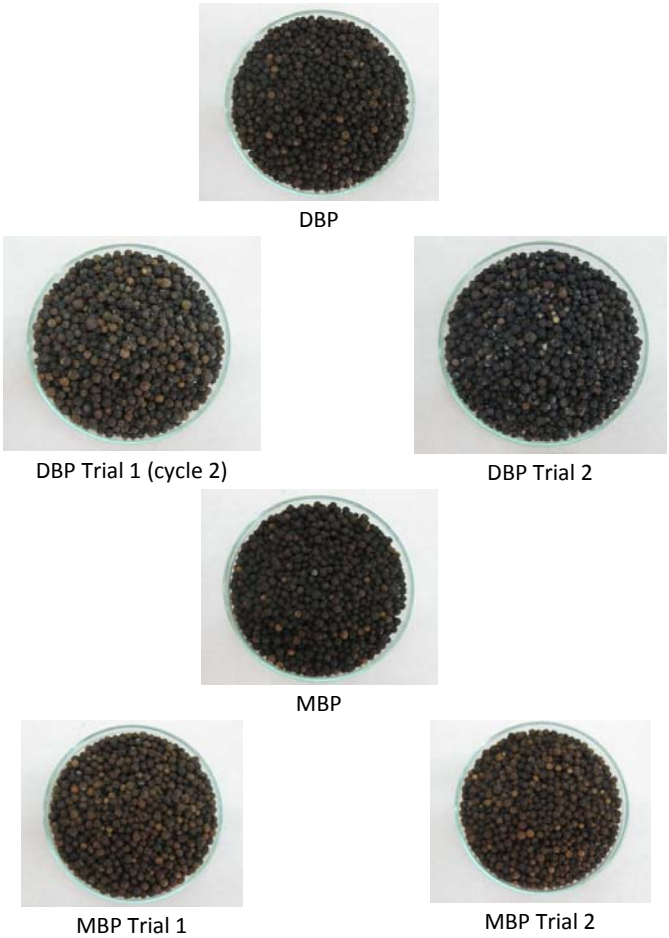


Figure 12. Samples of moistened and dry pepper before and after treatment with HPCD+US.

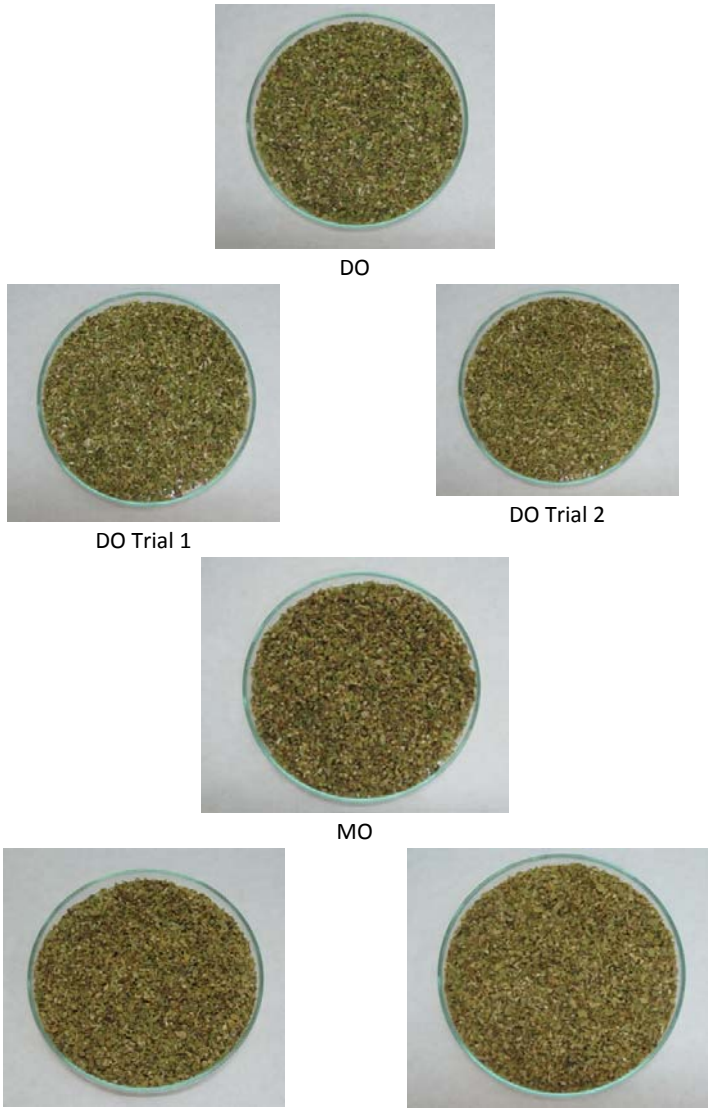


Figure 13. Samples of moistened and dry oregano before and after treatment with HPCD+US.

