Article

Multi-Target Alternative Approaches to Promoting Fresh-Cut Carrots' Bioactive and Fresh-Like Quality

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Supplementary Material

Tables

Supplementary Material Table S1. Factor loadings of the preliminary Principal Component Analysis (PCA) of the full data matrix (56 samples and 13 variables).

Variable	Factor 1	Factor 2	Factor 3	Factor 4
TPC	0.202268	-0.822794	-0.335067	0.077934
CA	0.121653	-0.894850	0.212862	0.168795
PAL	0.061471	-0.859681	0.171582	-0.290313
TCC	0.383605	0.201281	-0.502062	0.177074
AOx	0.179585	-0.552866	-0.633246	0.218847
pH	0.774382	0.142915	-0.380450	0.052821
SSC	0.360808	-0.180590	0.609355	0.501420
Rejection	-0.901081	-0.199603	-0.011145	0.044524
O_2	0.758970	-0.176641	0.133980	-0.392505
CO_2	-0.860636	0.310495	-0.116615	0.320082
TAPC	-0.878943	-0.416320	-0.052911	0.085895
LAB	-0.941584	-0.147247	-0.060289	0.053976
Y&M	-0.688761	-0.031297	-0.140881	-0.569591

Supplementary Material Table S2. Used variable and sample codes for hierarchical cluster analysis and PCA analysis for overall quality assessment.

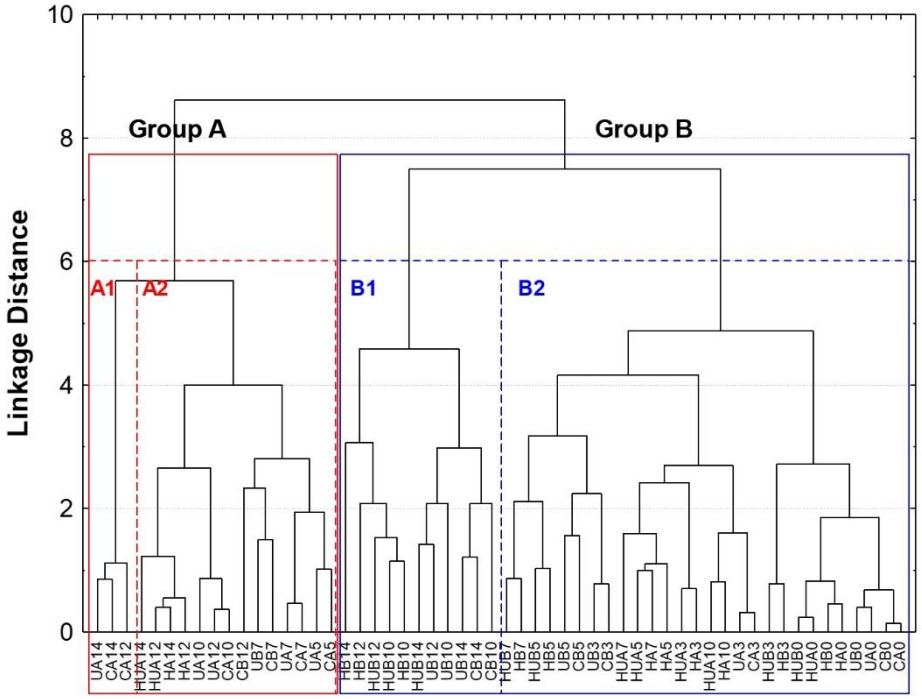
Variables	**Codes**
Total phenolic content	TPC
PAL activity	PAL
Chlorogenic Acid	CA
Total aerobic plate counts	TAPC
Lactic acid bacteria counts	LAB
Oxygen concentration	O_2
Carbon dioxide concentration	CO_2
pH	pH
Rejection index (sensorial)	Rejection
Samples	**Codes**
Control (untreated) packed in film A_day 0-14	CA0; CA3; CA5; CA7; CA10; CA12; CA14
Control (untreated) packed in film B_day 0-14	CB0; CB3; CB5; CB7; CB10; CB12; CB14
Heat-treated packed in film A_day 0-14	HA0; HA3; HA5; HA7; HA10; HA12; HA14
Heat-treated packed in film B_day 0-14	HB0; HB3; HB5; HB7; HB10; HB12 ;HB14
UV-treated packed in film A_day 0-14	UA0; UA3; UA5; UA7; UA10; UA12; UA14
UV-treated packed in film B_day 0-14	UB0; UB3; UB5; UB7; UB10; UB12; UB14
HS x UV-treated packed in film A_day 0-14	HUA0; HUA3; HUA5; HUA7; HUA10; HUA12; HUA14
HS x UV-treated packed in film B_day 0-14	HUB0; HUB3; HUB5; HUB7; HUB10; HUB12; HUB14

