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Development of antioxidant breads enriched with carob byproducts and seaweeds

DANIEL RICO[1], ANA ALONSO DE LINAJE[2], ANA HERRERO[2], CARMEN ASENSIO-VEGAS[1], JONATAN MIRANDA[3], CRISTINA MARTÍNEZ-VILLALUENGA[4], DANIEL ANTONIO DE LUIS[5] and ANA BELEN MARTIN-DIANA[1]

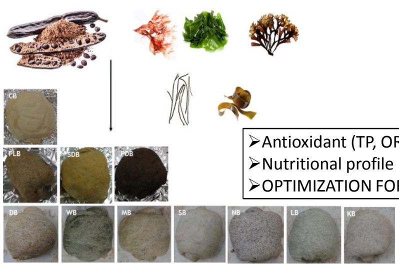
Cristina Martínez-Villaluenga[3]

[1]Agro Technological Institute of Castilla y León, Spain, [2]University of the Basque Country (UPV/EHU) and Lucio Lascaray Research Institute, Spain, [3]CIBERobn, Institute of Health Carlos III, Spain, [4]Institute of Food Science, Technology and Nutrition (ICTAN-CSIC), Spain, [5]Universidad de Salamanca, Spain.

- Due to their important role in human nutrition as source of carbohydrates and other nutrients, baked products are one of the most widely consumed foods in the world, with an annual worldwide consumption of bread of over 9 billion kg (20 billion lb).
- Trends within the bakery and pastry market focused on health and wellness products have followed double strategies based on either health or nutrition claims.
- The partial substitution of wheat flour with legume flours is an effective means to improve the nutritional quality of cereal-based foods; it is well known that legume's amino acidic composition is complementary to the one of cereals Furthermore, legumes provide other potential bioactive compounds such as fibres and phytochemicals. Carob tree (*Ceratonia siliqua L.*), native from the Mediterranean area, belongs to this food-group.
- In other hand seaweeds contain a variety of potentially bioactive compounds some of which are not present in terrestrial plants.

The aim of this paper was to screen different carob by-products and seaweeds species in order to formulate bread with functional properties and improved nutritional value

Seed peel was obtained during grinding of carob seeds and germ from the decortications and calibrated grinding of carob seeds. In the case of seaweeds, different species were used in the formulation, i.e. *Ulva rigida, Himanthalia elongata, Undaria pinnatifida, Porphyra purpurea, Laminaria ochroleuca, Chondrus crispus, and Palmaria palmata.*



- Antioxidant (TP, ORAC,DPPH,FRAP,TEAC)
- Nutritional profile
- OPTIMIZATION FORMULATION

Figure 1. Breads produced using carob byproducts or seaweeds. *CB-Control bread, PLB-Peel carob bread, GB-Germ bread, PD- Pod carob bread DB--Palmaria palmata Bread, SB- Himanthalia elongata Bread, WB- Undaria pinnatifida Bread, NB- Porphyra purpurea Bread, LB- Ulva rigida Bread, MB- Chondrus crispus Bread and KB- Laminaria ochroleuca Bread.*

- Results showed that carob presented significant high levels in total phenol (TP) compared to seaweeds and those were especially high (99.71 µmol GAE/g) in peel seed.
- Among analysed seaweeds, *Himanthalia elongata* was the one with higher TP content observed.
- *In vitro* antioxidant methods, DPPH, ORAC and TEAC, highlighted that carob by-products had more antioxidant activity than seaweeds and, among the last*, H. elongata* was more active than the rest, regardless of the method used.
- Quencher methods showed that carob by-products had higher antioxidant activity than the major part of flours seaweed analysed, probably associated to non-extractable phenolic compounds linked with fibre.
- The incorporation of carob peel was perceived by the sensory panel due to high content in fibre and pigments compared to control, for this reason carob pod flour and *H. elongata* seems to be a potential combination for the production of healthy breads.

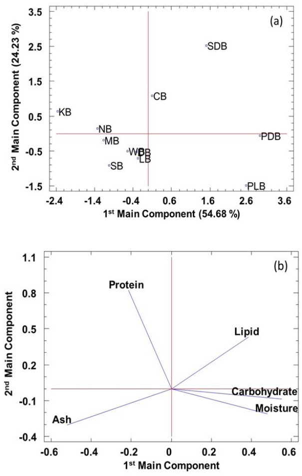


Figure 2. Principal component analysis (PCA) of different breads based on Humidity, Fat, Ash, Protein and Carbohydrate content). *CB-Control bread, PLB-Peel carob bread, GB-Germ bread, PD- Pod carob bread DB--Palmaria palmata Bread, SB-Himanthalia elongata Bread, WB- Undaria pinnatifida Bread, NB- Porphyra purpurea Bread, LB- Ulva rigida Bread, MB-Chondrus crispus Bread and KB- Laminaria ochroleuca Bread*

