

Sustainable production and postharvest handling of avocado

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Foreword

From indigenous trees growing in south-central Mexico 8-10000 years ago to international superfruit status today, the avocado fruit has achieved worldwide renown for its dietary and bioactive properties as well as its social and cultural significance. Avocado (*Persea americana* Mill) was domesticated in Mesoamerica where archeological sites in Coxcatlán (in the region of Tehuacán, Puebla State, Mexico) document human consumption as far back as approximately 8000-7000 BC. Intensely nutritious, with a wide range of highly desirable nutrients and health-conferring properties, avocados are grown around the world today from their centre of origin in Mexico to a multitude of countries from New Zealand to Israel, from USA to Australia. Avocados are now grown commercially in more than 30 countries with warm temperate to subtropical climates around the world. The majority of avocados are grown in Latin America and the Caribbean with Mexico remaining the major producer.

Demand for this highly nutritious fruit has increased dramatically in the last two decades as its health attributes have become recognized, and production has expanded to many countries. An OECD report estimates that production of avocado will exceed 12 million tonnes (Mt) by 2030. International demand for avocado is increasing and will exceed that for pineapple and mango reaching 3.9 Mt of exports valued at >US\$8 billion by 2030, making it one of the most valuable fruits produced globally. This follows the rapidly expanding demand for this fruit from a growing list of countries, including China, Japan and the Middle East.

In 2021 the international market for fresh avocado was estimated to be US\$14 billion and, such is the increasing demand, it is expected to increase at a compounded annual growth rate (CAGR) of >9% through to 2028. Continued emphasis on healthy eating, as well as a growing awareness of the importance of nutritional value of food for healthy minds, bodies and lifestyles, contribute to the developing market demand for these ubiquitously healthy fruits among an increasing middle class in many new and traditional markets. An increasing availability of processed avocado products, for food or cosmetic purposes, is also contributing to increased international demand.

As a consequence it is imperative that the production, marketing, scientific and education sectors have access to the latest technical information to optimise sustainable production in widely different climatic and edaphic conditions. There have been many major advances in knowledge about the avocado since the seminal 2002 text edited by Schaffer, Wolstenholme and Whiley 'The Avocado: Botany, Production and Uses'. However, the time is now ripe for a comprehensive update. This book, written by Professor Elhadi

M. Yahia Kazuz, a senior scientist based in a major horticultural laboratory at the Autonomous University of Queretaro, Mexico, comes at an opportune time in the continuing development of the avocado industry. Professor Yahia conducts research on the global food industry in areas such as food security, postharvest technology, food science and technology and human nutrition. He has been involved in research on a range of fruit crops during his career and he has a specific interest in avocado as well as tropical and subtropical fruit. He is a prolific writer and editor having published on a wide range of topics over many years. He has published 26 books in three languages, and has published more than 450 book chapters, scientific and technical articles on the biology, technology and handling of perishable foods. He has a particular interest in disinfestation of fresh fruit as well as the added and bioactive value of novel fruits and vegetables. He is well placed to present this comprehensive book on avocado which arose originally in the productive valleys of south-central Mexico.

Professor Yahia has extensive international experience. He was an Agro-Industry Officer in the FAO where he collaborated on launching the Global Initiative on Food Loss and Waste Reduction, a major international programme to reduce food waste. In addition he developed has helped develop national and regional agro-industry strategies. He has consulted widely in many countries through the FAO, the World Bank, the Asian Development Bank, the World Logistics Organisation, USAID, USDA and ICARDIA.

This new book makes a major contribution to current knowledge and practices of avocado for a broad international audience. It consists of 7 chapters including an introduction to avocado; a chapter on nutritional values, health benefits and uses; a global view of the avocado industry including established and new areas of production; advances in preharvest management (including cultivars grown, rootstocks, cultivation practices including nutrition, irrigation and management of pests and diseases; advances in postharvest physiology, technology and handling; processing including technologies and co-products; and, finally, trade and marketing. Information included within the 7 chapters of this book provides an invaluable reference point for all those involved with this rapidly evolving industry from producers, to consultants (both private and public), researchers and educators (including students), postharvest operators, processors and marketers, both wholesale and retail. It should become a standard text for all those involved with and contributing to the growth and development of the avocado industry worldwide.

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Chapter 1

Avocado: an introduction to the fruit and its pre- and postharvest processing

- 1 Introduction: origin and history
- 2 Global production and consumption
- 3 Avocado races and cultivars
- 4 General characteristics
- 5 Pre- and postharvest management: opportunities and challenges
- 6 Conclusion and future trends
- 7 What this book covers
- 8 Acknowledgements
- 9 Appendix: institutions and organizations involved with avocados
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1 Introduction: origin and history

Persea americana, commonly known as avocado (as well as avocado pear or alligator pear among other names), originated in Central America and southern Mexico. Based on archaeological evidence found in Tehuacán (Puebla, Mexico), it is believed to have been associated with humans for approximately 12 000 years. The first evidence of avocado consumption dates back to 8000–7000 BC, and it is believed that this fruit began to be cultivated for human consumption at least 5000 years ago (Yahia, 2012).

The center of origin of the fruit has been established as the central part of Mexico, spreading through Guatemala to Central America. Avocado continues to be an essential part of the diet of many of the communities in North and Central America where it originated, e.g. in Mexico and Guatemala. The wild gene stock can be found in this region, providing a resource for the genetic improvement of the species. As evidence for this theory, primitive avocado trees have been found in the ‘Oriental Sierra Madre’ along the State

of Nuevo León in the north of Mexico through to Costa Rica. From this region, avocado dispersed to the southeastern part of the USA, the West Indies and then to a large part of South America including Colombia, Venezuela, Brazil, Ecuador, Peru, Bolivia and Chile (Yahia, 2012). It is believed that avocado was introduced to Peru, and from there to the rest of South America in pre-Columbian times, by the Inca Tupac Yupanqui after he conquered the southern part of Ecuador.