Supplementary Material Table S3. Changes in atmosphere composition (O_2 and CO_2), total phenolic content (TPC), chlorogenic acid content (CA), PAL activity (PAL), pH, total aerobic plate count (TAPC), lactic acid bacteria (LAB) and yeast and moulds (Y&M) and rejection index (sensorial) of shredded carrot samples as affected by abiotic stress treatments and MAP conditions during low-temperature storage (5 °C, 14 days).

Treatment	Packaging film	Storage (days)	O_2	CO_2	TPC	CA	PAL	pH	TAPC	LAB	Y&M	Rejection
C	A	0	21.0^{r}±0.0	0.0^{a}±0.0	57.67^{cdefghi}±3.23	2.90^{abcde}±0.01	30.47 ^{abcd}±2.05	6.2^{opqr}±0.0	4.3^{defgh}±0.2	2.6^{cdefgh}±0.1	3.2^{bcdefghi}±0.2	1.2^{ab}±0.4
		3	0.5^{ab}±0.5	20.3^{klmno}±0.9	61.10^{efghi}±3.32	2.64^{ab}±0.02	72.57 ^{defgh}±8.94	5.8^{klmnop}±0.1	6.1^{ijkl}±0.1	4.9^{ijklmn}±0.1	3.9^{defghij}±0.2	1.2^{ab}±0.3
		5	0.0^{a}±0.1	28.8^{rs}±1.2	81.60^{ijklm}±2.25	3.04^{abcdefg}±0.07	24.50^{abc}±1.65	5.5^{ghijk}±0.1	6.9^{jklm}±0.1	6.0^{mno}±0.1	3.7^{cdefghij}±0.3	2.4^{de}±0.3
		7	0.1^{a}±0.2	30.0^{s}±1.7	86.97^{jklm}±14.67	3.04^{abcdefg}±0.16	25.07^{abc}±1.55	6.3^{r}±0.0	7.6^{lmno}±0.1	7.0^{opqu}±0.0	3.4^{cdefghij}±0.4	3.6^{hij}±0.4
		10	0.0^{a}±0.0	38.1^{t}±0.9	42.63^{abcde}±4.63	2.50^{ab}±0.04	8.77^{a}±1.06	5.3^{efghi}±0.1	8.2^{mno}±0.2	8.2^{quv}±0.2	4.0^{efghij}±0.4	3.9^{jk}±0.4
		12	0.0^{a}±0.0	39.3^{t}±1.4	35.83^{abcd}±0.21	3.01^{abcdefg}±0.04	12.40^{a}±1.61	4.7^{bc}±0.0	8.6^{no}±0.1	8.5^{uv}±0.1	4.4^{ghij}±0.3	4.4^{kl}±0.3
		14	0.0^{a}±0.1	42.3^{t}±0.9	32.80^{ab}±0.66	2.31^{a}±0.06	11.83^{a}±1.42	4.2^{a}±0.0	8.9^{o}±0.1	8.8^{v}±0.1	4.8^{ij}±0.1	4.9^{l}±0.2
	B	0	21.0^{r}±0.0	0.0^{a}±0.0	56.33^{bcdefgh}±2.20	2.90^{abcdef}±0.03	31.30^{abcde}±2.95	6.2^{pqr}±0.1	4.1^{cdefg}±0.1	2.6^{cdefgh}±0.2	3.3^{bcdefghi}±0.1	1.1^{a}±0.2
		3	7.5^{efghijkl}±1.8	10.3^{efgh}±0.5	67.97^{fghijk}±6.38	4.31^{hij}±0.02	212.57^{pq}±26.76	5.8^{jklmno}±0.0	6.1^{ijkl}±0.3	4.9^{ijklm}±0.3	4.3^{fghij}±0.0	1.2^{ab}±0.3
		5	6.3^{cdefghij}±1.6	13.2^{ghi}±1.4	89.63^{klmn}±7.22	3.62^{cdefghi}±0.02	129.93^{jklm}±17.57	5.5^{fghijk}±0.0	7.1^{klmn}±0.2	5.6^{klmno}±0.3	4.1^{efghij}±0.2	2.2^{k}±0.3