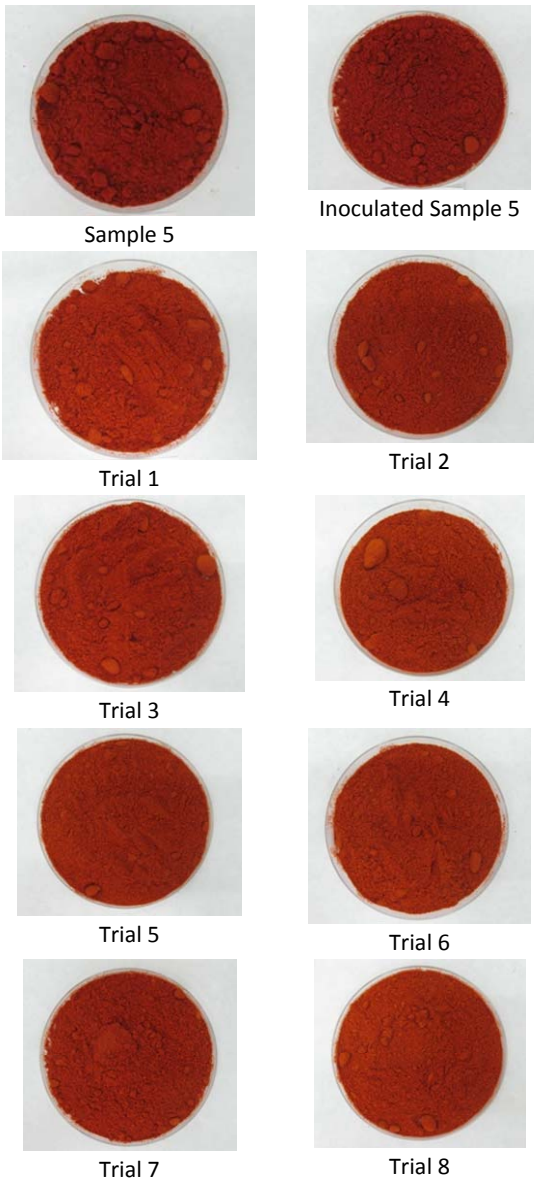


Figure 14. Sample 5 before and after treatment with HPCD+US.

