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# The order matters: a green process for rice straw valorization

[1]Laura Andrea Cabrera-Villamizar, [2]María José Fabra-Rovira, [2]Antonio Martínez-Abad and [2]Amparo López-Rubio

[1]*Food Safety and Preservation Department, Institute of Agrochemistry and Food Technology (IATA-CSIC), Valencia, 46980, Spain*
[2]*Food Safety and Preservation Department, Institute of Agrochemistry and Food Technology (IATA-CSIC), Valencia, 46980, Spain; Interdisciplinary Platform for Sustainable Plastics towards a Circular Economy—Spanish National Research Council (SusPlast-CSIC), Madrid, 28006, Spain*

## Abstract

Rice straw is a usable residue massively produced in all rice-producing countries worldwide and which can be transformed into added-value products such as polyphenols, antioxidants, lignin, and cellulose. Although rice straw pulping to obtain cellulose is already an industrial practice in some countries, greener strategies avoiding the use of aggressive chemicals and an integral valorization of other added-value compounds are desirable for a more eco-sustainable process. The present study aimed at using a green process combining a mild alkali treatment, ozone, and enzymatic treatments to extract cellulose and other added-value compounds from rice straw and to evaluate the effect of the order of applying the different extraction steps. Specifically, the alkali treatment was performed using an autoclave at pH 13 for 3 h, the ozonation was carried out at pH 13 for 2 h at 100 g/$Nm^3$ and the enzymatic hydrolysis was done using a xylanase capable of working optimally at pH 9 for 5 h. This combined strategy breaks, oxidizes and purifies the biomass to obtain different products in the process. Both, the solid extracts and the supernatants obtained after each treatment were collected for further physicochemical characterization. The solid extracts were also examined using fluorescent microscopy. The alkali (A)-ozone (O)-enzyme (E) treatment showed the best capacity to extract high purity cellulose from rice straw and other valuable compounds during the process. Accordingly, the relative presence and abundance of cellulose fibers observed in the microscope increased after the alkali hydrolysis in both treatments. The amount of lignin was reduced in both processes. However, lignin content was lower in the solid extract obtained after the SAOE process compared to the SOAE process. Also, the TGA analysis showed that SAOE and SOAE samples increased their thermal stability after the enzymatic process. In the obtained supernatants (L), polymeric xylan or xylose and arabinose were enriched after the alkali hydrolysis using both approaches. Additionally, the antioxidant capacity and the polyphenol contents were higher in LA and LOA. In

contrast, LO and LAO samples showed lower antioxidant capacity and polyphenol content, probably as a consequence of ozone oxidation. Thus, the alkali process allowed the purification and extraction of various valuable compounds from the rice straw. In conclusion, the AOE strategy is suggested to become a greener method for extracting cellulose and other added-value compounds that could be used to develop packaging and active materials in the future.

**Keywords:** rice straw, cellulose, alkali, enzyme, ozone