		7	4.0^{abcdefg}±0.9	16.5^{ijk}±2.2	111.93^{nopq}±20.46	6.00^{mn}±0.09	165.03^{mno}±8.89	6.1^{mnopqr}±0.0	8^{mno}±0.2	6.3^{mnop}±0.2	3.9^{defghij}±0.4	3.1^{fghi}±0.2
		10	2.1^{abcd}±0.8	19.1^{jklm}±1.4	98.63^{lmno}±12.88	7.61^{p}±0.55	232.00^{pqr}±8.18	5.6^{hijkl}±0.1	8.9^{o}±0.3	6.8^{opqu}±0.4	5.2±0.2	3.5^{hij}±0.4
		12	1.5^{abc}±0.6	18.9^{jklm}±1.6	80.20^{hijklm}±15.80	7.46^{op}±0.18	76.23^{efghi}±9.86	5.4^{efghij}±0.0	8.9^{o}±0.2	6.7^{nopq}±0.3	5.2±0.2	4.2^{k}±0.3
		14	5.2^{bcdefghi}±4.3	14.8^{hij}±4.8	102.67^{mnop}±12.80	7.97^{p}±0.19	268.87^{r}±14.14	4.8^{cd}±0.2	8.9^{o}±0.1	6.6^{nopq}±0.2	5.2±0.3	4.9^{l}±0.2
H	A	0	21.0^{r}±0.0	0.0^{a}±0.0	53.87^{bcdef}±2.65	2.70^{abc}±0.05	27.13^{abc}±2.20	6.3^{qr}±0.1	2.6^{abc}±0.1	<10^{1} CFU.g^{-1}	<10^{1} CFU.g^{-1}	1.0^{a}±0.0
		3	2.2^{abcd}±0.2	6.3^{bcde}±1.7	68.10^{fghijk}±8.16	2.73^{abc}±0.01	63.43^{cdefg}±7.99	6.0^{lmnopqr}±0.0	3.7^{bcdef}±0.5	1.4^{abc}±0.1	<10^{1} CFU.g^{-1}	1.1^{a}±0.2
		5	1.1^{ab}±0.1	8.7^{cdefg}±0.9	88.40^{klmn}±8.91	2.80^{abcd}±0.03	18.80^{abc}±2.33	6.1^{mnopqr}±0.1	4.6^{defgh}±0.5	2.2^{bcdefg}±0.6	<10^{1} CFU.g^{-1}	1.3^{ab}±0.2
		7	2.6^{abcde}±1.6	16.8^{ijkl}±0.8	97.17^{lmno}±1.79	2.93^{abcdefg}±0.09	20.60^{abc}±1.47	6.4^{r}±0.0	5.5^{ghij}±0.2	2.9^{cdefgh}±0.4	<10^{1} CFU.g^{-1}	1.5^{abc}±0.4
		10	1.8^{abcd}±1.1	23.3^{mnopq}±1.7	55.90^{bcdefg}±2.09	3.32^{bcdefg}±0.10	35.77^{abcde}±4.68	6.3^{qr}±0.1	6.2^{ijkl}±0.6	3.5^{defghi}±1.7	<10^{1} CFU.g^{-1}	2^{cd}±0.3
		12	0.1^{a}±0.1	23.6^{mnopqr}±0.5	34.67^{abcd}±1.50	3.32^{bcdefg}±0.02	18.70^{abc}±0.30	5.4^{efghij}±0.0	6.3^{ijkl}±0.5	4.4^{hijkl}±0.6	<10^{1} CFU.g^{-1}	2.5^{de}±0.2
		14	0.1^{a}±0.0	25.3^{opqrs}±2.0	33.07^{ab}±1.01	2.89^{abcde}±0.05	26.47^{abc}±1.95	5.4^{efghij}±0.2	6.4^{ijkl}±1.3	5.3^{jklmno}±0.7	<10^{1} CFU.g^{-1}	2.9^{efg}±0.2
	B	0	21.0^{r}±0.0	0.0^{a}±0.0	55.40^{bcdefg}±3.51	3.70^{defghi}±0.03	34.37^{abcde}±2.11	6.2^{pqr}±0.1	2.4^{ab}±0.3	0.7^{ab}±0.6	<10^{1} CFU.g^{-1}	1.0^{a}±0.0
		3	14.3^{opq}±0.4	6.1^{bcde}±0.1	50.77^{abcdef}±6.43	3.77^{efghi}±0.01	159.87^{lmn}±29.54	6.0^{lmnopqr}±0.1	3.5^{bcd}±0.6	1.9^{bcde}±0.3	<10^{1} CFU.g^{-1}	1.1^{a}±0.2