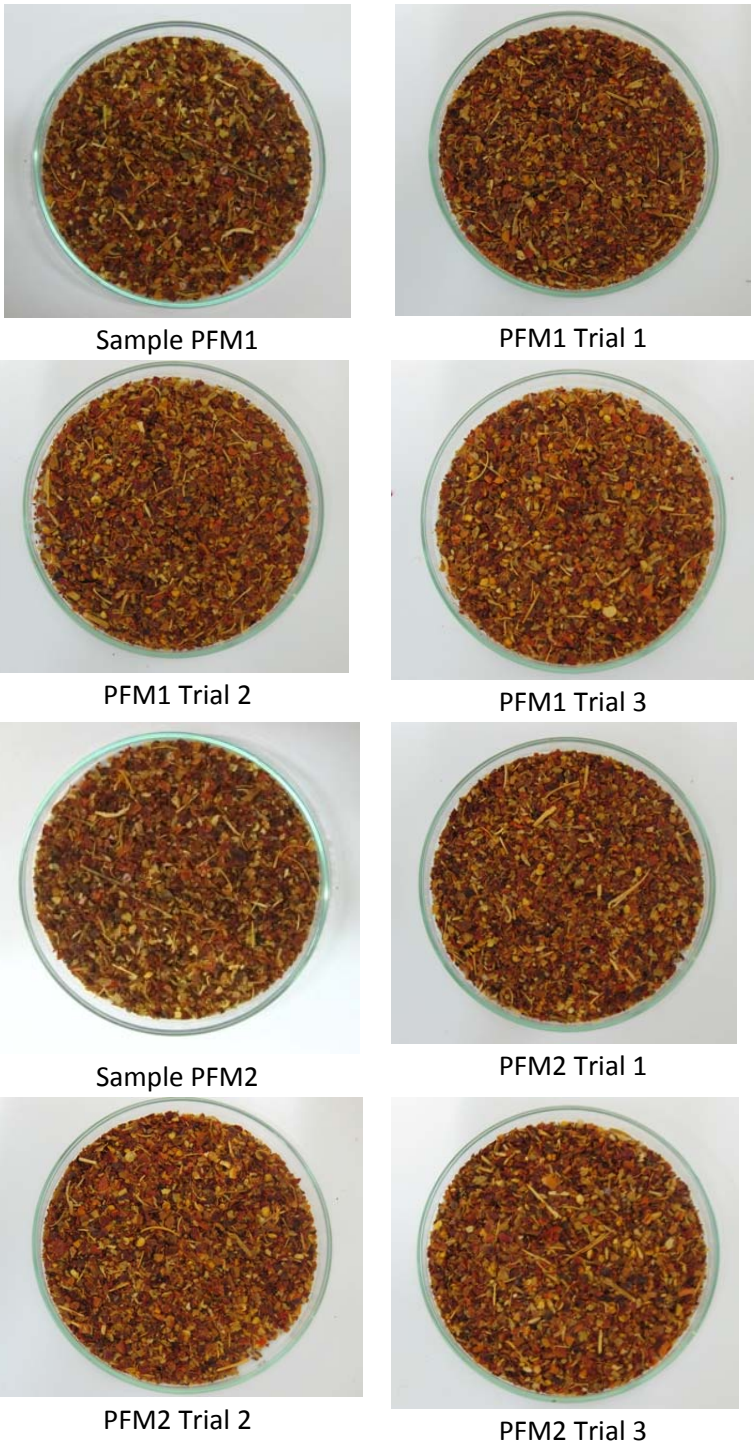


Figure 15. Paprika flakes before and after treatment with HPCD+US.

Sample OM1

OM1 Trial 1

OM1 Trial 2

Sample OM2

OM2 Trial 1

OM2 Trial 2

Figure 16. Moistened oregano before and after treatment with HPCD+US.

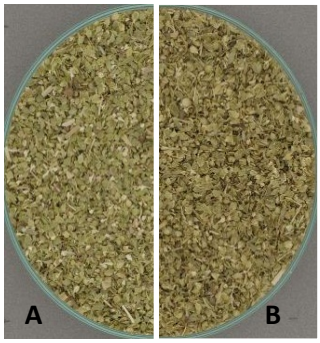


Figure 17. A) Untreated raw material vs. B) IR treated oregano at 90°C for 10 min followed by final drying.

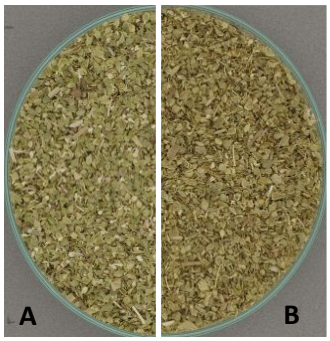


Figure 18. A) Untreated raw material vs. B) IR treated oreagano at 100°C for 10 min followed by final drying.

