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Specialty Coffee vs. Dark Roast Coffee: Bioethical, Chemical, and Public Health Implications on Human Consumption

El café de especialidad frente al café de tueste oscuro: implicaciones bioéticas, químicas y de salud pública en el consumo humano

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Abstract:

Coffee is one of the most widely consumed beverages worldwide and represents an economic and cultural pillar in producing countries such as Mexico. However, the growing demand for specialty coffee has led to more rigorous cultivation and roasting practices that influence not only sensory quality but also chemical composition, potential toxicity, and ethical implications. This narrative review integrates evidence from PubMed, Scopus, and SciELO regarding chemical transformations during roasting—particularly in chlorogenic acids, caffeine, antioxidants, acrylamide, and polycyclic aromatic hydrocarbons (PAHs)—and their impact on nutritional value and safety. Moderate roasting tends to preserve bioactive compounds, whereas dark roasts may increase thermal contaminants such as acrylamide and PAHs. Epidemiological evidence suggests that moderate coffee consumption is associated with reduced mortality and lower risk of cardiovascular, metabolic, and neurodegenerative diseases. Nevertheless, excessive intake or poorly controlled roasting may compromise these benefits. From a bioethical perspective, coffee production and consumption involve the principles of beneficence, non-maleficence, autonomy, and justice. Transparency, sustainability, and fair trade are ethical imperatives throughout the production chain. In Mexico, promoting ethically and environmentally sustainable coffee could enhance public health and social equity. That is why the objective of this article is to offer an integrated vision that contributes to scientific debate and the design of fairer and more conscientious policies and practices.

Keywords:

Roasting, specialty coffee, antioxidant, bioethics, coffee

Resumen:

El café es una de las bebidas más consumidas a nivel mundial y representa un pilar económico y cultural en países productores como México. Sin embargo, la creciente demanda de café de especialidad ha llevado a prácticas de cultivo y tostado más rigurosas que influyen no solo en la calidad sensorial sino también en la composición química, la toxicidad potencial y las implicaciones éticas. Esta revisión narrativa integra evidencia de PubMed, Scopus y SciELO sobre las transformaciones químicas durante el tostado, particularmente en ácidos clorogénicos, cafeína, antioxidantes, acrilamida e hidrocarburos aromáticos policíclicos (HAP), y su impacto en el valor nutricional y la seguridad. El tostado moderado tiende a preservar los compuestos bioactivos, mientras que los tostados oscuros pueden aumentar los contaminantes térmicos como la acrilamida y los HAP. La evidencia epidemiológica sugiere que el consumo moderado de café se asocia con una menor mortalidad y un menor riesgo de enfermedades cardiovasculares, metabólicas y neurodegenerativas. Sin embargo, la ingesta excesiva o el tostado mal controlado puede comprometer estos beneficios. Desde una perspectiva bioética, la producción y el consumo de café involucran los principios de beneficencia, no maleficencia, autonomía y justicia. La transparencia, la sostenibilidad y el comercio justo son imperativos éticos en toda la cadena de producción. En México, la promoción de un café ético y ambientalmente sostenible podría mejorar la salud pública y la equidad social. Es por eso que el objetivo de este artículo es ofrecer una visión integrada que contribuya al debate científico y al diseño de políticas y prácticas más justas y conscientes.

***Palabras Clave*:**

Tueste, café de especialidad, antioxidante, bioética, café

INTRODUCTION

Coffee is one of the most consumed beverages in the world and constitutes a cultural, social, and economic pillar in many regions, especially in producing countries like Mexico, where it is a strategic crop since its production employs more than 500,000 producers in 14 states and 480 municipalities. However, the growing demand for specialty coffee has driven more

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rigorous cultivation, selection, and processing practices, aimed at preserving sensory qualities to validate a more delicate roast profile.[1]
However, these technical decisions also have chemical, health, and ethical implications that deserve integrated consideration.[1]

During the roasting process, purely harmless compounds can be transformed into substances such as acrylamide, generated by the reaction between sugars and asparagine at high temperatures. This molecule has characteristics that increase its relevance at high temperatures. This molecule has characteristics that exacerbate its toxicological relevance: it is highly soluble in water, which facilitates its transfer to the beverage, making analytical detection difficult because it forms in low concentrations and lacks perceptible color or odor. Acrylamide has been a source of concern due to its genotoxic properties and because, in animal studies, high doses cause adverse effects (cancer). However, its relevance to humans remains a subject of debate: while some epidemiological studies show no clear association with cancer in regular consumers, others warn of the need to minimize dietary exposure.[2-4]

