Oats Nutrition and Technology
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Why a book on the life cycle of oats?

To our knowledge, a book that discusses the life cycle of oats from on-farm production to finished product to health and policy has not previously been presented. As a result, we felt that such a compendium of articles from multidisciplinary fields would be interesting and educational.

_Oats Nutrition and Technology_ presents a comprehensive and integrated overview of the coordinated activities of plant scientists, food scientists, nutritionists, policy makers, and the private sector in developing oat products for optimal health. Many areas of expertise are integrated, necessarily so, to create the continuum that we know as the contemporary food system (i.e., from “farm to fork”). Readers will gain a good understanding of the value of best agricultural production and processing practices that are important in the oats food system, as well as of all other aspects of today’s food system. The book reviews plant agricultural practices for the production of oat products, the food science involved in the processing of oats, and nutrition science aimed at understanding the health effects of oats and how they can affect nutrition policies. There are individual chapters that summarize oat breeding and processing, the many bioactive compounds that oats contain, and their health benefits. With respect to the latter, the health benefits of oats and oat constituents on chronic diseases, gut health, and skin health are reviewed. The book concludes with a global summary of food labeling practices that are particularly relevant to oats.

The book is framed from the perspective of multiple disciplines: plant breeding and processing, the nutritional value of oats (i.e., nutrients and bioactive components) and related health effects, and nutrition policies related to food labeling and health claims. There is much we have learned about the oat food system, but the reality is that much remains to be learned about all of these areas and the advances that are needed to develop the best and most cost-effective oat products for farmers and processing companies in a way that benefits consumers’ health as much as possible. In addition, oats and oat products must meet consumer quality expectations that relate to both their sensory preferences and nutritional expectations. Oats must be acceptable to consumers with respect to appearance, texture, flavor, and aroma.

The contents of this book are deliberately organized to familiarize the readers with the various stages of the oat product life cycle. This approach underscores an
appreciation for building on the scientific discoveries and knowledge contributed by each discipline, and how important this process is to the development and validation of future oat products for human health.

The eighteen chapters in this book are divided into six sections, with an introductory section (Chapter 1) on oat nutrition research and production. The five remaining sections include Part II: Oat Breeding, Processing, and Product Production; Part III: Oat Nutrition and Chemistry; Part IV: Emerging Nutrition and Health Research; Part V: Public Health Policies and Consumer Response; and Part VI: Future Recommendations. Each section provides readers with an overview on current insights into research, issues, and opportunities.

Part II: Oat Breeding, Processing, and Product Production: This section consists of two chapters (Chapters 2 and 3) that focus on the importance of oat breeding and current challenges in farming and agriculture. Readers will gain a good understanding of the value of best agricultural production and processing practices that are important in the oat food system, and also an appreciation of all other aspects of today’s complexity of food production, farming challenges, and product developments.

Part III: Oat Nutrition and Chemistry: This section comprises five chapters (Chapters 4–8) covering chemical and nutritional compositions of whole oats. Discussions also include recently discovered bioactive compounds/phytochemicals in oats, such as avenanthramides, which have strong antioxidative properties and potential health effects. Biosynthesis of bioactive compounds is also discussed.

Part IV: Emerging Nutrition and Health Research: This section consists of seven chapters (Chapters 9–15) that cover emerging research on lipid and lipoprotein metabolism, blood pressure, weight and satiety, diabetes and carbohydrate metabolism, gut health, and skin health. Current insights on studies related to the effects of oats and whole grains on disease and health are presented.

Part V: Public Health Policies and Consumer Response: This section comprises two chapters (16 and 17) that provide global insights into regulatory claims, substantiation requirements, and health policies in the USA, Canada, and the European Union. These chapters also discuss the impact of health claims on government public educational programs (food labeling and advertising), food industry innovation in oat products and sales, and consumer and professional responses to oat products.

Part VI: Future Recommendations: In this section, summaries of the previous 17 chapters are discussed in a single chapter. Future research needs and recommendations are discussed as well. There are many opportunities to expand our knowledge of oats and their development to optimize nutrition, as well production and sustainability.

This book is intended to offer scientists and health practitioners interested in this field in-depth information about the life cycle of oats. It is intended to be thought provoking and stimulate readers to address the many research challenges associated with the oat life cycle and food system.

YiFang Chu
In the field of nutrition, having the opportunity to work with oats and to edit a book about them is a true blessing. I am deeply grateful to Marianne O’Shea and Richard Black for this privilege. I am also thankful for colleagues and mentors who made the process fun and rewarding: Yuhui Shi, Alan Koechner, Yongsoo Chung, Sarah Murphy, Debbie Garcia, and Maria Velissarioi. Special thanks go to Chor San Khoo, who challenged and drove us to bring this book to a much better place.