		5	9.5^{hijklmno}±1.9	9.0^{cdefg}±0.7	94.30^{lmno}±3.60	5.32^{klm}±0.10	60.37^{bcdefg}±3.84	6.0^{lmnopqr}±0.2	4.5^{defgh}±0.5	3.1^{defghi}±0.6	<10^{1} CFU.g^{-1}	1.2^{ab}±0.2
		7	12.7^{nopq}±2.3	7.1^{bcde}±1.7	133.67^{qrst}±6.65	9.14^{q}±0.21	115.27^{hijkl}±16.88	6.2^{pqr}±0.1	5.5^{ghij}±1.0	4.2^{hijkl}±1.6	<10^{1} CFU.g^{-1}	1.3^{ab}±0.4
		10	11.0^{jklmnop}±0.6	8.1^{bcdefg}±0.1	143.17st±4.46	11.77^{r}±0.17	144.67^{klm}±24.82	6.0^{lmnopqr}±0.2	6.9^{jklm}±0.3	3.6^{efghij}±0.1	<10^{1} CFU.g^{-1}	1.7^{bc}±0.3
		12	11.7^{klmnopq}±0.3	8.9^{cdefg}±0.5	94.40^{lmno}±0.26	15.97^{t}±1.06	217.50^{pq}±22.12	6.1^{nopqr}±0.1	7.1^{klmn}±0.5	3.5^{defghi}±0.6	<10^{1} CFU.g^{-1}	2.1^{cd}±0.2
		14	13.6^{nopq}±3.7	6.5^{bcde}±2.8	117.63^{opqr}±0.47	21.16^{u}±0.98	201.90^{nop}±4.95	5.2^{defg}±0.0	7.2^{klmn}±0.6	3.4^{defghi}±0.6	<10^{1} CFU.g^{-1}	2.5^{de}±0.4
U	A	0	21.0^{r}±0.0	0.0^{a}±0.0	53.97^{bcdef}±2.06	2.63^{ab}±0.02	53.57^{abcdef}±9.28	6.2^{opqr}±0.0	3.9^{bcdef}±0.2	2.3^{bcdefg}±0.2	3.2^{bcdefghi}±0.1	1.0^{a}±0.0
		3	1.3^{abc}±2.1	22.0^{lmnop}±2.7	58.17^{defghi}±10.34	2.63^{ab}±0.05	74.73^{defgh}±8.66	5.9^{klmnopq}±0.1	5.8^{hijk}±0.1	5^{ijklmn}±0.2	4.3^{fghij}±0.2	1.2^{ab}±0.3
		5	0.4^{ab}±0.6	27.8^{qrs}±1.4	78.93^{ghijklm}±8.51	2.99^{abcdefg}±0.03	27.20^{abc}±4.46	6.0^{lmnopqr}±0.1	6.5^{ijkl}±0.1	5.9^{mno}±0.3	3.8^{defghij}±0.2	2.2^{d}±0.2
		7	0.4^{ab}±0.2	30.2^{s}±3.7	81.77^{ijklm}±9.28	3.15^{abcdefg}±0.03	25.23^{abc}±1.31	6.3^{r}±0.1	7.1^{klmn}±0.2	6.8^{opqu}±0.3	3.2^{bcdefghi}±0.2	3.2^{fghi}±0.3
		10	0.0^{a}±0.0	38.6^{t}±1.5	44.17^{abcdef}±1.68	3.03^{abcdefg}±0.02	26.23^{abc}±1.70	5.7^{jklmn}±0.2	8.1^{mno}±0.2	8.0^{pquv}±0.5	4.0^{efghij}±0.0	3.6^{ij}±0.2
		12	0.0^{a}±0.0	38.4^{t}±1.4	40.10^{abcde}±0.36	3.20^{abcdefg}±0.04	25.00^{abc}±2.86	5.4^{efghij}±0.0	8.4^{no}±0.1	8.3^{uv}±0.3	4.3^{fghij}±0.2	4.0^{k}±0.2
		14	0.0^{a}±0.0	43.1^{t}±1.2	53.03^{abcdef}±0.06	3.13^{abcdefg}±0.12	26.63^{abc}±4.85	4.3^{ab}±0.0	8.6^{no}±0.1	8.5^{uv}±0.2	4.5^{ghij}±0.3	4.4^{kl}±0.4
