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EDIBLE FILM BASED ON POLYSACCHARIDES FROM THE SEAWEED *ULVA INTESTINALIS* TO IMPROVE THE SHELF LIFE OF REFRIGERATED PORK

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I. INTRODUCTION

The accumulation of *Ulva intestinalis* biomass in the Mar Menor (Region of Murcia, Spain), due to its opportunistic character derived from eutrophication [1], poses significant environmental challenges, but also an opportunity to develop new sustainable and biodegradable packaging solutions for meat, such as edible films produced from polysaccharides, proteins and lipids [2]. Although hydrocolloids from brown and red algae are widely used for film production, their low stability and moderate water resistance make other alternatives to be explored. However, green algae, little explored in this field due to their more complex structure, stand out for their unique chemical composition, which gives them better stability and can improve the shelf life of foods [2].

It should be noted that the prevention of oxidation and microbial reproduction are essential to preserve the quality of fresh pork, which under refrigerated storage conditions is only 4 days [3]. Physical processing techniques are the main approaches to preserve and maintain the safety and quality of pork. Therefore, the objective is to evaluate the effect of edible *Ulva intestinalis* algae film on the technology quality of pork meat during refrigerated storage.

II. MATERIALS AND METHODS

The green macroalgae *Ulva intestinalis*, collected from the Mar Menor lagoon (Murcia, Spain), was used. Before use, it was subjected to a pre-treatment to remove impurities and reduce its particle size. Subsequently, its hydrocolloid was extracted using an acid extraction method with 1% (w/v) citric acid, following the procedure of Manikandan et al. [4], incubated for 4 hours at 90 °C.

For the preparation of the edible films, 3% dry hydrocolloid obtained and 30% sorbitol (E-420, Sigma-Aldrich) as plasticizer were used, dissolved in distilled water (w/v) and macerated at 80 °C for gelation. Once ready, the film was applied on pork *longissimus thoracis et lumborum* (LTL) muscle fillets stored in polystyrene trays without a protective atmosphere at 4 °C. The fillets were randomly assigned to the two alternative packaging treatments: control group and edible algae film group. Three production batches were produced.

A shelf-life study was carried out at different storage times (0, 4, 7 and 11 days) to evaluate the technological quality of pork fillets without edible film (control) and fillets with edible film (treatment). Analyses of pH [5], lipid oxidation (TBARs, thiobarbituric acid reactive substances, mg MDA kg-1 meat) [6], water holding capacity (WHC, %) [7] and moisture content (MC, %) [8], were carried out. All analyses were performed in triplicate. Data processing was performed with SPSS 28 statistical software, applying a two-way analysis of variance with a significance level of $P < 0.05$.

III. RESULTS AND DISCUSSION

Table 1 shows the results of the technological properties of the pork, showing significant differences during refrigerated storage time ($P < 0.05$) caused by food spoilage. As storage time is prolonged, some of the proteins and amino acids in the pork meat decompose into alkaline substances, such as ammonia and amine compounds, due to the actions of bacteria and meat enzymes [9], causing an increase in pH. At the same time, lipids undergo oxidation processes, generating reactive compounds such as hydroperoxides and aldehydes, which contribute to the oxidative deterioration of the meat [6]. This is manifested in increased TBARs values and a decrease in water holding capacity and moisture, these effects being more pronounced in the control samples without film ($P < 0.05$), reflecting a lower degree of freshness.

Regarding the effect of the application of *Ulva* film, significant differences can be seen after 4 days of storage ($P < 0.05$), presenting lower moisture loss and therefore higher water holding capacity, and lower lipid oxidation index.

The TBARS values of the control group increased rapidly, reaching 0.84 mg/kg after seven days of refrigeration, reaching the established threshold of rancidity detectable by consumers (1 mg MDA / kg of meat) [10]. These results suggest that the *Ulva* film contributes to preserving product quality by its good barrier properties against oxygen and moisture loss, thanks to the bioactive nature of the sulphate polysaccharides, such as ulvan [11].

Table 1 –Effect of *Ulva* edible film application and storage time on technological quality parameters of pork under refrigeration.

	Control				**Edible *Ulva* Film**			
Storage	Day 0	Day 4	Day 7	Day 11	Day 0	Day 4	Day 7	Day 11
pH	5.46 ± 0.01^{w}	$5.68\pm0.00^{b,x}$	$5.77\pm0.01^{b,y}$	6.49 ± 0.02^{z}	5.47 ± 0.01^{w}	$5.61\pm0.03^{a,x}$	$5.66\pm0.02^{a,x}$	6.38 ± 0.04^{y}
$TBAR_S$	0.00 ± 0.00^{w}	0.31 ± 0.04^{x}	$0.84\pm0.09^{b,y}$	$1.92\pm0.02^{b,z}$	0.00 ± 0.00^{w}	0.21 ± 0.01^{x}	$0.57\pm0.01^{a,y}$	$1.38\pm0.07^{a,z}$
MC	71.90 ± 0.14^{y}	65.30 ± 1.84^{xy}	63.10 ± 1.56^{x}	$48.00\pm2.83^{a,w}$	71.20 ± 1.13^{y}	66.90 ± 1.27^{x}	64.70 ± 0.99^{x}	$58.30\pm0.42^{b,w}$
WHC	89.98 ± 1.08^{x}	89.08 ± 1.11^{x}	$76.93\pm0.35^{a,w}$	$70.18\pm3.04^{a,w}$	90.47 ± 1.08^{y}	88.70 ± 0.33^{y}	$80.94\pm0.47^{ab,x}$	$75.20\pm0.71^{b,w}$

pH: hydrogen potential, TBARs: thiobarbituric acid reactive substances (mg MDA kg-1 meat), MC: moisture content (%), WHC: water holding capacity (%). Values with different superscripts in a row differ significantly at $P < 0.05$. * a,b: effect of packaging treatment ** w, x, y, z: effect of storage time.

IV. CONCLUSION

It is possible to develop edible films with good technology quality from *Ulva intestinalis* algae waste. The developed films provided good barrier properties, preventing water loss, delaying oxidation and deterioration. Therefore, this study highlights the potential of green algal waste and proposes an innovative and sustainable approach for the development of biodegradable packaging films.

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