In addition to chemical and toxicological aspects, the consumption, production, and marketing of coffee involve ethical and social issues that food bioethics can explore. Decisions such as what roast level to offer, what level of transparency to provide regarding risks and benefits, how to influence public health regulations, and how to ensure fairness for producers, consumers, and the environment are dimensions that cannot be resolved with data alone. In the bioethical field of food, with a focus on the responsibilities of good coffee production, principles such as autonomy (the consumer's right to be informed), non-maleficence (avoiding harm), beneficence (promoting well-being), and justice (distribution of risks and benefits) are fundamental.[5]

On the other hand, Mexican coffee faces particular challenges: its production chain, genetic diversity, international market pressures, and economic and environmental inequalities. Incorporating a bioethical approach into coffee evaluation allows for the promotion of responsible consumption, sustainable production, and public policy aligned with collective health. This narrative review seeks a bioethical approach that synthesizes the scientific evidence on the chemical transformations of coffee, the potential effects on human health, and risk reduction strategies; but, at the same time, it seeks to reflect on the ethical obligations of actors such as producers, roasters, regulators, and consumers. The objective is to offer an integrated perspective that contributes to the scientific debate and the design of fairer and more conscious policies and practices.

MÉTODO

For this narrative review, a literature search was conducted in databases such as PubMed, Scopus, SciELO, and Google Scholar. Following the established methodology for narrative reviews, keywords such as coffee, roasting, antioxidant, bioethics, and specialty coffee were used. Articles published within the last 10 years were prioritized, although seminal and classic references were also included to contextualize the fundamental concepts.[6]

COFFEE PLANT

The coffee plant belongs to the genus Coffea arabica (and to a lesser extent to other species such as Coffea canephora), of the Rubiaceae family. This species is a shrub that, when cultivated, typically reaches between 3 and 5 meters in height, although in the wild it can reach 10–12 meters.[7]
The leaves are opposite, simple, dark green on the upper surface, with prominent veins; the inflorescences are axillary, with white flowers of a light aroma, which subsequently produce drupe-like fruits commonly called “coffee cherries” that ripen from green to purplish-red, and typically contain two seeds or “beans.” Coffea arabica thrives at moderate to high altitudes (ideally between ~1000 and 2000 meters above sea level), with cool temperatures, well-distributed rainfall, slightly acidic soils, and good drainage; These conditions favor the development of more complex flavor profiles.[7]
It is distinguished by its self-compatibility (self-fertility), which allows it to self-fertilize, a characteristic not common to all Coffea species.[8]

COMPOSICIÓN QUÍMICA DEL TUESTE SEGÚN EL GRADO DE TUESTE

Transformation of compounds during roasting

Roasting is the thermal process that transforms the green bean into a roasted bean and is the main determinant of the sensory profile and chemical composition of coffee. As the roast level increases (from light to dark), complex reactions take place, mainly Maillard reactions and pyrolysis, which degrade the bean's original compounds such as: phenols and sugars, generating new volatile compounds responsible for the aroma and roasted color. These reactions differentially affect relevant compounds from a nutritional and toxicological point of view, including chlorogenic acids, caffeine, total antioxidants, acrylamide, and polycyclic aromatic hydrocarbons (PAHs).[9,10]

Chlorogenic acids (CGA)

Polyphenols abundant in the bean that provide antioxidant activity and contribute to the acidity and flavor; during roasting, CGAs progressively decrease: light roasts retain higher amounts, while medium and dark roasts show losses due to thermal degradation and participation in secondary reactions. Thus, the antioxidant capacity in dark-roasted coffee is diminished when compared by weight of the original material.[10,11]

Caffeine

Caffeine is relatively stable to heat; nonetheless, evidence shows that the observed changes in caffeine content among roasted beans are moderate and dependent on the species (Arabica vs. Robusta), the measurement method (by weight or by volume), and the bean's mass loss during roasting. However, the concentration in the prepared beverage can vary according to the extraction method and the bean's density.[12]

Antioxidants and total antioxidant capacity

In addition to CGAs, roasting generates melanoidins (products of the Maillard reaction) which also possess antioxidant capacity;

however, the net balance usually shows that medium roasts retain the best proportion of useful phenolic compounds, while samples of very dark roasts tend to lose original phenolic compounds, although they maintain other newly formed antioxidant molecules. The final result depends on the analyzed marker and the beverage preparation method.[11]

