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

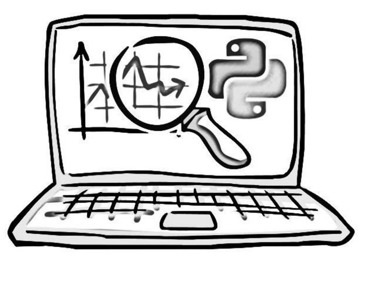
- Cook
- Thermal desorption 72 °C, 40 min

Volatile analysis

- GC-MS

Statistical analysis

- PLSR-ANOVA



Results

ANOVA Partial Least Squares Regression

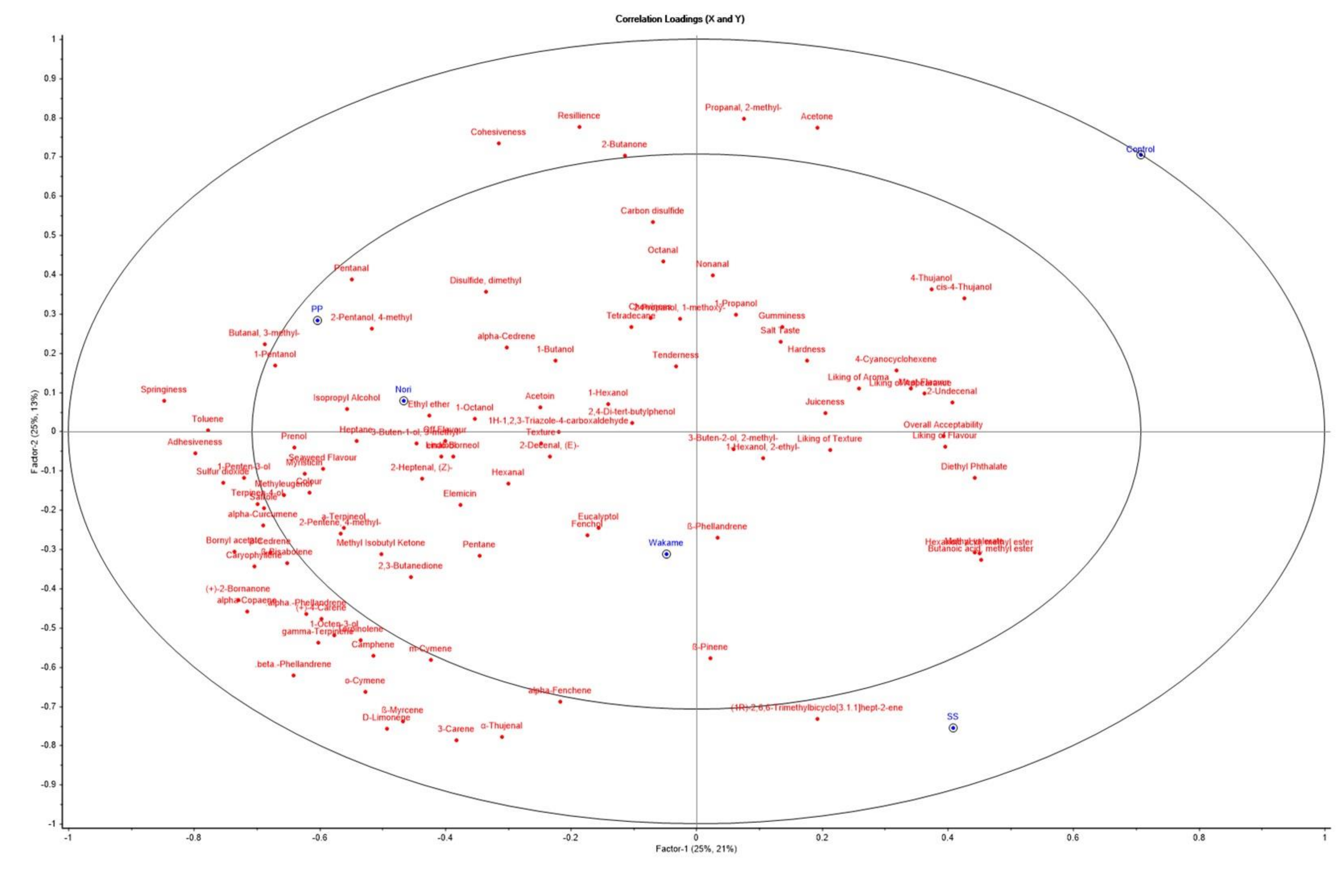


Figure 1. ANOVA-Partial Least Squares Regression (APLSR) correlation loadings plot for frankfurter formulations with different salt/fat replacers (code: PP = *Palmaria Palmata* (Dulse); Nori = *Porphyra Umbilicalis*; Wakame = *Undaria pinnatifida*; SS = *Himanthalia elongata* (Sea Spaghetti). Shown are the X-(sensory and instrumental data) and Y- (treatment groups) variables for the first 2 PCs for the • = sensory descriptors, instrumental variables and volatile compounds , and ◘ = 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
Sensory and hedonic terms					
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***
Instrumental measurements					
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***

Table 1. Significance of estimated P-values from ANOVA partial least squares regression (APLSR) (ANOVA values) for the sensory and hedonic terms and instrumental measurements of various frankfurters formulations containing different edible seaweeds, including correlation. Samples with Dulse were scored higher (P<0.05) in all sensory, hedonic and instrumental terms, except for meat flavour; followed by samples with Nori, which scored lower in terms of tenderness, meat flavour and chewiness.