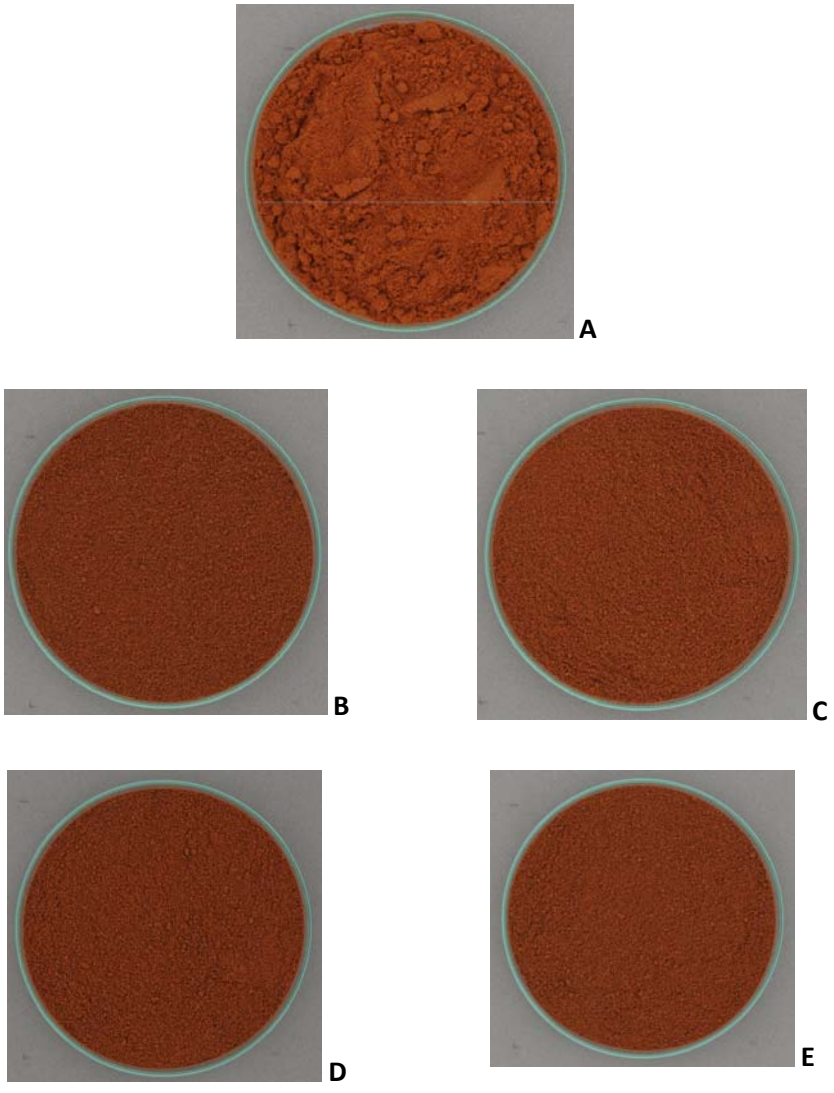
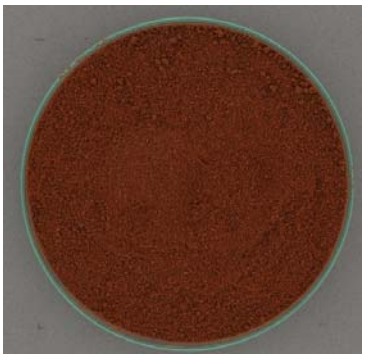


Figure 19. A) Untreated raw material, B) IR treated paprika for 10 min 98ºC, C) IR treated paprika for 20 min 98ºC, D) MW treated paprika for 10 min 98ºC and E) MW treated paprika for 20 min 98ºC. B) – E) have been subjected to a final drying step after the IR/MW treatment.

IR 98°C 10 min
Dried to aw 0.28
ΔE 9.2



IR 98°C 10 min
Dried to aw 0.54
ΔE 15.71

Figure 20. Example of two IR treated samples at 98°C for 10 min followed by drying to two different water activities (0.28 vs. 0.54). The sample with the higher water activity appeared to have a darker colour and showed clearly a higher ΔE compared to the undtreated raw material.

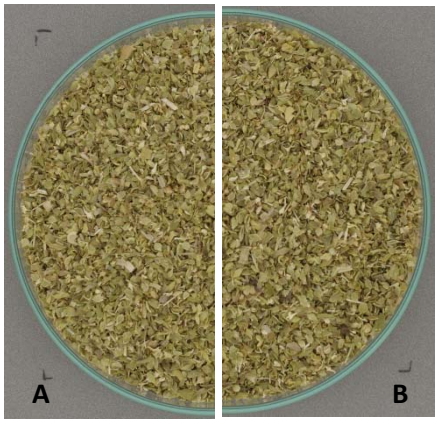


Figure 21. A) Untreated raw material, compared to B) the most affected IR treated sample (sample 6a) in terms of total colour change and water activity.

