

# Effect of salt and fat replacement by seaweed on the sensory and volatile component profile of frankfurters

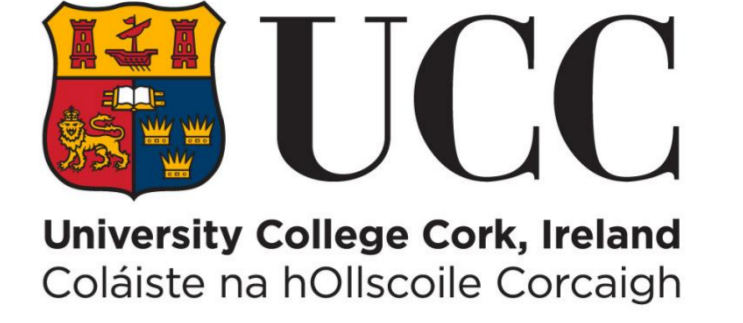
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## Introduction

Processed meat consumption increases the risk of chronic diseases due to the high levels of saturated fats and sodium. The optimization of processed meats through the replacement of salt and fat with edible seaweeds could potentially offset the risk.

This study aimed to obtain sensory and volatile component profiles of frankfurters with edible seaweeds as part of the ingredients, in order to evaluate the impact of matrix changes on the volatile profile related to flavour perception and overall acceptability.

The volatile fraction of frankfurters prepared with edible seaweed belonging to four species (*Himanthalia elongata*, *Undaria pinnatifida*, *Porphyra Umbilicalis* and *Palmaria palmata*) was analysed using gas chromatography-mass spectrometry, after cooking and thermal desorption extraction of samples. ANOVA Partial Least Squares Regression was applied to the instrumental data to visualize differences between the samples in terms of volatile compounds and sensory attributes.