	B	0	21.0^{r}±0.0	0.0^{a}±0.0	56.17^{bcdefgh}±2.53	3.84^{ghi}±0.14	62.87^{cdefg}±8.14	6.2^{opqr}±0.0	3.6^{bcde}±0.2	1.9^{bcdef}±0.1	3.0^{bcdefgh}±0.2	1.0^{a}±0.0
		3	10.5^{jklmnop}±2.3	8.0^{bcdefg}±1.4	56.70^{bcdefgh}±1.32	4.49^{ijk}±0.27	214.13^{pq}±25.03	5.9^{klmnopq}±0.1	5.8^{hijk}±0.3	3.8^{ghij}±0.1	3.6^{cdefghij}±0.5	1.2^{ab}±0.3
		5	12.9^{nopq}±2.3	7.4^{bcdef}±2.0	78.20^{ghijkl}±1.21	5.70^{lmn}±0.09	103.03^{ghijk}±14.38	5.8^{jklmno}±0.1	6.5^{ijkl}±0.3	3.9^{ghijk}±0.5	2.8^{bcdefgh}±0.5	2.2^{d}±0.2
		7	1.7^{abc}±0.6	18.4^{jklm}±0.8	88.50^{klmn}±5.00	8.17^{p}±0.28	133.70^{jklm}±19.91	6.1^{mnopqr}±0.0	7.2^{klmn}±0.5	4.0^{ghijk}±1.2	1.9^{bc}±1.5	3.1^{fghi}±0.2
		10	15.2^{pq}±1.5	5.1^{abcd}±0.6	135.27^{qrst}±13.41	10.00^{q}±0.22	250.73^{qr}±16.38	5.7^{ijklm}±0.2	8.6^{no}±0.2	5.8^{lmno}±0.3	4.6^{hij}±0.1	3.3^{ghi}±0.3
		12	9.8^{ijklmno}±4.3	9.3^{cdefg}±4.0	91.53^{klmn}±8.80	11.43^{r}±0.06	217.13^{pq}±23.91	5.1^{cde}±0.6	8.7^{o}±0.3	5.8^{lmno}±0.5	4.8^{ij}±0.5	3.8^{jk}±0.2
		14	1.4^{abc}±0.5	18.8^{jklm}±1.0	99.47^{lmno}±15.94	9.29^{q}±0.28	220.20^{pq}±21.67	5.0^{cde}±0.1	8.8^{o}±0.3	5.7^{klmno}±0.8	4.9^{ij}±0.3	4.2^{k}±0.3
HU	A	0	21.0^{r}±0.0	0.0^{a}±0.0	52.67^{abcdef}±1.62	4.42^{ijk}±0.10	39.83^{abcde}±7.48	6.2^{pqr}±0.1	1.9^{a}±0.4	<10^{1} CFU.g^{-1}	<10^{1} CFU.g^{-1}	1.0^{a}±0.0
		3	3.4^{abcdef}±0.4	12.4^{fghi}±0.4	63.60^{efghij}±1.97	3.41^{bcdefgh}±0.03	92.33^{fghij}±7.34	6.0^{lmnopqr}±0.0	4.1^{cdefg}±0.3	1.5^{abc}±0.4	<10^{1} CFU.g^{-1}	1.1^{a}±0.2
		5	2.4^{abcd}±1.5	19.7^{jklmn}±2.5	78.37^{ghijkl}±3.46	3.82^{fghi}±0.05	31.33^{abcde}±3.02	6.2^{opqr}±0.1	4.7^{defgh}±0.6	1.9^{bcde}±0.2	<10^{1} CFU.g^{-1}	1.3^{ab}±0.2
		7	4.6^{abcdefgh}±0.1	18.8^{jklm}±0.7	123.77^{pqrs}±5.31	4.44^{ijk}±0.18	16.03^{ab}±2.14	6.3^{r}±0.0	5.2^{fghi}±1.2	2.3^{bcdefg}±0.3	<10^{1} CFU.g^{-1}	1.5^{abc}±0.4
		10	0.5^{ab}±0.5	25.2^{opqrs}±1.2	48.77^{abcdef}±4.11	6.04^{mn}±0.07	35.17^{abcde}±4.20	6.2^{pqr}±0.1	5.7^{hijk}±0.3	3.7^{fghij}±0.3	<10^{1} CFU.g^{-1}	2^{cd}±0.3
		12	0.3^{ab}±0.3	27.2^{pqrs}±2.7	28.97^{a}±1.60	3.39^{bcdefgh}±0.05	26.23^{abc}±3.69	5.5^{ghijk}±0.3	6.4^{ijkl}±0.6	5.1^{ijklmn}±0.2	<10^{1} CFU.g^{-1}	2.6^{ef}±0.2
