Rheology and extrusion

Juiciness perception

Measuring the lubricating properties of meat analogues via soft tribology

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Introduction

It is projected that the global population will reach the milestone of 10 billion individuals by 2050. Feeding this growing population poses significant challenges to food security, nutrition, and sustainable development with an environmentally conscious approach. Substituting animal proteins with plant proteins, either partially or entirely, offers a promising solution to meet the protein needs of a growing population while mitigating the environmental impact of the food industry.

One alternative to meat comes in the form of plant-based meat analogues, produced via high moisture extrusion cooking.[1] In order to satisfy the expectations of consumers, it is necessary to develop new products that not only replicate the texture of muscular fibers but also authentically mimic the taste, aroma, and juiciness of meat.[2] Therefore, the primary technological challenge of today is to achieve the organoleptic properties, texture, juiciness, and sensory perception in meat substitutes that are comparable to those of animal products. Here, lipids play a crucial role in the quality of meat products and are closely associated with the consumer's perception of juiciness. Therefore, the addition of lipids to meat analogues is of utmost importance.

The juiciness of meat analogues is linked to the lubrication properties of the product. When we consume food, it undergoes processes such as mastication, transportation, and swallowing, all of which involve friction. The lubricating ability of the consumed food plays a key role in determining the perceived mouthfeel.[3, 4, 5, 6] These properties are often assessed using oral tribology, which has emerged as a valuable tool for measuring the lubrication properties of soft foods and their correlation to sensory attributes like juiciness and creaminess.

In this application note, we assess the influence of oil on the surface properties of pea-based meat analogues.

Materials and methods

Extrusion trials

Extrusion trials were conducted using a co-rotating Thermo Scientific™ Process™ 16 Twin-Screw Extruder. The extruder has a split-barrel design, with a length-to-diameter ratio (L/D) of 40. The barrel is fully ported and each of its eight sections can be cooled or heated independently. An extendable modular cooled slit die set to 50 °C was used. The pea protein isolate was fed with a gravimetric twin-screw feeder by Kubota Brabender Technologie, and two peristaltic pumps were used for water and oil feeding, respectively. See Figure 1.

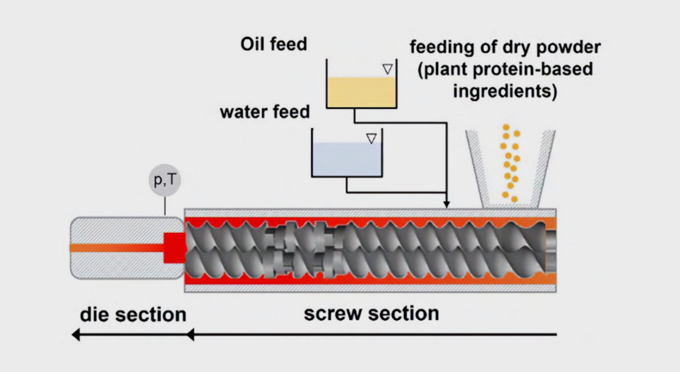

Figure 1: Schematic of granulation process using twin screw extrusion.

Pea protein isolate was fed into the first section; water and oil were added in the third section. The water-to-solid ratio remained constant throughout the whole process at 45:55 protein to water. The oil concentration was varied to 0, 2, 4 and 6 percent by mass. The total throughput was 2 kg/h.

Extrusion experiments were performed applying screw speeds of 400 rpm. The barrel temperatures were adjusted to $T_{barrel2}$ = 40 °C, $T_{barrel3}$ = 80 °C, $T_{barrel4}$ = 100 °C, $T_{barrel5}$ = 120 °C $T_{\text{barrel6-7-}}$ = 140 °C, $T_{\text{die\_adapter-}}$ = 140 °C. The cooled slit die was set to 50 °C.

Tribological characterization

The friction coefficient of the extrudate's surface was determined using a stress controlled HAAKE™ MARS™ 60 Rheometer, and a Stribeck curve was plotted. For this purpose, a three-ball-on-plate geometry was attached to the rheometer, where glass balls and the extrudates samples were used as tribo-pairs to measure the oil surface of the samples. The plates were cut out from the extrudate. The coefficient of friction between tribo-pairs and sample was plotted versus the rotational normal force of 2 N and a temperature of 20 °C, with 100 measurement points taken. Each individual sample preparation was analyzed a minimum of 5 times.

Results

Initially, we evaluated the visual characteristics of the examined samples immediately after production. Sample preparation was conducted to permit visual inspection of the inner fibrous structure of the samples. For this, samples were pre-cut to predetermine a breaking point. Cuts were set lengthwise transversal to flow direction. Pea protein samples with minimal oil content exhibited minor variations in their anisotropic structure. Furthermore, in samples made from this protein type, we observed a gradual loss of distinct fiber outlines as the oil concentration increased. Finally, at the highest investigated oil concentration, the pea protein sample transformed into a texture resembling dough, with a mushy consistency. See Figure 2.

In addition to the oil droplets present within the protein matrix, a portion of the oil may also reside on the surface of the meat analogues.

Figure 2: Pea protein extrudates with varying rapeseed oil concentrations.

This surface oil alteration affects both the friction experienced within the extrusion barrel and the initial sensory perception upon consumption of the product.

In order to test this, tribological measurements were conducted to assess whether oil was well-encapsulated inside the protein matrix or if it was found on the surface of extrudates. The results are shown in Figure 3.

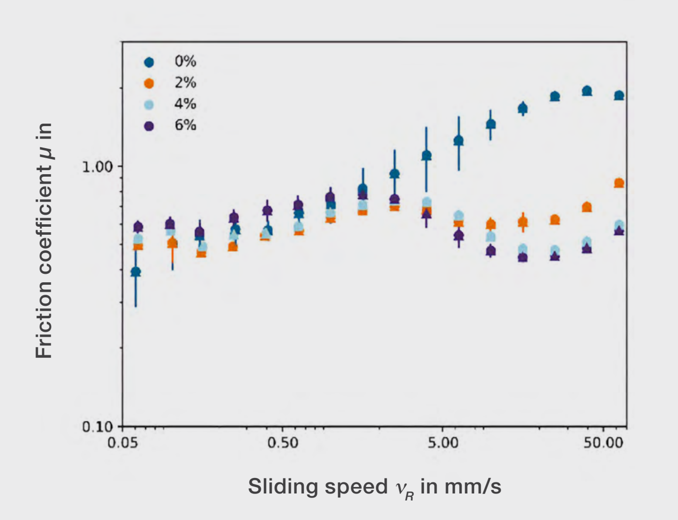

Figure 3: Stribeck curves of pea protein extrudates with varying rapeseed oil concentrations.

As seen from Figure 3, the friction coefficient of the investigated samples differs depending on the amount of oil added during the extrusion process. Whereas samples with no added oil display increasing friction with increasing sliding speed, samples containing oil display a reduction in friction with increasing sliding speed. This is an indication that oil is found on the surface of the extrudates. As oil lubricates the tribo-pairs, the friction coefficient decreases. Additionally, the amount of oil affects the lubrication properties, as samples with 4 and 6 % oil show a lower friction coefficient than the sample with 2 % added oil.

Conclusions

This study addressed the application of tribology as a characterization method to gain insights into formulation and process parameters, enabling an objective evaluation of the resulting product.

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