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1.1 A landmark health claim

The landmark approval of a health claim for oats in 1997 by the United States Food and Drug Administration (FDA) marked the first food specific health claim. The FDA had concluded that an intake of at least 3 g β-glucan from oats as part of a diet low in saturated fats could help reduce the risk of heart disease (Chapter 17). Of importance is that the oat health claim signifies for the first time recognition by a public health agency that dietary intervention could be beneficial in disease prevention, and that certain foods or food components, when consumed as part of a healthy diet, may reduce the risk of certain diseases. It is, therefore, not surprising that the first food-related health claim was approved for reducing the risk of cardiovascular disease (CVD), the leading cause of death in the United States and many western countries, including Canada (Health Canada, 2010). Often under communicated is that CVD is the leading cause of death among women in the United States (Roger et al., 2012). The FDA approval of a health claim elevated the role of diet in overall health, adding emphasis to disease prevention in addition to treatment. For example, many of the risk factors
associated with CVD are preventable by dietary interventions, including high blood pressure, high total serum cholesterol, low-density lipoprotein-cholesterol (LDL-C) and very low density lipoprotein-cholesterol, and high blood glucose associated with type 2 diabetes, and obesity.

1.2 The growing interest in oats and health

The oat health claim that underwent extensive scientific review for approval by the FDA sparked great interest in the scientific community. For the first time, health practitioners (dietitians, nutritionists, and physicians) had the option to recommend that a specific food be incorporated into a diet for an adjunct intervention in the management and prevention of disease.

The unique chemistry and nutritional composition of oats suggest that the benefits of oats may not be confined to just a cholesterol-lowering effect but, as demonstrated by further research, that they may also have other favorable health benefits. As of 2010, ischemic heart disease (number 1 ranking) and stroke (number 3 ranking) were two of the top 12 world health problems that could be favorably affected by oat consumption (Cohen, 2012; Lim et al., 2012). Important risk factors recently highlighted by the Global Burden of Disease Study that could be affected by oats include high blood pressure, high body mass index, and high fasting blood glucose levels (Cohen, 2012; Lim et al., 2012), as well as an elevated LDL-C level as noted by the American Heart Association (Roger et al., 2012).

The oat health claim has sparked interest in developing a better understanding of oats, from breeding for the best oat cultivar, processing, nutrition research on oats and health, as well as public health education and policy. It has become clear that the challenges to improving the quality of oats are not just yield but rather a combination of three possible dependent traits—yield, groat percentage, and \( \beta \)-glucan level (Chapter 2).

Recent advances in research have focused on oat chemistry and nutrition with the goal of demonstrating the mode of action of oats on lipid and glucose metabolism. Of interest is the form of \( \beta \)-glucan in oats, which differs from other whole grain soluble fibers. In oats, the majority of the soluble fibers are \( \beta \)-glucan, accounting for 3–6% of whole groat weight. Although \( \beta \)-glucan also exists in barley and wheat, the \( \beta \)-glucan in oats differ in many physicochemical properties, such as solubility, gelation, and molecular weight, all of which affect physiological functions in the gastrointestinal tract, for example, bile acid binding, colonic viscosity accumulation, and fermentation. These differences in \( \beta \)-glucan structure may explain the reduction in cholesterol and postprandial blood glucose levels with oat consumption (Chapter 5).

The health benefits of oats can be attributed largely to their unique chemistry and nutrient profile. Recent efforts have focused on isolating, identifying, and characterizing the bioactive constituents unique to oats. Compared to other whole grains such as corn, wheat, and rice, oat nutrition profiles are uniquely “complete” across many constituents, ranging from nutrients to phytochemicals and bioactive compounds. Nutritionally, oats provide many essential nutrients.
On a 100 g basis, oats are a significant source of dietary fiber, soluble fiber mostly as β-glucan, thiamin, folate, iron, magnesium, copper, and zinc. Additionally, oats are an excellent source of potassium and are low in sodium, with a Na:K ratio less than one (Chapter 4).

Avenanthramides are phytonutrients in oats known to have anti-inflammatory and antioxidative activity, and may be involved in some of the health effects unique to oats. Avenanthramides are emerging as an interesting class of chemicals that may be beneficial for skin health, including treatment for atopic dermatitis, contact dermatitis, pruritic dermatoses, sunburn, drug eruptions, and other conditions. Colloidal oatmeal has also been used to relieve skin irritation and itching, and for cleansing and moisturizing. The flavonoids in oats may also protect against ultraviolet A radiation.

More recently, research has focused on the impact of oat intake on other health outcomes beyond the lipid lowering effect, such as blood pressure, body mass index and weight, glucose metabolism and type 2 diabetes, as well as caloric regulation and satiety. These studies are ongoing and the data are still preliminary. A consistent finding is that oat β-glucan lowers serum cholesterol, and although the magnitude of cholesterol lowering varies, it correlates to the amount of β-glucan consumed.

