ASSESSMENT OF PECTIN AND DIETARY FIBER PRESERVATION IN PUMPKIN AND SESAME BIOMASS DURING THERMAL PROCESSING

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Abstract

The valorization of agricultural and food-processing by-products as functional feed ingredients requires processing methods that ensure both storage stability and preservation of nutritionally valuable constituents. Pectic substances and dietary fiber are particularly important components of plant-derived biomass, and their retention during thermal processing largely determines the potential value of the resulting feed materials. The present study evaluated changes in pectin and dietary fiber contents of pumpkin processing residues, sesame flowers, and sesame stems subjected to convective drying at different temperatures.

The initial chemical composition of the investigated materials differed substantially. Pumpkin processing residues contained the highest level of pectin (**6.50% DM**), followed by sesame flowers (**4.28% DM**) and sesame stems (**2.67% DM**). In contrast, sesame stems were characterized by the highest dietary fiber content (**46.2% DM**), compared with 28.6% in sesame flowers and 21.8% in pumpkin residues.

The materials were dried at 50, 60, and 70°C using a constant air velocity of 1.0 m/s. Drying temperature had a pronounced effect on pectin preservation. At 50°C, pectin retention ranged from 95.7 to 96.6%, whereas drying at 60°C maintained 93.1–93.6% of the initial pectin. Increasing the temperature to 70°C reduced pectin retention to 86.0–86.5%. Dietary fiber showed greater thermal stability; at 60°C, its content remained at 21.2% in pumpkin residues, 27.8% in sesame flowers, and 45.1% in sesame stems.

The results demonstrate that moderate-temperature drying provides favorable preservation of functional plant components. Pumpkin residues can be considered a promising pectin-rich secondary raw material, while sesame stems represent a concentrated source of dietary fiber. Drying at **60°C** provided an appropriate balance between thermal treatment and preservation of these constituents, suggesting its suitability for producing pectin- and fiber-rich powdered ingredients intended for further application in compound feed formulations.

Keywords: pectin, dietary fiber, pumpkin processing residues, sesame biomass, convective drying, thermal processing, functional feed ingredients, agricultural by-products.

1. Introduction

The increasing emphasis on resource-efficient agricultural production has stimulated interest in the valorization of plant-derived by-products. Considerable quantities of biomass generated during crop production and food processing remain underutilized despite containing carbohydrates, dietary fiber, pectic polysaccharides, minerals, and other potentially valuable constituents. Their conversion into functional ingredients can contribute to waste reduction while expanding the range of locally available raw materials for food and feed production [1, 2].

Plant-processing residues rich in structural carbohydrates are particularly attractive because their properties differ substantially from those of conventional energy- and protein-based feed ingredients. Dietary fiber consists of a heterogeneous group of plant-derived carbohydrates with important physicochemical and functional properties [5]. Pectic substances are also of technological interest because of their water-binding and structural characteristics. Consequently, preservation of these components during processing is important when plant by-products are intended for further utilization.

Pumpkin processing generates peel, fibrous tissues, and other residual fractions that contain appreciable quantities of pectic substances and dietary fiber. Previous studies have demonstrated that pumpkin by-products can be processed into fiber-enriched materials and can serve as sources of pectin and other functional compounds [1, 2]. This suggests that pumpkin residues should be considered as potential secondary raw materials rather than simply processing waste.

Sesame (Sesamum indicum L.) is primarily cultivated for its oil-rich seeds, while its vegetative biomass is considerably less utilized. Studies of sesame stems have demonstrated substantial concentrations of structural components, including cellulose and related fibrous fractions [3]. Assessments of sesame crop residues have also indicated their potential for further agricultural utilization [4]. In addition, sesame-derived fractions are known to contain dietary fiber with useful physicochemical characteristics [8].

A major limitation to the direct utilization of these materials is their moisture content after harvesting or processing. Drying is therefore required to improve stability, facilitate milling, and prepare the material for subsequent incorporation into formulated products. Convective drying remains one of the most accessible methods for processing agricultural raw materials [6].

However, drying conditions can substantially influence product quality. Increasing temperature accelerates moisture removal but may simultaneously affect thermally sensitive components and modify the physicochemical properties of plant tissues [6, 7]. Therefore, the most rapid drying regime is not necessarily the most suitable when preservation of functional components is a priority.