		14	1.4^{abc}±0.5	24.7^{nopqr}±0.4	33.80^{abc}±4.10	3.01^{abcdefg}±0.07	23.00^{abc}±3.03	5.1^{cdef}±0.0	7.0^{jklm}±1.0	6.4^{mnop}±0.3	<10^{1} CFU.g^{-1}	3.1^{fgh}±0.3
	B	0	21.0^{r}±0.0	0.0^{a}±0.0	50.40^{abcdef}±0.61	5.06^{jkl}±0.04	50.00^{abcdef}±5.71	6.2^{opqr}±0.0	1.7^{a}±0.4	<10^{1} CFU.g^{-1}	<10^{1} CFU.g^{-1}	1.0^{a}±0.0
		3	15.1^{pq}±2.3	5.2^{abcde}±1.8	62.47^{efghi}±5.31	5.18^{jklm}±0.05	206.97^{opq}±38.70	6.0^{lmnopqr}±0.1	3.5^{bcde}±0.5	1.9^{bcd}±0.2	<10^{1} CFU.g^{-1}	1.1^{a}±0.2
		5	13.5^{nopq}±4.0	6.1^{bcde}±2.6	90.20^{klmn}±2.27	6.62^{no}±0.07	120.43^{ijklm}±16.85	6.0^{lmnopqr}±0.0	4.3^{defgh}±0.5	2.6^{cdefgh}±0.4	<10^{1} CFU.g^{-1}	1.2^{ab}±0.2
		7	16.5^{qr}±0.7	3.1^{ab}±0.7	134.00^{qrst}±5.92	8.13^{p}±0.31	145.63^{klm}±26.36	6.2^{opqr}±0.1	5.1^{efghi}±0.5	3.3^{defghi}±0.6	<10^{1} CFU.g^{-1}	1.3^{ab}±0.4
		10	8.9^{ghijklmn}±2.1	9.8^{defgh}±1.0	153.10^{t}±6.08	13.43^{s}±0.17	217.20^{pq}±8.40	6.0^{lmnopqr}±0.1	6.4^{ijkl}±0.8	4.3^{hijkl}±0.9	<10^{1} CFU.g^{-1}	1.7^{bc}±0.3
		12	13.2^{nopq}±0.2	7.7^{bcdef}±0.3	141.67^{rst}±1.65	15.67^{t}±0.72	197.60^{nop}±10.10	5.7^{jklmn}±0.1	6.9^{jklm}±0.5	5.1^{ijklmn}±0.4	<10^{1} CFU.g^{-1}	2.2^{d}±0.2
		14	12.5^{mnopq}±0.3	7.0^{bcde}±0.9	94.30^{lmno}±12.75	13.80^{s}±0.66	219.07^{pq}±10.97	5.3^{efgh}±0.1	7.3^{klmn}±0.3	5.8^{lmno}±0.3	<10^{1} CFU.g^{-1}	2.7^{ef}±0.4

Treatment: **C**- Control (untreated); **H**- Heat shock (100 °C/45 s); **U**- UV-C (2.5 kJ.m^{-2}); **HU**- Heat shock (100 °C/45 s) x UV-C (2.5 kJ.m^{-2}); **Packaging film**: **A**-no microperforations; **B**- laser established micro-perforations at 120 µm intervals (PPlus® - 35PA120).
Variables units: O_2- %; **CO_2**- %; **TPC** –mg CAE.100 g^{-1}; **CA** – mg.100 g^{-1}; **PAL**- µmol t-cinnamic acid.h^{-1}.100 g^{-1}; **TAPC, LAB, Y&M** – Log$_{10}$ CFU.g^{-1}; **Rejection** –hedonic scale.
Values are mean of five replicates±SD. In the same column, different letters represent significant differences at p=0.05 (Tukey HSD test).

Figures



Supplementary Material Figure S1. Hierarchical cluster analysis dendrogram of the data matrix.