3 Cold atmospheric plasma - summary of product-process interactions

Paprika powder

Characterization of the raw material

Natural flora [CFU/g]	TPC	1.1×10^7
	Aerobic mesophilic spores	5.6×10^6
	Yeasts and Molds	2.4×10^4
Color / CIELab [-]	L	31.76 ± 1.346
	a	23.16 ± 2.6
	b	53.7 ± 2.0
Moisture content [%]	6.2 ±0.2	

Sample properties after plasma treatment

Treatment conditions	**Microorganism**	**Microbial Reduction [log (N/N_0)]**	**Color**			
			L	**a**	**b**	**ΔE**
DBD-System (25 min)	TPC	-0.43 ± 0.2	56.7	15.31	29.41	35.7
PLEXc-system (60 min)	TPC	-3.1 ± 0.2	26.6	20.16	45.1	10.5
	Aerobic spores	-1.3 ± 02				
	Yeasts and moulds	Below detection limit				

Oregano

Characterization of the raw material

Natural flora	TPC	1.7×10^5
[CFU/g]	Aerobic mesophilic spores	3.1×10^3
	Yeasts and Molds	9.7×10^3
Color / CIELab [-]	L	31.74 ± 3.15
	a	4.25 ± 2.52
	b	43.04 ± 6.85
Moisture content [%]	11.5 ± 0.6	

Sample properties after plasma treatment

Treatment conditions	**Microorganism**	**Microbial Reduction [log (N/N_0)]**	**Color**			
			L	**a**	**b**	**ΔE**
DBD-System (10 min)	TPC	-1.89 ± 0.46	29.47	4.72	27.52	15.7
	Aerobic spores	-0.59 ± 0.17				
PLEXc-system (60 min)	TPC	-1.2 ± 0.1	33.59	5.63	29.1	14.1
	Aerobic spores	-1.3 ± 0.3				
	Yeasts and moulds	-1.0 ± 0.4				

Whole Black pepper

Characterization of the raw material

Natural flora [CFU/g]	TPC	1.0×10^8
	Aerobic mesophilic spores	5.6×10^7
	Yeasts and Molds	6.0×10^3
Color / CIELab [-]	L	30.74 ± 1.7
	a	1.78 ± 0.7
	b	0.93 ± 1.9
Moisture content [%]	10.4 ± 0.4	
Piperine [g/L]	$0.47 \pm 8.1*10^5$	
Essential oils [mL/100g]	2.9 ± 0.2	

Sample properties after plasma treatment

Treatment conditions	Microorganism	Microbial Reduction [log (N/N_0)]	Color L	a	b	ΔE	Piperine [g/L]	Essential oils [mL/100g]
Plasma jet (15 min)	TPC		28.5	2.75	1.85	2.6	0.44 ± $1.5*10^{-3}$	2.7 ± 0.2
	Aerobic spores							
	E. coli	-4.11 ± 0.13						
	Salmonella enterica	-2.93 ± 0.33						
	B. subtilis spores							
	B. atrophaeus (dry)							
	B. atrophaeus (moistened)							
DBD-System (10 min)	TPC	-1.3 ± 0.8	27.4	2.2	2.1	3.5	-	-
	Aerobic spores	-0.72 ± 0.4						

Treatment conditions	Microorganism	Microbial Reduction [log (N/N_0)]	Color				Piperine [g/L]	Essential oils [mL/100g]
			L	a	b	ΔE		
PLEXc-system (30 min)	TPC (dry)	-3.2 ± 0.1	27.39	2.2	2.0	3.5	0.44 ± $1.2*10^{-3}$	2.8 ± 0.2
	TPC (moistened)	-3.44 ± 0.6						
	Aerobic spores (dry)	-2.83 ± 0.7						
	Aerobic spores (moistened)	-3.3 ±0.7						
	B. subtilis spores (dry)	-2.15 ±0.2						
	B. subtilis spores (moistened)	-2.59 ± 0.3						
	B. atrophaeus spores (dry)	-2.88 ± 0.1						
	B. atrophaeus spores (moistened)	-2.1 ± 0.7						
PLEXc-system (60 min)	TPC	4.10 ± 0.1	29.15	2.27	1.11	1.6	0.45 ± $1.4*10^{-3}$	2.8 ± 0.2
	Aerobic spores	3.16 ± 0.3						
	Yeast and Moulds	Below detection limit						
	Salmonella enterica	-4.10 ± 0.87						