Acrylamide

Acrylamide is formed by thermal reactions between reducing sugars and asparagine, mainly in the initial phase of roasting; its formation can peak in light to medium roasts and decrease in extremely dark roasts due to its subsequent degradation or secondary reactions. Therefore, the relationship "darker = more acrylamide" is not linear. Concern about acrylamide stems from its potential genotoxicity observed in animal models and the interest in reducing human dietary exposure.[13,14] In this regard, the European Union, through Regulation (EU) 2017/2158, established indicative benchmark levels for coffee-based products: 400 µg/kg for roasted coffee and 850 µg/kg for instant coffee. To put these values in perspective, it has been estimated that the average cup of filtered coffee (approximately 200 mL) prepared with 10 g of roasted coffee would contain, on average, between 2 and 10 µg of acrylamide, depending on the roast level and preparation method. Although these conditions are well below levels considered an acute risk, monitoring is important due to chronic cumulative exposure.[15,16]

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs can form through incomplete combustion and pyrolysis processes during roasting, especially when there is direct contact with flames or very high temperatures. The concentration of PAHs in the final product depends on the roasting method, heat source, and control conditions; in general, the literature shows variability between brands and processes, and there is no simple universal pattern (i.e., some controlled roasting procedures minimize PAHs even in dark roasts).[17]

IMPACT ON NUTRITIONAL VALUE AND POTENTIAL TOXICITY

The change in chemical composition during roasting has two relevant consequences: it modifies the load of potentially beneficial compounds (antioxidants, CGA) and functional compounds (caffeine), and it determines the presence and concentration of thermal contaminants (Acrylamide, PAHs, furan, among others). These transformations must be evaluated both at the bean level and in the final beverage, since extraction during preparation (filtered, French press, espresso, instant) alters which compounds reach the cup and in what quantity.[11,18]

Nutritional value

The benefits attributed to coffee (antioxidant activity, possible protective effect in metabolic and neurodegenerative diseases) are partly associated with polyphenols like CGAs and other bioactive fractions. When roasting rapidly reduces these compounds, the "nutritional" profile can change; however, the presence of compounds formed during roasting (e.g., melanoidins) also provides biological properties, so the evaluation must be comprehensive. Likewise, factors such as bean origin, post-harvest processing, and extraction method are determinants of the beverage's final content.[10]

Potential toxicity in human practice

Although acrylamide and certain PAHs are subjects of monitoring due to their carcinogenic potential in animal studies, epidemiological evidence on habitual coffee consumption shows complex results: broad reviews have pointed to a lack of consistent association between coffee consumption and most cancers, and in fact, many series associate moderate coffee consumption with protective effects on mortality and chronic diseases. This does not eliminate the need to minimize avoidable exposures (e.g., reducing acrylamide in poorly controlled industrial or roasting processes), but rather suggests that the risk-benefit assessment of coffee is multifactorial and cannot be based solely on the presence of an isolated compound.[4,19]

Variabilities and mitigation factors

The magnitude of compound loss or formation depends on controllable variables: roasting profile and time/temperature, type of heat source, atmosphere control in the roaster, origin and composition of the bean (e.g., asparagine level), and beverage preparation methods. Therefore, technological and operational strategies exist to reduce undesirable compounds (optimization of roasting profiles, control of the roast point, varietal selection, or post-harvest treatment) without completely sacrificing the desired organoleptic properties.[4,20]

EFFECTS OF COFFEE CONSUMPTION ON HEALTH

Recognized benefits

Habitual coffee consumption has been the subject of numerous epidemiological investigations and meta-analysis reviews, many of which suggest that moderate consumption is associated with protective effects for human health. For example, an umbrella review, which analyzed meta-analyses, indicated that drinking coffee was consistently associated with a lower risk of all-cause mortality, lower risk of cardiovascular diseases (CVD), and metabolic diseases like type 2 diabetes, and some types of cancer.[21]

Specifically, for cardiovascular health, a meta-analysis of 36 prospective studies (more than 1,279,000 participants) found that the relationship between coffee consumption and CVD risk has a non-linear shape: the lowest risk was observed with approximately 3 to 5 cups a day, and higher consumption was not associated with a significant increased risk.[20]

Regarding type 2 diabetes and other metabolic disorders, it has been observed that coffee consumption correlates with a lower incidence of T2D and a lower risk of non-alcoholic fatty liver disease. Furthermore, coffee contains bioactive compounds such as chlorogenic acids, caffeine, and other polyphenols that could act through antioxidant and anti-inflammatory mechanisms, which would contribute to its beneficial effects.[21-23]

From a cognitive and neurological standpoint, some research also shows that moderate coffee consumption is associated with a lower risk of Alzheimer's and other dementias, as well as increased alertness and better cognitive performance in certain contexts. For example, a recent meta-analysis found that consuming 1-4 cups of coffee per day was associated with a lower risk of Alzheimer's, while excessive consumption (more than 4 cups) could attenuate or reverse this effect.[24] In summary, the recognized benefits of coffee consumption seem to depend on a pattern of moderate consumption, along with consideration of other lifestyle factors, allowing coffee to be seen as part of a healthy dietary pattern when consumed consciously.