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

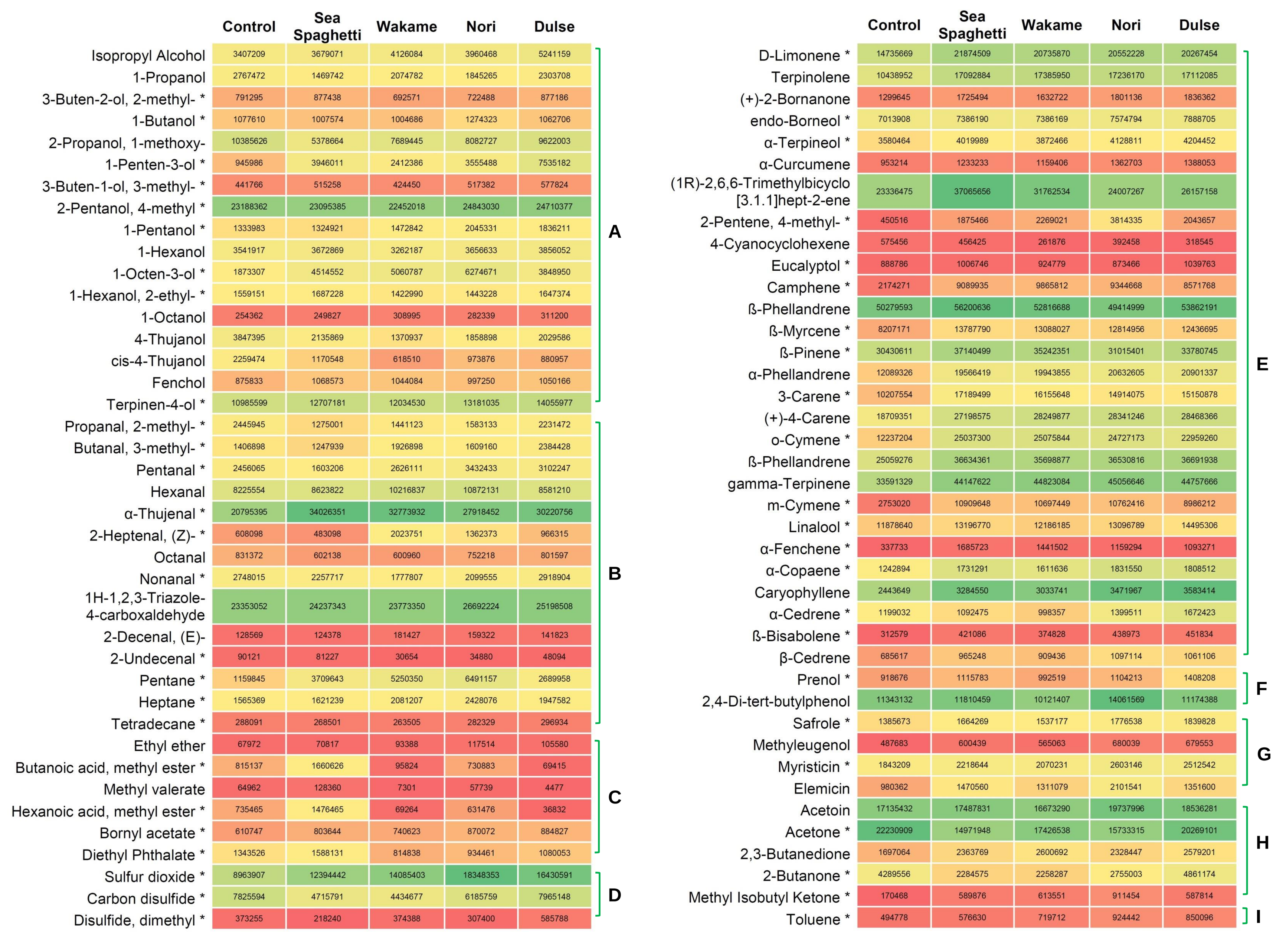


Figure 2. Heat-map of volatile compounds derived from frankfurters produced with different edible seaweeds. A total of 28 terpenes (E), 17 alcohols (A), 14 aldehydes (B), 6 esters (C), 5 ketones (H), 4 phenylpropenoids (G), 3 sulphur compounds (D), 2 phenols (F) and 1 hydrocarbon (I), were detected among 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 ß-Phellandrene, γ-Terpinene, (1R)-2,6,6-Trimethylbicyclo[3.1.1]hept-2-ene, Caryophyllene and α-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. ß-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.**

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