4 Ultra sound assisted high pressure carbon dioxide treatment - summary of product-process interactions

Groups of trials	Work conditions	Microbial Results	Other quality parameters.
1 PAPRIKA (SAMPLE 1)	100, 200, 250, 300 bar 60/120 min 40/50°C 180 g of paprika Flow of CO_2 was 10 kg/h **No ultrasounds**	**No significant reductions** of **total aerobic mesophilic cells and yeast and moulds**. Slight reductions with **longer treatment times** (120 min) and **high pressures** (250-300 bar)	**Slight reductions** in the moisture content. Colour: ASTA: **No significant changes** CieLab: Slight differences (ΔE<5)
2 PAPRIKA (SAMPLE 2) naturally contaminated with ***Salmonella***	250/300 bar 60/120 min 40/50°C 230 g of paprika Flow of CO_2: 10kg/h Power of ultrasounds: 75V	**Slight reductions** (max $1\log_{10}$) of **total viable counts, yeasts and moulds and sulfite reducing anaerobes.** **Inactivation of *Salmonella*** at 250 bar, 50ºC and 60 min	**Reductions** of the moisture content Colour: **Slight differences**, (5<ΔE<6)
3 CHILLIE (SAMPLE 3)	300 bar 120 min 70ºC 230 g of chillie Flow of CO_2: 10kg/h Power of ultrasounds: 75V Analysis of micotoxins	**None significant reductions** of **yeast and moulds, total viable counts and sulfite-reducing anaerobes.**	No mycotoxins reduction. Reduction of the moisture content from 4,7 % to 2,6% (Higher processing temperature 70ºC). No significant differences of colour.

Groups of trials	Work conditions	Microbial Results	Other quality parameters.
4 PAPRIKA (SAMPLE 2), naturally contaminated with ***Salmonella*** Moistened up to 19-20% **The longer storage time before treatment and after wetting don't have an impact on the microbial reductions.**	250bar 60/90min 50/70ºC 180g of paprika (stored 24-48h in refrigeration after wetting) Flow of CO_2: 10kg/h Power of ultrasounds: 75V	Slight destruction of the **total aerobes (0.5-0.6 log_{10} of reduction),** but **none effectiveness against spores.** **Total destruction of moulds and yeasts (4 log_{10})** in 3 treatments. In all trials ***Salmonella*** **was eliminated.**	Decrease in the moisture content of up to 6,1% and in the a_w of up to 0,12, **higher at higher temperature and longer treatment times→samples closer to their features for commercial use.** Slight differences of colour (ΔE=5,52-7,21). No pesticides were found and no reductions of mycotoxins were observed.
	250bar 60-90min 70ºC 180g of paprika (stored 7 days in refrigeration after wetting) Flow of CO_2: 10kg/h Power of ultrasounds: 75V	**None effectiveness against spores of aerobes** and a very **low reduction of total viable counts (<0.5 log_{10})** was achieved. **Total destruction of moulds and yeasts (>3 log_{10})** in all treatments In all trials ***Salmonella*** **was eliminated.**	
5 PAPRIKA (SAMPLE 4) Inoculated with *E.coli*. 24 h before treatment Final approximated amount of 10^4 of *E.coli*	250/300bar 30-60min 50ºC 180g of paprika Moisture content of the inoculated material: **4,4%** Flow of CO_2: 10kg/h Power of ultrasounds: 75V	**Reduction of spores < 0.5log_{10}** **No treatment reaches a total decontamination of the *E. coli*.** Around 50% of reduction.	**No significant changes of colour** in 4A ΔE=4,38-5,31 and **moderated changes of colour** in 4B ΔE=4,54-6,40. Higher reduction of the moisture content and a_w at longer treatment times (60 min) and higher pressures (300 bar)→ decrease in the moisture content of up to 2,1% and decrease of the a_w of up to 0,1.
	250/300bar 30-60min 50ºC 180g of paprika Moisture content of the inoculated material: **7,4%** Flow of CO_2: 10kg/h Power of ultrasounds: 75V	**Reduction of spores < 0.5log_{10}** **Total destruction of *E. coli* in all treatments**. **Higher reduction of the microbial loads linked to the higher moisture content of the samples**	

