Journal of Food Engineering 126 (2014) 178–189

Contents lists available at ScienceDirect

Journal of Food Engineering

journal homepage: www.elsevier.com/locate/jfoodeng

Lupine and rapeseed protein concentrate in fish feed: A comparative assessment of the techno-functional properties using a shear cell device and an extruder

Vukasin Draganovic [a,b,*], Remko M. Boom [b], Jan Jonkers [a], Atze Jan van der Goot [b]

[a] Skretting Aquaculture Research Centre (a Nutreco Company), PO Box 48, 4001 Stavanger, Norway
[b] Lab. of Food Process Engineering, Wageningen University, PO Box 17, 6700 AA Wageningen, The Netherlands

ARTICLE INFO

Article history:
Received 28 August 2013
Received in revised form 13 November 2013
Accepted 14 November 2013
Available online 23 November 2013

Keywords:
Extrusion
Fish feed
Soy
Lupine
Rapeseed
Protein concentrate

ABSTRACT

The techno-functional properties of soy, lupine and rapeseed protein concentrates (SPC, LPC and RPC, respectively) in fish feed were evaluated relative to fish meal (FM). The effects were studied using a shear cell device and an extruder with emphasis on the added moisture content. Six diets were formulated: an SPC-based diet with 300 g SPC kg^{-1}, diets containing 100 and 200 g LPC kg^{-1} or 100 and 200 g RPC kg^{-1} and an FM-based diet with 450 g FM kg^{-1}. Each diet was extruded with an added moisture content of 29%, 25% and 22% of the mash feed rate. It was found that the technological properties of LPC closely resemble FM, being high solubility, low water-holding capacity (WHC) and low paste viscosity. The LPC 100 and 200 g kg^{-1} diets could be extruded at 22% moisture, which gives an extrudate with reduced drying requirements. In addition, less specific mechanical energy was needed for extrusion. In contrast, both SPC and RPC have high WHC and paste viscosity. This explains the higher feed moisture required during extrusion. The properties of the feeds containing RPC could be well within the ranges acceptable for commercial fish feed use at even higher moisture content compared with SPC. The results of the extrusion trials confirmed the observations made from the shear cell device. Thus, the shear cell device can be used to study processing conditions that are close to extrusion conditions.

1. Introduction

Fish meal (FM) is a finite protein source for commercial salmon and trout feeds. Soy protein concentrate (SPC) possesses most of the nutritional characteristics required for an alternative feedstuff to FM (Gatlin et al., 2007). However, regardless of these benefits of SPC, sustainability also implies the use of plant proteins originating from different sources and locations.

From a technological viewpoint, SPC is easy to store, handle and blend with other ingredients. Furthermore, it possesses good expansion capabilities during extrusion and contributes to the strength of the pellets. However, the inclusion of SPC in the feed also requires the addition of more moisture for the extrusion process due to its high water-holding capacity (WHC) (Bhattacharya et al., 1986; Zayas, 1997; Draganovic et al., 2011). The extra water has to be removed subsequently after extrusion through drying. This is undesirable because it is very energy intensive, emits odour to the environment and may compromise plant safety (dust generation). It is therefore interesting to evaluate other plant materials. Recent advances in fractionation technologies have provided more fractions, such as lupine protein concentrate (LPC) and rapeseed protein concentrate (RPC), with higher protein and lower carbohydrate contents relative to their unprocessed raw materials.

From the point of view of reduced addition of moisture during extrusion, LPC might be interesting because of its low viscosity as demonstrated by Chew et al. (2003). In addition, the nutrient profile of lupines shows their potential to replace significant proportions of FM in aquafeeds (Glencross et al., 2004, 2005; Gatlin et al., 2007; Sørensen, 2012; Zhang et al., 2012; Molina-Poveda et al. 2013). Although some work has been done on the technological aspects of lupine kernel meals in fish feed (Glencross et al., 2010), we are not aware of such studies on the use of LPC.

Rapeseed is one of the most abundant protein meals and it represents 12.4% of the world protein meal production (Ash and Dohlman, 2006), ranked second behind soy (Drew, 2004). The high biological value of rapeseed protein products has already been confirmed in feeding trials with salmonids (Higgs et al., 1994; Mwachireya et al., 1999). It is therefore remarkable that the techno-functional characteristics of RPC in fish feed have not yet been reported.

* Corresponding author at: Skretting Aquaculture Research Centre (a Nutreco Company), PO Box 48, 4001 Stavanger, Norway. Tel.: +47 51 82 55 47; fax: +47 51 82 55 01.
E-mail address: vukasin.draganovic@skretting.com (V. Draganovic).

0260-8774/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jfoodeng.2013.11.013

The current article presents a compilation of the most interesting techno-functional properties of three plant protein-rich ingredients in comparison with FM. In this study, we show that LPC allows the addition of less moisture during extrusion of low FM diets. In contrast, when replacing SPC with RPC, product properties can be maintained only with greater addition of moisture. Although the main objective of this research was to investigate the effects of partial replacement of SPC with RPC and LPC on the specific mechanical energy usage during extrusion, the feed moisture requirements and the properties of the fish feed products, we also evaluated the usefulness of the pilot-scale shearing cell device as a fast and simple method to investigate the techno-functional properties of the feed ingredients.

