Automatic detection of nematodes in cod fillets by hyperspectral imaging

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Introduction

Nematodes, often referred to as cod worms, constitute a cosmetic as well as a food safety problem. Today all cod fillets (*Gadus Morhua)* are skinned and manually inspected from both sides on a candling table, and remnants such as blood spots, black lining, skin remnants, pin bones and nematodes are located and removed by hand. Due to the high costs of manual inspection, it is of great interest to have this operation automated. The goal for such a system is to separate clean fillets from fillets with remnants that need manual processing, and hence reduce the amount of manual labor required. The focus of this work is automatic detection of nematodes (*Anisakis simplex and Pseudoterranova decipiens)* in cod fillets. The spectral profile of nematodes and fish muscle differs in the vis/NIR region, and several absorbing compounds have previously been identified. The manual detection efficiency of nematodes in cod fillets under industrial conditions is reported to lie between 60 and 70%. This relatively low detection rate is due to multiple scattering of visible light in the cod muscle, and light scattering makes nematodes embedded deeper than 4 – 6 mm into the muscle difficult to detect by manual inspection.

Materials and methods

A hyperspectral imaging system has been developed, capable of inspecting cod fillets at a conveyer belt speed of 400 mm s^{-1}, or approximately one fillet per second. The system consists of a conveyer belt, an imaging spectrometer and two fiber optic light lines mounted together in an interactance configuration (Figure 1).

The recorded image has 64 spectral bands in the region 400–1000 nm, each with a spatial resolution of 0.5 mm × 1.0 mm and a spectral resolution of approximately 10 nm. Due to thickness variations resulting in variable optical path lengths and multiple scattering in the fish muscle, the light interacting with the nematodes varies spectrally. The spectra recorded from a nematode will vary accordingly, making the classification difficult. To reduce this variation, a novel method for calibrating hyperspectral images has been developed. The method uses the estimated local background spectra to calibrate each spectrum in the image, reducing the spectral variations of the nematodes and surrounding muscle. The calibrated spectra are then classified as either nematode

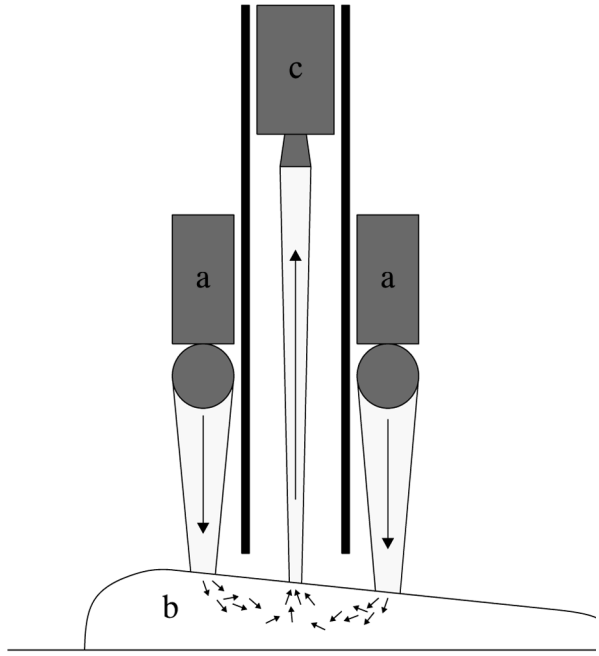

Figure 1. Setup for imaging cod fillets (b) consists of a spectrometer (c) and two fiber optic light lines (a) mounted over a conveyer belt.

or not by a QDA (Quadratic Discriminant Analysis) classifier. In this experiment the QDA classifier was trained on spectra from 22 different nematodes located in 6 different fillets, and then tested on 40 fillets containing 83 nematodes of varying size and color. The fillets were only

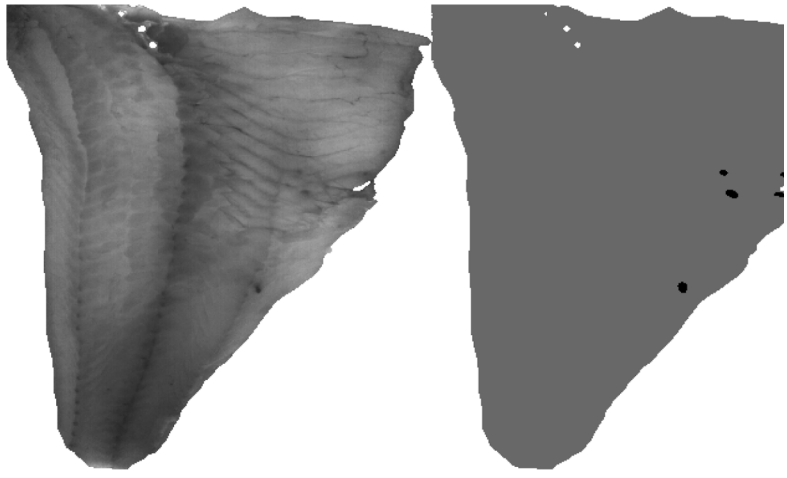

Figure 2. Image band ratio (550 nm/715 nm) automatically segmented from the background (left) and detection result, where five nematodes are detected and showed in black (right).

imaged from one side, the fillet side, and hence the detection results were only compared to the nematodes located from the fillet side, i.e. down to 6 mm.

Results and discussion

Figure 2 illustrates the detection of nematodes in cod fillets.

The overall detection rate was found to be 68%. The false alarm rate was relatively high, where 52% of the fillets had one or more false alarms. The reported detection rate was comparable to that of human inspection. These results are from a work in progress, where future research and development will focus especially on increasing the overall detection rate, but also on reducing the false alarm rate.