## Methods

### Sensory analysis

- ◆ Consumer Testing
- ◆ Ranking Descriptive Analysis



### Texture analysis

- ◆ Texture profile analysis



### Color analysis

- ◆ CIE L\* a\* b\* colour system



### Sample extraction

- ◆ Cook
- ◆ Thermal desorption



### Volatile analysis

- ◆ GC-MS



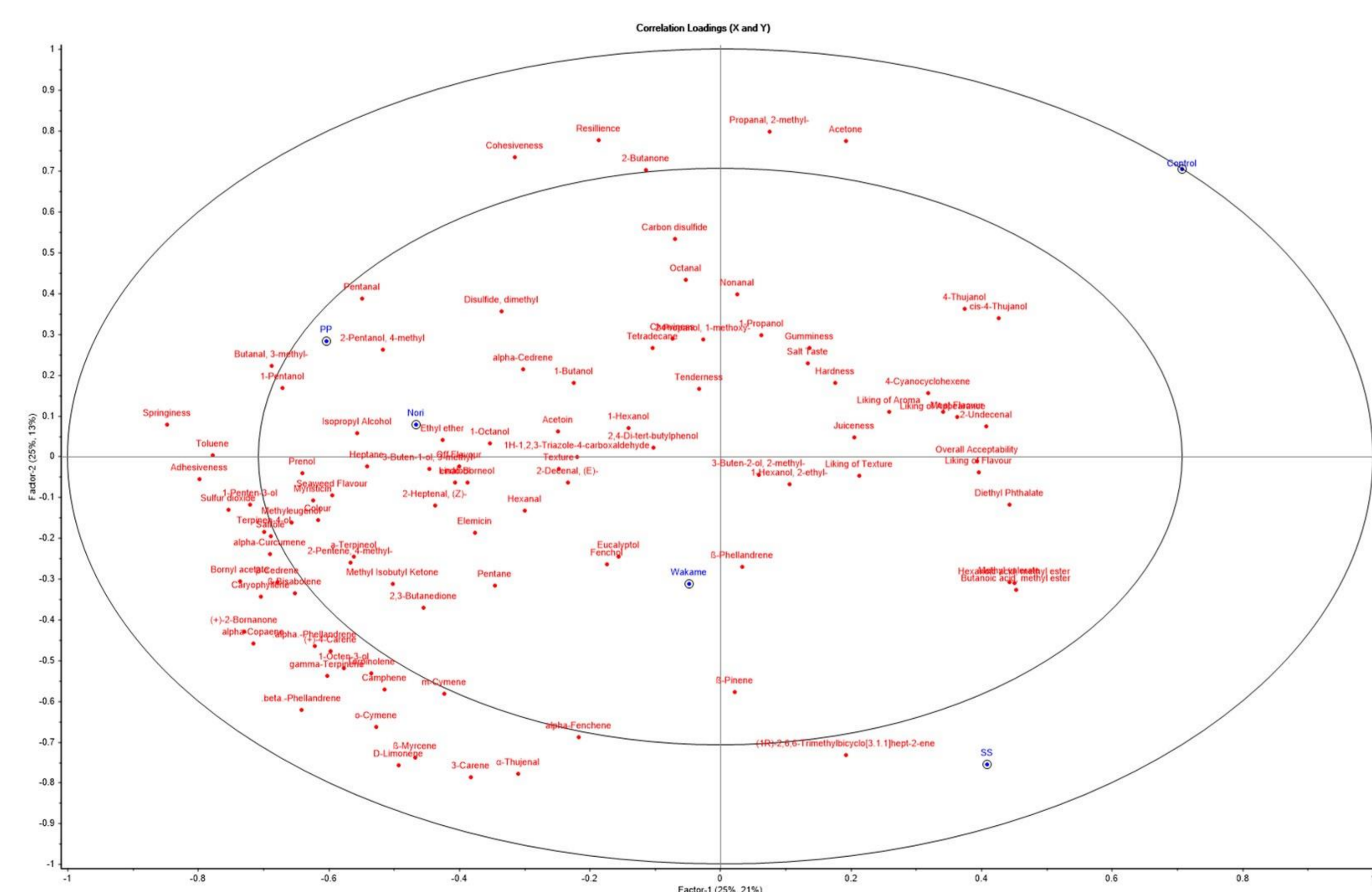
### Statistical analysis

- ◆ PLSR-ANOVA



## Results

### ANOVA Partial Least Squares Regression



**Figure 1.** ANOVA-Partial Least Squares Regression (APLSR) correlation loadings plot for frankfurter formulations with different salt/fat replacers (code: PP = *Palmaria Palmata* (Dulse); Nori = *Porphyra Umbilicalis*; Wakame = *Undaria pinnatifida*; SS = *Himanthalia elongata* (Sea Spaghetti)). Shown are the X- (sensory and instrumental data) and Y- (treatment groups) variables for the first 2 PCs for the  $R^2 =$  sensory descriptors, instrumental variables and volatile compounds, and  $R^2 =$  control and reformulated frankfurters. The concentric circles represent 100% (outer) and 50% (inner) explained variance. Texture and gumminess; texture and cohesiveness; and chewiness, as measured by the texture analyzer, were significantly ( $P < 0.05$ ) negatively correlated to frankfurters containing Sea Spaghetti, Wakame and Nori samples, respectively. Liking of aroma and meat flavor were greatly significantly ( $P < 0.01$ ) positively correlated to Sea Spaghetti, whereas tenderness was greatly significantly ( $P < 0.01$ ) negatively correlated to Nori.

### P-values from ANOVA partial least squares regression

Attribute	Control	Sea Spaghetti	Wakame	Nori	Dulse
<b>Sensory and hedonic terms</b>					
Colour	<0.0001***	<0.0001***	<0.0001***	<0.0001***	0.0012**
Liking of appearance	<0.0001***	0.0260*	-0.0179*	<0.0001***	<0.0002***
Liking of aroma	<0.0001***	0.8732 ns	-0.5142 ns	-0.0009***	-0.0005***
Liking of flavour	<0.0001***	0.0017**	0.0015**	-0.0026**	<0.0001***
Liking of texture	0.0209*	0.0162*	0.1118 ns	-0.0095**	<0.0001***
Overall acceptability	<0.0001***	0.0017**	0.0753 ns	-0.0001***	<0.0001***
Tenderness	0.0661ns	0.0132*	-0.0066**	-0.9556 ns	0.0047**
Juiciness	0.0002**	0.2658 ns	-0.5795 ns	-0.0014**	-0.0044**
Salt taste	<0.0001***	-0.7731 ns	-0.1403 ns	-0.0029**	<0.0001***
Meat flavour	<0.0001***	0.0017**	0.0589 ns	-0.1931 ns	-0.5057 ns
Off flavour	<0.0001***	-0.0253*	-0.0404*	0.0004***	<0.0001***
Seaweed flavour	<0.0001***	-0.1263 ns	-0.0009***	0.0002**	<0.0001***
<b>Instrumental measurements</b>					
Texture	<0.0001***	-0.1883 ns	-0.7241 ns	0.0045**	0.0001***
Hardness	0.0015**	0.0075**	<0.0001***	<0.0001***	<0.0001***
Adhesiveness	<0.0001***	<0.0001***	0.0419*	<0.0001***	<0.0001***
Springiness	<0.0001***	<0.0001***	0.0553 ns	<0.0001***	<0.0001***
Cohesiveness	<0.0001***	<0.0001***	-0.3415 ns	<0.0001***	<0.0001***
Gumminess	0.0002**	-0.8391 ns	<0.0001***	<0.0001***	<0.0001***
Chewiness	0.0419*	-0.0002**	<0.0001***	0.0595 ns	<0.0001***
Resilience	<0.0001***	<0.0001***	<0.0001***	<0.0001***	<0.0001***

Significance of P-values: ns, not significant; \* $P < 0.05$ , \*\* $P < 0.01$ , \*\*\* $P < 0.001$ . Sign dictates weather the correlation is positive or negative.