The **aim of this study** was to evaluate the influence of convective drying temperature on pectin and dietary fiber preservation in pumpkin processing residues, sesame flowers, and sesame stems and to assess their potential as functional secondary raw materials for compound feed production.

2. Materials and Methods

The experimental materials included pumpkin processing residues, sesame flowers, and sesame stems. Pumpkin residues consisted mainly of peel and fibrous tissues obtained after primary processing. All samples were cleaned of foreign materials prior to drying. Pumpkin residues and sesame stems were reduced to relatively uniform particle sizes to improve the consistency of heat and mass transfer.

Before thermal treatment, the initial moisture, dry matter, pectin, and dietary fiber contents of each raw material were determined. Pectin and dietary fiber contents were expressed on a dry matter (DM) basis to allow direct comparison among materials with different initial moisture levels.

The initial pectin content was **6.50 ± 0.18% DM** in pumpkin processing residues, **4.28 ± 0.14% DM** in sesame flowers, and **2.67 ± 0.11% DM** in sesame stems. Initial dietary fiber contents were **21.8 ± 0.7, 28.6 ± 0.9, and 46.2 ± 1.1% DM**, respectively.

Convective drying was performed at **50, 60, and 70°C** with a constant air velocity of **1.0 m/s**. Drying was continued until the samples reached a final moisture content of approximately 8–10%. Each treatment was performed in triplicate.

After drying, samples were cooled to ambient temperature and milled to obtain homogeneous powders. Pectin and dietary fiber contents were subsequently determined in the dried materials.

Pectin retention was calculated according to the following equation:

$$\mathbf{PR = (P_1 / P_0) \times 100}$$

where **PR** is pectin retention (%), $\mathbf{P_0}$ is the initial pectin content (% DM), and $\mathbf{P_1}$ is the pectin content after drying (% DM).

Experimental results were expressed as mean ± standard deviation. Differences among drying treatments were evaluated statistically, and differences were considered significant at $p < 0.05$.

3. Results and Discussion

The initial chemical composition of the investigated materials showed considerable differences. Pumpkin processing residues contained **6.50% pectin on a dry matter basis**, compared with 4.28% in sesame flowers and 2.67% in sesame stems. The relatively high pectin concentration observed in pumpkin residues supports previous findings identifying pumpkin processing by-products as promising sources of pectic polysaccharides [1, 2].

An opposite pattern was observed for dietary fiber. Sesame stems contained **46.2% dietary fiber**, more than twice the level detected in pumpkin processing residues (21.8%). Sesame flowers contained 28.6%. The high fiber concentration of sesame stems is consistent with previous reports describing sesame vegetative biomass as rich in structural carbohydrates, particularly cellulose-containing fractions [3, 4].

Drying temperature produced a clear effect on pectin preservation. At 50°C, pectin retention ranged from **95.7 to 96.6%**, demonstrating that mild-temperature dehydration caused relatively limited losses. At 60°C, retention remained above 93% in all materials: 93.1% in pumpkin residues, 93.2% in sesame flowers, and 93.6% in sesame stems.

Increasing the temperature to 70°C resulted in a more pronounced reduction, with pectin retention declining to **86.0–86.5%**. The observed temperature-dependent response confirms the importance of considering compositional quality when selecting drying conditions. Drying processes can induce physical and chemical change stems.

Table 1. Effect of drying temperature on pectin retention and dietary fiber content of plant by-products

Material	Drying temperature, °C	Pectin, % DM	Pectin retention, %	Dietary fiber, % DM
Pumpkin processing residues	Initial	6.50 ± 0.18	100.0	21.8 ± 0.7
	50	6.22 ± 0.16	95.7	21.4
	60	**6.05 ± 0.15**	**93.1**	**21.2**
	70	5.61 ± 0.14	86.3	20.5
Sesame flowers	Initial	4.28 ± 0.14	100.0	28.6 ± 0.9
	50	4.11 ± 0.12	96.0	28.1
	60	**3.99 ± 0.11**	**93.2**	**27.8**
	70	3.68 ± 0.10	86.0	26.9
Sesame stems	Initial	2.67 ± 0.11	100.0	46.2 ± 1.1
	50	2.58 ± 0.09	96.6	45.6
	60	**2.50 ± 0.08**	**93.6**	**45.1**
	70	2.31 ± 0.08	86.5	43.8

Increasing the temperature to 70°C resulted in a more pronounced reduction, with pectin retention declining to **86.0–86.5%**. The observed temperature-dependent response confirms the importance of considering compositional quality when selecting drying conditions. Drying processes can induce physical and chemical changes in plant-derived materials, and the magnitude of these changes generally increases with treatment intensity [6, 7].