### 1.3 Declining production poses threats to the growth of oat intake

Although oat and health research have advanced significantly, a very different picture is emerging on the global scene with respect to oat production and consumption. Since the approval of the health claim for oats in 1997, there has been a steep growth in the demand for hot breakfast cereals and oats sales have soared. This positive trend developed in North America was also observed in eastern and western Europe over the same period. On the other hand, world production of oats has declined and is at a record low rate. In 2011, world oat production lagged behind wheat, corn, and barley, dropping to its lowest level since 1960, from 6.8 to 0.8% of the world’s crop production. In the United States, oats are fading from a commodity to a specialty crop. The worldwide drop in production may be attributed to several factors, including more land devoted to growing more profitable crops for foods, feeds, biofuels, and vegetable oils; low amounts of funding for research, little innovation in production techniques; and a weak demand for oats as a feed source (Strychar, 2011). Today, oats are considered an orphan crop, receiving little research investment from either government or industry.

If the trend of decreased oat production continues, oats will become so expensive that affordable and widely accessible oat products for the public may be limited. Reversing this trend will require programs that involve both public and private collaborations to assure an adequate level of research investment for advancing the understanding and securing the accessibility of this important crop.
References


Part II
Oat Breeding, Processing, and Product Production
2

Breeding for Ideal Milling Oat: Challenges and Strategies

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2.1 Introduction

Both acreage devoted to oats and oat production have dramatically decreased worldwide since the 1960s, as working horses have been replaced by modern farm machinery. The introduction of short-seasoned and more profitable corn and soybean cultivars to the northern regions of the United States and southern areas of Canada in the recent decade is another major reason for reduced oat production. However, the oat acreage in Canada has more or less stabilized at around 1.5 million hectares in recent years (Agriculture and Agri-Food Canada, 2010). This is partially due to the need for growing oats as a rotation crop and the use of oats as a forage crop, oat grains as feed, and oat straw for animal bedding. However, more important are the increased purchase and processing of oat grains by the milling industry and increased awareness and human consumption of oat products as healthy food.

Oats are a minor crop compared with other cereal crops and oilseeds. In addition, it is a self-pollinated crop, obviating the need for purchasing hybrid seed every year. Because of its lower profitability, relatively little breeding and research on oats are carried out. The limited breeding and research effort has been supported primarily through government funding with support from the oat milling industry and growers of oat seed and grain. As a result, breeding for superior milling oats has become a main driving force for oat breeding and related research. Although there are some differences in the specifications for oats used as feed or fodder, oats that are excellent for milling are also suitable
for forage and feed. In this chapter, an attempt is made to define the ideal milling oat cultivar and the challenges and strategies in breeding such an oat cultivar to discuss.

2.1.1 What is an ideal milling oat?

An ideal milling oat cultivar must be defined from the perspective of the oat value chain, which starts with the oat growers and ends with consumers of the oat product, with the oat processors serving as the key link between the two. An ideal oat cultivar must benefit each of these stakeholders. A reliably high yield, along with supporting agronomic traits (good resistance to important diseases and pests, lodging resistance, and proper maturity), is the number one consideration of oat growers when choosing a crop cultivar. The second factor they consider is whether the quality of their oat grains meets the requirements of potential buyers (i.e., millers), because selling to millers is often more profitable than using or selling the oats as feed. The requirements of the millers include higher groat percentage, so that more oat product can be produced per unit weight of purchased oat grains, uniform grains and easy dehulling to reduce the energy cost for processing, and better compositional quality so their oat products meet consumers’ expectations. Consumers consider oat products to be nutritious and especially healthy because of the dietary fiber contained in the oat groat (β-glucan in particular). Oat products must contain a minimum level of β-glucan and total dietary fiber to be labeled as healthy food (Chapter 6). The traits of an ideal milling oat cultivar are listed in Table 2.1.

Despite the tremendous effort of oat breeders and great progress made in improving oat cultivars throughout the world, a cultivar with all the desired traits has not yet been developed. Why is this so? Is it even possible to achieve such a goal? What are the challenges for developing the ideal cultivar? What strategies should be used in breeding towards such a cultivar? These are the questions this chapter attempts to answer.

<table>
<thead>
<tr>
<th>For growers</th>
<th>For millers</th>
<th>For consumers</th>
</tr>
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<tbody>
<tr>
<td>High and stable grain yield for the target environment</td>
<td>High groat percentage (milling yield)</td>
<td>High β-glucan and dietary fiber content</td>
</tr>
<tr>
<td>Good lodging resistance</td>
<td>Easy dehulling</td>
<td>High protein content</td>
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<tr>
<td>Proper maturity</td>
<td>Uniform kernels</td>
<td>High levels of essential amino acids</td>
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<tr>
<td>Good resistance to relevant diseases and pests</td>
<td>Low groat breakage during dehulling</td>
<td>Low oil content</td>
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<tr>
<td>Good tolerance to relevant abiotic stresses</td>
<td>White groat color</td>
<td>High antioxidant content</td>
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<td>High test weight</td>
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<td>Other desirable ingredients</td>
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<td>Large kernels</td>
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<td>High straw yield</td>
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