### Volatile component profile

	Control	Sea Spaghetti	Wakame	Nori	Dulse
Isopropyl Alcohol	3407208	2050071	4120804	2065688	5241150
1-Propanol	2161472	1485124	2014932	1842248	2302738
3-Buten-2-ol, 2-methyl-	789295	874528	802571	725488	877186
1-Butanol	1077610	1007574	1008889	1294223	1802708
2-Propanol, 1-methoxy-	1038528	537884	788445	8082727	1622003
1-Penten-3-ol	949386	3940211	2412286	3554848	7351182
3-Buten-1-ol, 3-methyl-	447186	81528	424450	517382	577824
2-Pentanol, 4-methyl-	2118830	2206385	2245218	2484300	24710277
1-Pentanol	1333893	1324821	1472842	2045311	1832111
1-Hexanol	3541917	3872869	3282187	3598633	3886652
1-Octen-3-ol	1873007	4514502	500787	6274671	3848950
1-Hexanol, 2-ethyl-	1591915	1687228	1422090	1443228	1647374
1-Octanol	254362	248827	30895	282339	311200
4-Thujanol	384735	213889	137037	188888	202646
cis-4-Thujanol	229474	117048	818510	973876	880657
Fenchol	875833	1088573	1044084	997250	1050166
Terpinen-4-ol	1088589	1270781	1203430	13181035	14058877
Propanal, 2-methyl-	2445845	1275001	1441123	1581313	2231472
Butanal, 2-methyl-	1408888	1247939	162888	1009190	2084328
Pentanal	2456055	1605208	2026111	3424243	3102247
Hexanal	822554	802802	10216837	10872131	8891210
$\alpha$ -Thujenal	2079536	1402851	3277392	2791842	3022076
2-Heptenal, (Z)-	60808	48308	202751	150273	96315
Octanal	831972	602138	600660	752218	801587
Nonanal	2748015	2257717	1777807	206955	2918904
1H-1,2,3-Triazole-4-carboxaldehyde	2335302	3423743	2377200	2860224	2019808
2-Decenal, (E)-	128589	124278	181427	150222	141823
2-Undecenal	90121	81227	30554	34880	48084
Pentane	1158845	3708643	5250250	6481157	2888958
Heptane	1565369	1621239	2081207	2428078	1847582
Tetradecane	288091	288051	283555	283228	288584
Ethyl ether	6792	78917	8338	117514	105580
Butanoic acid, methyl ester	815137	1660208	9524	73083	89415
Methyl valerate	6482	128380	7301	57739	4417
Hexanoic acid, methyl ester	735465	1474565	69284	631478	38832
Bornyl acetate	610747	802844	76023	870272	884827
Diethyl Phthalate	1343028	1588131	814838	934481	1088053
Sulfur dioxide	866307	1298462	1485403	1634023	1642091
Carbon disulfide	782594	4715791	4434877	6165759	789548
Disulfide, dimethyl	373255	214840	37438	307400	582788
D-Limonene	1473599	247098	2073970	3055238	2057044
Terpinolene	1043892	1750284	1738952	1728070	1715285
(+)-2-Bornanone	128846	1725488	183222	180118	183280
endo-Borneol	701508	738619	738619	757474	788255
$\alpha$ -Terpineol	358684	481989	387248	412811	408442
$\alpha$ -Curcumene	88214	123233	115848	138203	158893
(1R)-2,6,6-Trimethylbicyclo[3.1.1]hept-2-ene	2335475	3706556	3176254	2407207	2615718
2-Pentene, 4-methyl-	40516	187446	259201	381435	204387
4-Cyanocyclohexene	175456	45423	261878	30458	318541
Eucalyptol	38878	1005746	524779	87348	102763
Camphene	212471	988935	988512	934668	817178
$\beta$ -Phellandrene	1027950	3622036	5281988	4814890	5382781
$\beta$ -Myrcene	8207171	1378790	1308027	1381496	1243695
$\beta$ -Pinene	3642811	3714048	3524291	3101580	3378748
$\alpha$ -Phellandrene	1209208	1888419	1983855	2003205	2091737
3-Carene	1027554	1170469	1615546	14014075	1151878
(+)-4-Carene	1870301	2718875	2828977	2824136	2848386
$\alpha$ -Cymene	1227204	2503728	2507844	2472773	2298260
$\beta$ -Phellandrene	2059276	3063430	3588877	3620816	3669188
gamma-Terpinene	3591329	4414722	4482384	4255646	4477086
m-Cymene	275520	1508048	1089448	1076248	888212
Linolool	1187840	1319875	1218185	1308789	1449335
$\alpha$ -Fenchene	33773	168273	1441022	159284	1982271
$\alpha$ -Copalene	124284	173231	1611636	183150	180852
Caryophyllene	244249	324850	303741	347187	354314
$\alpha$ -Cedrene	119032	102475	98837	139511	187423
$\beta$ -Bisabolene	31278	42108	37428	43873	451834
$\beta$ -Cedrene	88817	86248	808436	1097114	1061106
Prentol	81878	115783	96259	1104213	1482828
2,4-Di-tert-butylphenol	1134312	1181049	10121407	1480189	11174388
Safrole	138573	164289	1537177	177838	183628
Methylugenol	48783	60428	58500	68039	67855
Mysticin	184259	221844	2070231	2803146	251242
Elemicin	86362	147050	1311079	2101541	1301001
Acetoin	1715432	1748781	1687200	1973286	1852021
Acetone	2220909	1497188	1748208	1573215	2028911
2,3-Butanedione	1607084	238789	206092	232847	257001
2-Butanone	428956	228475	225087	275003	486174
Methyl Isobutyl Ketone	67048	58878	61551	611454	587814
Toluene	48478	51830	71972	62442	85008