The fruit was called 'Ahuacatl' in one of the indigenous languages of pre-Colombian Mexico (Nahuatl), which formed the basis for the term 'aguacate' (in Spanish), then 'avocado' (in English), 'avocat' (in French), 'abacate' (in Portuguese) and so on. The term 'Ahuacatl' means testicles, reflecting the fruit shape. The fruit is also called 'palta' in Chile, Ecuador and Peru. Other names include 'alligator pear', 'vegetable butter', 'butter pear' and 'midshipman's butter' (Yahia, 2012). The term 'Aguacate' was first used in 1550 by Pedro de Cieza de Leon (1518-54), Spanish conquistador and historian, who noted that the fruit grew in Panama, Ecuador, Colombia and Peru at that time. Avocados were also regularly mentioned during the sixteenth century by various explorers travelling in Ecuador and Peru, northward through Central America and southern Mexico, and as far north as Mexico City. Explorers and travelers in the West Indies also encountered avocados, although it is believed that they were introduced to these islands after the Spanish conquest of South America. The first English language mention of avocado was in 1696. In 1751, George Washington wrote that he had tasted 'agovago pears' in Barbados, as they were popular and abundant in the markets there. In the 1700s, European sailors called avocados 'midshipman's butter' because they used them as a spread on hardtack biscuits commonly eaten on long voyages. Avocados then gradually became known around the world, though avocado consumption remains low in many countries.

2 Global production and consumption

Avocados belong to three races (Table 1):

- Mexican;
- West Indian; and
- Guatemalan.

Avocado is cultivated in at least 70 countries in several tropical and subtropical regions of the world and expanding significantly. However, the American

Table 1 Characteristics of the three avocado races (masl: meter above sea level)

Characteristic	Race		
	Mexican	Guatemalan	West Indian
<i>General, tree</i>			
Medium annual temperature (°C) for native trees	13.5-20.5	21.0-28.0	24.0-27.0
Medium annual temperature (°C) for introduced trees	20.5-25.5	18.0-28.5	19.0-20.0
Medium annual precipitation (mm) for native trees	560-2200	800-3400	1100-3350
Optimum altitude (masl)	950-2250	20-1200	500-800
Elevation where it was originated	1500-2500 masl; 19-24°N	1000-2000 masl; 14-16°N	>1000 masl; 8-15°N
Native climate	Cool	Temperate	Warm
Climatic adaptation	Temperate-Subtropical	Subtropical	Tropical
Minimum tolerable temperature (°C)	-9	-4.5 to 6	-2.2 to 4.0
Optimal temperature range (°C)	5-8	12-22	22-28
Cold tolerance	High	Intermediate	Low
Salt tolerance	Low	Low	High
Humidity tolerance	Low	Medium	High
Alkalinity tolerance	Medium	Low	High
<i>Tree</i>			
Leaf size	Small	Medium	Large
Leaf anise	Yes	No	No
Young leaf color	Green	Green with red tinge	Pale yellow
Mature leaf color	Dark green	Dark green	Pale green
<i>Fruit</i>			
Average fruit weight (g)	100	310	315
Development duration	5-7 months	10-18 months	6-8 months
Color	Often dark	Green	Green or reddish
Size	Small	Variable	Variable
Oil content	High	Intermediate	Low

(Continued)

Table 1 (Continued)

Characteristic	Race		
	Mexican	Guatemalan	West Indian
Peel texture	Membrane like	Corky	Leathery
Peel consistency	Smooth	Woody, brittle	Flexible
Peel thickness	Thin or very thin	Medium, thick or very thick	Thin, medium or thick
Skin surface	Waxy bloom	Rough	Shiny
Seed shape	Oval-elliptical	Flattened base and conical or rounded apex	Flattened base and conical or rounded apex
Seed cover	Thin	Thin	Thin
Seed size	Large	Small	Large
Seed cotyledon	Rough	Smooth	Rough
Seed surface	Smooth	Smooth	Rough
Seed cavity	Loose	Tight	Variable
Pulp flavor	Anise like, rich	Rich	Sweeter, milder

continent accounts for about 75% of world production (Figs. 1–3). Avocado is a high-value crop and has become a very popular fruit in the diets of many countries; therefore its consumption is growing worldwide. The USA and the European Union (EU) are the main importers of this fruit, accounting for about 80% of world imports (Figs. 4 and 5).

Avocado global production is currently over 8 million tons (Fig. 6), representing a cultivated area of over 800 000 ha in around 70 countries (Fig. 7). In production terms, avocado ranks 22nd among the main fruits produced around the world, far behind bananas with 116 million tons, watermelons with 104 million tons and apples with 86 million tons. Avocado represents less than 1% of world fruit production, which has been estimated at more than 860 million tons.

The main area of avocado production is in Latin America, which accounts for more than 75% of global production. Africa produces about 11%, Asia produces about 9% and the Mediterranean region produces about 4% of avocados globally (Fig. 1). Of the 75% of global production located in America, Mexico is the main producer (Figs. 8 and 9) with about 30% of world production (FAOSTAT, 2022). Other important producing countries include Colombia with almost 11%, Dominican Republic and Peru with about 8% each, Indonesia with almost 8%, Kenya with 4%, Brazil with a little over 3%, the USA with a little over 2%, Chile with 2%, China with 1.5%, South Africa and Spain with just over 1% each, Australia and Morocco with almost 1% each

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