2. Materials and methods

2.1. Feed ingredients and diet formulations

The formulations consisted of a commercial salmon grower diet (SPC diet), based on SPC, and four experimental diets in which SPC was partly replaced by either LPC or RPC to give diets containing 100 and 200 g LPC kg^{-1} or 100 and 200 g RPC kg^{-1}. In addition, the composition of the sixth feed (FM diet) was similar to that of some feeds still available on the market (with FM as the major constituent). All diets were formulated to be roughly isonitrogenous and isoenergetic and contained approximately 110 g starch kg^{-1}. The chemical composition of the raw materials is given in Table 1, while the formulations and chemical composition of the diets are given in Table 2.

2.2. Shear cell trials

2.2.1. Shearing device

Shear cell trials were performed at the Laboratory of Food Process Engineering at Wageningen University (Wageningen, The Netherlands). The shearing device was developed to study the influence of simple shear deformation on breakage and structure development in a number of biopolymer systems (Peighambardoust et al., 2004; Manski et al., 2007; van der Zalm et al., 2012). The device allows processing under conditions that are relevant to extrusion (van den Einde et al., 2005; Emin et al., 2012). The device consists of stationary and rotating cones, which are both jacketed; the temperature is regulated by a circulating water flow. The shearing device is connected to a Thermo drive unit (Thermo Scientific, Staffordshire, UK) with an interface and controlling unit for on-line measurement of temperature and torque values. The contact surface of the cone and plate is grooved to avoid slippage of the material during shear processing. The detailed description of the device can be found elsewhere (Peighambardoust et al., 2004). A configuration of the shear cell is shown in Fig. 1.

2.2.2. Sample preparation and shearing process

Before the shear processing, the sample material was blended with water in a Philips kitchen blender (type HR 7744, Amsterdam, The Netherlands) for 1 min. The mass ratios between the dry flour and water was 40:60 for feed ingredients; ratios of 65:35, 60:40 and 50:50 were used for each sample of meal mix. After blending with water, the total amount that was placed in the shear cell was 54 g and 82 g in the case of feed ingredients and meal mixes, respectively. After filling the shear cell zone with the material, the cone-plate cell was closed hydraulically with a vertical compression force of 3500 N onto the material, which was kept constant during all experiments. The pressure inside the chamber was adjusted to 2 bar to prevent evaporation of water during the experiments. All samples were sheared at 90 °C and 50 rpm for 20 min.

2.3. Extrusion trials

All diets were processed at Skretting ARC Technology Plant (Stavanger, Norway). The dry ingredients were pre-mixed in a vertical mixer (custom designed; Skretting ARC, Stavanger, Norway) and ground in a Dinnissen 30 kW hammer mill (Dinnissen, Sevenum, The Netherlands), with a screen size of 0.75 mm. The ingredients were then mixed in a Dinnissen horizontal ribbon mixer (500LTR, Sevenum, The Netherlands) for 7 min. The feed mash was conditioned in a differential diameter conditioner (DDC 2; Wenger Manufacturing, Sabetha, KS, USA) and extruded in a Wenger TX-57 twin screw extruder. The barrel of the extruder was 57 mm in diameter and the length-to-diameter ratio was 17.5:1. The extruder barrel consisted of four head sections, with each section jacketed to permit either steam heating (Sections 1–4) or water cooling (Sections 2–4). Temperature control of the second, third and fourth sections was achieved by balancing the heating and cooling power input.

The ingredients were extruded as described, yielding extrudates with a diameter of approximately 9 mm and a length of approximately 10 mm. The knife rotation speed was adjusted according to the specified length of the extrudates. The feed was dried in a Wenger Series III horizontal 3-zones dryer (Wenger Manufacturing, Sabetha, KS, USA) to approximately 900 g kg^{-1} dry matter. Subsequently, the pellets obtained were coated with oil in a Forberg 6-l vacuum coater (Forberg, Oslo, Norway). After running for at least 10 min, discrete samples of pellets ($n = 3$; ×3000 g) were collected every 15 min to create a repeated measures assessment of each diet.

Table 1
Chemical composition of the feed ingredients used in the diets.

	Wheat[a]	Faba beans (dehulled)[b]	FM[c]	SPC[d]	LPC[e]	RPC[f]	Sunflower meal[g]
Analyzed composition (g kg^{-1} dry matter)							
Dry matter (g kg^{-1})	869	886	932	922	935	958	914
Protein	142	303	724	652	630	665	384
Fat	32	33	137	17	119	50	31
Starch	688	525	5	64	4	2	2
Crude fibre	25	38	0	57	5	63	191
Ash	17	31	142	62	36	74	76

[a] Supplied by Skretting AS, Stavanger, Norway.
[b] Supplied by Skretting AS, Averøy, Norway.
[c] Low temperature dried FM, Welcon, Egersund, Norway.
[d] Supplied by Imcopa SA, Araucaria, Brazil.
[e] Supplied by L.I. Frank, Twello, The Netherlands.
[f] Supplied by Bunge, St. Louis, MO, USA.
[g] Supplied by Skretting AS, Stavanger, Norway.