Groups of trials	Work conditions	Microbial Results	Other quality parameters.
6 PAPRIKA (SAMPLE 5) Inoculated with *Enterococcus faecalis* Final concentration of 10^7 cells/g of *E. faecalis* paprika	150/250 bar 20/60 min 40/60ºC 180g of paprika Moisture content of the inoculated material: **7,1%** Flow of CO_2: 10kg/h Power of ultrasounds: 75V	**No effect on the spores content.** **Reduction of *Enterococcus faecalis* up to 4 log_{10}.** **Total inactivation of moulds and yeasts (3 log_{10})**	A decrease in the moisture content and the a_w was observed in all trials up to features of commercial use. The higher differences have been found in trial 8 (60min; 250bar and 60ºC). In all trials ΔE<5, except for trials 6 and 8 were ΔE is 5,39 and 5,07 respectively Slight reduction in the capsaicinoids concentration with increasing pressure of treatment (250 bar)
9 Paprika flakes Inoculated with *Enterococus faecium* Final concentration of 10^6CFU/g	150bar 15, 30 and 60 min 80ºC 180g of paprika Moisture content of the inoculated material: **13,30** and **14%.** a_w of the inoculated material: 0,67 and 0,73. Flow of CO_2: 10kg/h Power of ultrasounds: 75V	Nearly 1 log_{10} of aerobes reduction is observed after 60 min. The most moistened samples achieved 0,5 log_{10} of spores reduction after 15 min. **Total inactivation of natural content of mould and yeasts** (4,5 log_{10} after 30 min). **Total inactivation of natural content of *Enterobacteriaceae*** ($4log_{10}$ of reduction) and of the **inoculated *Enterococcus faecium*** ($5log_{10}$ of reduction) after 15 min.	Higher reduction of the moisture content and a_w at longer treatment times (60 min). Moisture and a_w closer to features of commercial use were achieved. **No significant changes of colour** in M1 (ΔE=0,90-2,42) and **slight differences** of colour in M2 (ΔE=3,36-7,80).

Groups of trials	Work conditions	Microbial Results	Other quality parameters.
7 Black pepper Application of consecutive cycles Effect of increased moisture content (from 10% to 20%)	2 cycles trials (treatment 1): 250bar 30 min 70ºC 1cycle trials(treatment 2): 250bar 60 min 50ºC Flow of CO_2: 10kg/h Power of ultrasounds: 75V	**No effect of the moisture content on the spores** decontamination. Moistened samples achieved the **total inactivation of natural content of mould and yeasts** (nearly 5 log_{10} of reduction) under treatment 1 and 2.	**No significant changes of colour** have been found after treatment, in all cases **ΔE <**5. A decrease in the moisture content and the a_w was observed. up to features of commercial use. After two cycles the reduction of the moisture content and the a_w was higher.
8 (with oregano) Effect of increased moisture content (from 6% to 19,5%)	250 bar 60 min 50/70ºC 180 g of oregano Flow of CO_2: 10kg/h Power of ultrasounds: 75V	No effect on the spores decontamination. Moistened samples achieved the **total inactivation of natural content of mould and yeasts** (nearly 4,5 log_{10} of reduction) at 70ºC, 60min and 250 bar.	**No significant changes of colour** have been found (**ΔE <**5) A decrease in the moisture content and the a_w was observed
10 Oregano Inoculated with *Enterococus faecium* Final concentration of 10^6CFU/g Two different moisture levels were studied (M1 and M2)	150bar 15/30 min 80ºC 120g of oregano Moisture content of the inoculated material: **12,7** and **14,5%.** a_w of the inoculated material: 0,66 and 0,74. Flow of CO_2: 10kg/h Power of ultrasounds: 75V	Nearly **2 log_{10} of aerobes** reduction was achieved after 15 min and **1 log_{10} reduction of spores** after 30 min. **Total inactivation of natural content of mould and yeasts** (> 3 log_{10}) abd of the **inoculated *Enterococcus faecium*** (5log_{10} of reduction) after 15 min.	Higher reduction of the moisture content and a_w at longer treatment times (60 min): Moisture and a_w closer to features of commercial use were achieved. In all cases, Δ<5 → **no influence in the colour** of the samples.

5 Infrared and microwave heating - summary of product-process interactions

Characterization of the raw material

Oregano

The results below are performed on the batch delivered to SIK in April 2013. The microbial characterization is a mean value of four replicates. More details are found in D2.1 C.

Natural flora	TPC	2.9×10^4
[CFU/g]	Bacterial spores	8.4×10^3
	Yeasts and Molds	1.6×10^4
Color /	L	50.6 ± 1.75
CIELab	a	2.7 ± 0.14
	b	25.3 ±0.54
Moisture content [%]	10.3 ± 0.40	
Water activity	0.61 ±0.01	
Essential oils [%]	2.8	

Head space volatile compound	**Composition (% fraction of total FID area)**
α-Phellandrene	1.9
α-Pinene	1.3
Camphene	0.6
α-Myrecene	3.1
α-Terpinen	1.2
o-Cymene	7.0
γ-Terpinene	5.2
Terpinolene	2.0
α-Linalool	11.1
Isoborneol	1.4
Thymol	0.4
Carvacrol	39.2
β-Caryophyllene	1.3
β-Bisabolene	3.4
Others	20.8

Paprika

The results below are performed on the paprika batch delivered to SIK in October 2013. The microbial characterization is a mean value of five samples.