**Figure 2.** Heat-map of volatile compounds derived from frankfurters produced with different edible seaweeds. A total of 28 terpenes (E), 17 alcohols (A), 14 aldehydes (B), 6 esters (C), 5 ketones (H), 4 phenylpropanoids (G), 3 sulphur compounds (D), 2 phenols (F) and 1 hydrocarbon (I), were detected among the 80 volatile compounds identified. Terpenes and esters reached their highest levels in Sea Spaghetti; aldehydes, hydrocarbons, phenylpropanes and phenols in Nori; alcohols, ketones and sulphur compounds in Dulse; while Wakame was not predominant in any class of compounds. Highest amounts of  $\beta$ -Phellandrene,  $\gamma$ -Terpinene, (1R)-2,6,6-Trimethylbicyclo[3.1.1]hept-2-ene, Caryophyllene and  $\alpha$ -Thujenal were present across all samples, while lowest levels were found for 2-Undecenal, Methyl valerate and Ethyl ether. 1-Propanol; 2-Propanol, 1-methoxy; 4-Thujanol; cis-4-Thujanol; Propanal, 2-methyl; Octanal; 2-Undecenal; Acetone and 4-Cyanocyclohexene presented lower levels in all four modified frankfurters compared to Control. It is apparent from the heat-map that reformulation of frankfurters influenced the abundance of these volatiles. \*Significant difference ( $P < 0.05$ ).

## Conclusions

- △ Sensory acceptance test & Ranked Descriptive Analysis (untrained panellists)
  - Consumers found significant differences in colour, liking of appearance, aroma, flavour and texture attributes between the samples, except for liking of aroma on Sea Spaghetti and Wakame frankfurters, and liking of texture in Wakame frankfurters.
  - The overall acceptability of frankfurters containing seaweed was greatly influenced by seaweeds; however, there was no significant difference between frankfurters containing Wakame and Control.
  - Panellists found positive significant differences in meat flavour on Sea Spaghetti frankfurters, and in tenderness, off- and seaweed flavour on Nori and Dulse frankfurters.
  - Sea Spaghetti was the most significantly positively correlated salt/fat substitute in frankfurters with regards to sensory attributes.
- △ Texture analysis
  - Dulse was the most positively correlated to instrumental measurements.
- △ Aromatic Volatile Analysis (cooking + thermal desorption)
  - 80 volatile compounds were identified, mostly terpenes.  $\beta$ -Phellandrene was the most discriminating volatile compound.
  - Inclusion of seaweed in frankfurters influenced the abundance of volatiles compounds.
- △ The frankfurters containing seaweed spanned the APLSR with differences in sensory and flavour chemistry characteristics.
- △ Sea Spaghetti, Wakame, Nori and Dulse have the potential to reduce salt/fat levels in frankfurters, but the impact on overall acceptability is dependent upon type and dose.