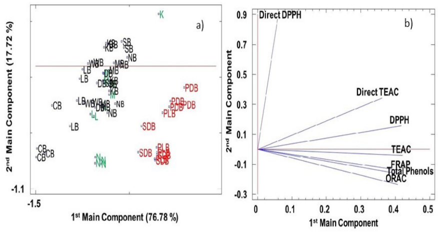


Figure 3. Principal component analysis (PCA) for breads based on antioxidant parameters. *CB-Control Bread, PLB-carob PeeL Bread, GB-carob Germ Bread, PDB-carob Pod carob Bread, PALB-Palmaria palmata Bread, HIMB-Himanthalia elongata Bread, UNDB-Undaria pinnatifida Bread, PORB-Porphyra purpurea Bread, ULVB-Ulva rigida Bread, CHOB-Chondrus crispus Bread and LAMB-Laminaria ochroleuca Bread.*

Breads (carob byproducts and seaweed)	Total Phenols (µmol gallic acid/g)	DPPH (% reduction)	TEAC (µmol Trolox/g)	FRAP (mmoles Fe reduced/g)	ORAC (µmol Trolox/g)	Direct DPPH (% reduction)	Direct TEAC (µmol Trolox/g)
PLB	1,73±0,22 ab	3,77±2,18 a	11,45±1,05 b	0,06±0,00 a	4,59± 0,01a	23,58±3,90 a	6,97±0,19a
GB	5,53±0,09 d	26,45±0,70e	25,84±0,52 e	0,24±0,01b	26,41± 0,02g	22,74±3,40 a	7,94±0,24b
PDB	5,95±0,57dc	22,16±3,77d	26,05±0,20 e	0,27±0,01b	29,56 ±0,00h	22,85±2,72 a	6,18±0,32 a
DB	6,81±0,12 e	27,69±2,56 e	33,38±0,24 f	0,47±0,02 c	18,38 ±0,01e	30,42±1,27 b	5,81±0,34a
SB	1,86±0,10 b	18,64±1,40 c	14,73±0,62 c	0,06±0,00 a	10,06 ±0,01bc	32,94±4,22 b	8,51±0,42b
WB	1,89±0,19 b	17,21±0,12 c	12,06±1,11 b	0,06±0,01a	7,39 ±0,04bc	32,14±3,81 b	7,49±1,56a
NB	2,16±0,58 c	20,34±2,54d	12,64±0,92 b	0,08±0,02a	14,26± 0,01d	31,71±3,52 b	7,46±1,44a
LB	2,51±0,30 c	21,76±2,71d	16,80±0,45d	0,09±0,00a	10,12 ±0,14c	35,10±3,43 b	7,73±0,89a
MB	2,60±0,14 c	24,78±1,36 de	16,65±0,21 d	0,10±0,00 a	8,42 ±0,00b	31,45±4,45 b	6,69±2,17a
KB	1,69±0,21 a	12,25±0,71b	10,18±0,06 c	0,07±0,01 a	13,72 ±0,02d	31,18±4,13 b	6,94±0,53 a
PLB	2,32±0,21 c	18,19±2,05c	12,04±0,54 b	0,09±0,01 a	21,40 ±0,05f	35,88±4,15 c	6,63±0,91 a

Table 1. Total phenol content (TP) and antioxidant activity (DPPH, TEAC, FRAP, ORAC, Direct DPPH, Direct TEAC) in breads prepared using wheat (control) and seaweeds or carob byproducts (8%). *CB-Control bread, PLB-Peel carob bread, GB-Germ bread, PD- Pod carob bread DB--Palmaria palmata Bread, SB- Himanthalia elongata Bread, WB- Undaria pinnatifida Bread, NB- Porphyra purpurea Bread, LB- Ulva rigida Bread, MB- Chondrus crispus Bread and KB- Laminaria ochroleuca Bread. Small letter in same column indicates differences (p≤0.05) between breads.*

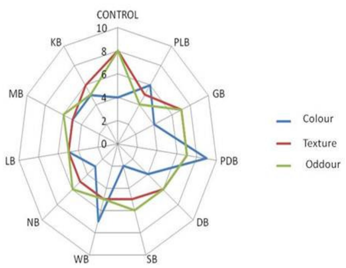


Figure 4. Sensory evaluation (colour, texture and odour) for bread produced using carob byproducts and seaweeds. *CB-Control bread, PLB-Peel carob bread, GB-Germ bread, PD- Pod carob bread DB--Palmaria palmata Bread, SB- Himanthalia elongata Bread, WB- Undaria pinnatifida Bread, NB-Porphyra purpurea Bread, LB- Ulva rigida Bread, MB- Chondrus crispus Bread and KB- Laminaria ochroleuca Bread.*

Flour from seaweeds and carob (*Ceratonia siliqua*) could be potential source for functional bread production. Both ingredients are rich in phenolic acids with high antioxidant properties. Bread formulated with seaweeds and carob by-products showed thermo-stability of their bioactivity. Carob peel, pod, and seaweed *Himanthalia elongata* were the most promising flours, since they showed the highest antioxidant activity as flour ingredient or formulated in breads. For this reason the use of both ingredients individually or combined can be an interesting alternative for the development of functional breads.

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