Natural flora	TPC	7.2×10^7
[CFU/g]	Bacterial spores	5.6×10^6
Color /	L	34.9 ±1.01
CIELab	a	36.8 ±0.18
	b	38.2 ±0.24
Moisture content [%]	5.6 ±0.09	
Water activity	0.38 ± 0.00	

Pepper

The results below are performed on the batch delivered to SIK in May 2013. The microbial characterization is a mean value of duplicates.

Natural flora	TPC	2.4×10^7
[CFU/g]	Bacterial spores	1.5×10^7
Color /	L	20.5 ± 0.51
CIELab	a	1.85 ± 0.07
	b	4.80 ± 0.21
Moisture content [%]	7.4 ± 0.1	
Water activity	0.49 ± 0.00	

Summary of the sample properties after IR and MW treatment

Infrared treatment of oregano

Conditions	Microorganism	Microbial Reduction [log CFU/g]		Water activity		Colour		Volatile oil content (%)	GC- Head Space Volatile compounds
				After IR	*After Drying*	a*	ΔE		
90°C 2 min	Inoculated *B. cereus* spores	2.71 ± 0.54		0.87	0.65	4.99	1.91	2.4	The total composition was altered, but the key aroma compounds (carvacrol and thymol) were not affected to any high extent (See D2.1C)
90°C 10 min		5.55 ± 0.30		0.87	0.63	5.43	2.47	2.4	
100°C 2 min		2.43 ± 0.27		0.83	0.65	5.34	2.46	2.0	
100°C 10 min		4.73 ± 0.18		0.76	0.59	5.98	3.15	2.0	
90°C 2 min	Natural flora	TPC	> 2.26						
		Bact. Spores	> 1.15						
		Moulds	> 2.20						
90°C 10 min		TPC	2.26						
		Bact. Spores	0.85						
		Moulds	> 2.20						

Infrared treatment of paprika and pepper

Spice	Conditions	Microorganism	Microbial Reduction [log CFU/g]	Water activity		Colour	
				After IR	*After drying*	**ΔE****	**ΔE**
Paprika	90°C 2 min	Natural Flora	0.16 ± 0.19 (TPC) 0.22 ± 0.21 (Bact. spores)	0.88		3.72	
	90°C 10 min	Natural Flora	0.48 ± 0.02 (TPC) 0.48 (Bact. spores)	0.88		3.82	7.7
	98°C 10 min	Natural Flora	1.76 ± 0.12 (TPC) 1.62 ± 0.01 (Bact. spores)	0.87	0.28		9.2
	98°C 20 min	Natural Flora	3.66 ± 0.14 (TPC) 2.28 ± 0.02 (Bact. spores)	0.87	0.28		11.7
Pepper	90°C 2 min	Natural Flora	0.65 ± 0.07 (TPC) 0.55 ± 0.16 (Bact. spores)	0.87		1.39	
	90°C 10 min	Natural Flora	0.38 ± 0.09 (TPC) 0.49 ± 0.10 (Bact. spores)	0.86		2.82	4.2

** Compared to conditioned raw material

Microwave treatment of oregano and paprika

Herb/Spice	Conditions	Microorganism	Microbial Reduction [log CFU/g]	Water activity		ΔE	GC- Head Space Volatile compounds
				After MW	*After drying*		
Oregano	90°C 2 min	Inoculated *B.cereus* spores	0.83 ± 0.51	0.88			The total composition was altered, but the key aroma compounds (carvacrol and thymols) were not affected to any high extent (See D2.1C).
	90°C 10 min	Inoculated *B.cereus* spores	1.76 ± 0.12	0.86	0.62	2.9	
Paprika	98°C 10 min	Natural Flora	2.43 ± 0.57 (TPC) 2.23 ± 0.17 (Bact. spores)	0.84	0.38	8.1	
	98°C 20 min	Natural Flora	4.79 ± 0.00 (TPC) 3.25 ± 0.09 (Bact. spores)	0.83	0.38	11.0	