Dietary fiber showed greater apparent stability than pectin under the investigated conditions. At 60°C, dietary fiber content remained at **21.2% in pumpkin processing residues, 27.8% in sesame flowers, and 45.1% in sesame stems**. Even at 70°C, sesame stems contained 43.8% dietary fiber. This relative stability is consistent with the structural nature of many dietary fiber components [5].

The results also demonstrate that the three investigated materials should not be considered interchangeable. Pumpkin residues contained approximately **2.4 times more pectin than sesame stems**, whereas sesame stems contained more than twice as much dietary fiber as pumpkin residues. Sesame flowers occupied an intermediate position for both components.

This compositional differentiation may be advantageous when developing feed ingredients. Pumpkin-derived powder may primarily contribute pectic substances, whereas sesame stem powder could be considered a concentrated fiber-rich component. Sesame flower powder may provide a more balanced combination of the two fractions.

Although the 50°C treatment provided maximum pectin preservation, selecting this regime exclusively on the basis of composition would overlook processing efficiency. Previous principles of convective dehydration indicate that lower drying temperatures generally require longer processing periods [6]. Conversely, excessive thermal intensity may accelerate undesirable changes in product quality [7].

Under the conditions of the present study, drying at **60°C and an air velocity of 1.0 m/s** represented the most appropriate compromise. More than 93% of the initial pectin was retained, while dietary fiber remained largely preserved. The resulting dried materials therefore retained the principal compositional characteristics required for their potential use as pectin- and fiber-rich feed ingredients.

These findings provide a basis for subsequent studies on the incorporation of the obtained powders into compound feeds. Particular attention should be given to their effects on water absorption, hygroscopicity, flowability, bulk density, pellet formation, and storage stability, because the high contents of pectin and dietary fiber may influence both the nutritional and technological properties of feed mixtures [5, 8].

4. Conclusion

The results demonstrated that pumpkin processing residues, sesame flowers, and sesame stems represent compositionally different but potentially valuable secondary plant resources. Pumpkin processing residues were distinguished by the highest initial pectin content (**6.50% DM**), while sesame stems contained the highest level of dietary fiber (**46.2% DM**). Sesame flowers occupied an intermediate position, containing **4.28% pectin and 28.6% dietary fiber**.

Drying temperature had a greater influence on pectin preservation than on dietary fiber content. Mild drying at 50°C resulted in the highest pectin retention (**95.7–96.6%**), whereas increasing the temperature to 70°C reduced this indicator to **86.0–86.5%**. At 60°C, more than 93% of the initial pectin was preserved in all investigated materials, with retention values of **93.1% for pumpkin residues, 93.2% for sesame flowers, and 93.6% for sesame stems**.

Dietary fiber showed comparatively high stability under moderate drying conditions. After treatment at 60°C, its content remained at **21.2% DM in pumpkin processing residues, 27.8% DM in sesame flowers, and 45.1% DM in sesame stems**. The particularly high fiber concentration of sesame stems indicates their potential as a fiber-rich secondary feed resource.

Considering the preservation of both pectic substances and dietary fiber, convective drying at **60°C with an air velocity of 1.0 m/s** can be regarded as an appropriate processing regime for the investigated plant materials. This condition provides high retention of the target functional components while producing stable dried materials suitable for subsequent milling.

The findings support the differentiated utilization of these agricultural by-products in feed production. Pumpkin-derived powder may be considered primarily as a pectin-rich ingredient, whereas sesame stem powder represents a promising source of dietary fiber. Sesame flower powder may provide an intermediate source of both components. Such complementary properties create opportunities for their individual or combined incorporation into compound feed formulations.

Further research should determine optimal inclusion levels of these powders in compound feeds and evaluate their effects on bulk density, flowability, hygroscopicity, water-holding capacity, pellet strength, and storage stability.

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