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Phosphorus sustainability: approaches for an efficient P utilization from cereal by-products in feed industry

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PURPOSE OF THE ABSTRACT

In this work, we investigate a new approach for a potential closing of the phosphorus (P) cycle as P is one of the most important elements on earth and no kind of life is possible without it. At the same time, P is a limited mineral resource - expected to be depleted within the next decades to centuries [1]. In a previous study, we identified the major P demand in the agricultural sector with over 80% of all P inputs. Main P losses occur as water runoff from agricultural land (55%), followed by P accumulation in slaughterhouse residues (29%) and in sewage sludge (15%). Hence, particularly a reduction of runoff as the largest P waste stream represents an effective starting point for a sustainable P management.
A novel and promising approach aiming to significantly reduce P water runoff is the customization of P content in animal feeds to the specific animal need. By-products of the milling industry, typically used as fodder, contain high amounts of P - mainly organically bound in the form of phytate. Phytate, however, can only very limited be digested by monogastric animals, such as swine and poultry, but rather shows anti-nutritional effects by complexing valuable minerals (e.g. Ca and Zn) [2]. Thus, mineral P needs to be supplemented and a major part of up to 70% of P from cereal-based animal feed is directly excreted [3]. This leads to P enriched manure which - when being depleted for fertilizing purposes - enhances P runoff and therefore the eutrophication problem [4].

Based on this, a potential process is evolved within this research aiming to reduce organic P content in rye bran and to make this P available for further efficient use in the feed, food, or fertilizer industry. This is investigated within a three-step process that comprises solubilization of phytate P from the solid rye bran (step 1) followed by a conversion into free phosphate (step 2) and a recovery of P in a directly usable form (step 3).
In the first step, phytate P is completely solubilized from the cereal substrate according to the standard procedure by extraction in diluted hydrochloric acid at room temperature. Residual extracted bran can, under strict feed control, be led back as animal fodder. Following microwave-assisted thermal treatment of the acidic rye bran extract shows high free P liberation rates. By threefold repeated treatment at 180 °C for 10 min, phytate conversion rates of > 90% up to complete cleavage within the uncertainty of measurement were achieved. Released inorganic P is then, as a last step, precipitated by slightly over-stoichiometric addition of magnesium and ammonia chloride at pH 8 to 9. Here, precipitation to an extent of > 99% of released free P could be observed. The residual stream can, for a complete valorization, be analyzed for further potential value products such as acid-soluble organic compounds.
The investigated process is aimed to achieve these three equally important positive effects:
- Enhanced nutritional quality of cereal-based animal feed (through a reduction of anti-nutritional effects of phytate)
- Substitution of mineral P (by valorization of P in side streams)
- Reduction of the eutrophication problem (via reduced soil P accumulation and runoff)

By establishing a process for tailor-made animal feed, significant amounts of over 10'000 metric tonnes P are expected to be recycled from cereal by-products in Europe only [5] and can, like that, be used more efficiently. Thus, the hereby investigated process can make an important contribution to closing the current P cycle.

FIGURES

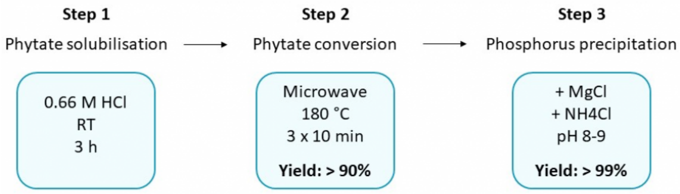

FIGURE 1

Three-step process for a valorization of P in cereal-based animal feed

FIGURE 2

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KEYWORDS

Phosphorus | Recovery | P management | Circular Economy

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