Potential risks of excess or very dark roast

Although data favor beneficial effects with moderate consumption, excessive coffee consumption or the ingestion of coffees processed in poorly controlled ways (e.g., very dark roasts generating undesirable compounds) can carry risks or attenuate benefits. For example, reviews on caffeine show that in healthy adults, up to ~400 mg/day is not associated with severe adverse cardiovascular effects, but the margin depends on individual susceptibility.[25]

Regarding high consumption, some research has observed that beyond a certain threshold (e.g., >5-6 cups per day), the benefits no longer increase, and neutral or even negative associations may arise, although causality is not established.[21]

From the perspective of dark roasting, although there are fewer epidemiological studies distinguishing roast levels, the fact that very dark roasts may involve greater degradation of phenolic compounds and greater formation of thermal contaminants (like acrylamide and PAHs) suggests a need for caution. This connects to a line of research suggesting that the coffee's profile (origin, processing, roasting) matters as much as the quantity consumed in determining risk/benefit. A concrete example of risk: in women, some cohorts have found a higher risk of bone fracture with high coffee consumption, although this effect appears to depend on sex, bone density, and other moderating factors. Likewise, specifically for hypertension, a review of prospective studies found that consuming 1-3 cups a day could increase hypertension risk in certain individuals, although the evidence is not conclusive.[21,26] Therefore, although habitual coffee seems safe for most healthy adults, excessive consumption and lack of control over the product's profile (roast, origin, preparation) can attenuate benefits and increase risks. This reinforces the need for a bioethical approach of informed consumption (which we will see in the next section) and transparency in production.

Ethical principles involved: beneficence, non-maleficence, autonomy, and justice

The production, commercialization, and consumption of coffee are not just technical or commercial processes: they directly activate bioethical values that have traditionally been applied to healthcare but are also fully valid in food and food systems. For example, the principle of beneficence demands that actors (producers, roasters, distributors) contribute to the well-being of consumers by offering safe, quality products with recognized benefits. In parallel, the principle of non-maleficence implies avoiding foreseeable harm, such as exposure to thermal contaminants (acrylamide or polycyclic aromatic hydrocarbons) generated by poorly controlled roasting or opaque production practices. The principle of autonomy relates to the consumer's capacity to make informed decisions regarding coffee consumption: understanding what they are drinking, knowing the risks and benefits, and deciding freely without coercion or insufficient information. In this sense, as studies on food systems and ethics point out, consumer autonomy can be limited if decisions are guided by misleading advertising or a lack of transparency in the production chain.[27]

Finally, the principle of justice extends to equitably distributing both the benefits and the risks throughout the coffee production chain: from the producers (often in vulnerable conditions) to the consumers, and including the environmental dimension. As a report from the Berman Institute of Bioethics states, "food systems are morally relevant because they simultaneously promote and threaten health and well-being." Food consumption can be detrimental to health and well-being.[27]

ETHICS OF INFORMED CONSUMPTION

Informed consumption presupposes that the consumer has access to reliable information about the product they acquire: origin, roast, chemical profile, potential risks, production practices, etc. When that information is lacking, consumer autonomy is seriously compromised; for example, if a consumer is unaware that a dark roast level can increase the presence of contaminants or degrade beneficial compounds, they cannot make a fully conscious decision. From an ethical perspective, this poses an obligation for producers and roasters to provide labels, traceability, and transparency. Furthermore, the regulatory system and public health agencies also have a responsibility to ensure that the information offered to the public is understandable and accurate.

In the case of Mexico, the current legal framework, particularly **NOM-255-SE-2022, Pluma Coffee-Denomination-Specifications-Commercial information and test methods**, defines the technical parameters, such as roast level, color, humidity, and processing temperature, but makes no reference to contaminants derived from the thermal process, such as acrylamide or polycyclic aromatic hydrocarbons (PAHs). This omission highlights a regulatory gap, as, unlike the European Union, Mexico does not have established limits or mandatory mitigation strategies for these substances in coffee.[28]

From a bioethical standpoint, this regulatory gap limits the consumer's ability to exercise their fully informed autonomy, which constitutes a challenge to the principle of non-maleficence, as there are no policies guaranteeing systematic control of contaminants in one of the country's most consumed products.

In the food sector, debates over paternalistic policies versus autonomy reflect this tension: limiting options to protect health can conflict with consumer autonomy.[29]

Ethics in production: fair trade, sustainability, and environmental respect.

Ethics in coffee production involves criteria beyond economic performance: it includes the dignified treatment of agricultural workers, the responsible use of natural resources, the minimization of emissions and pollutants, and the adoption of practices that ensure long-term sustainability. For example, roasting policies that involve high heat emissions, poorly controlled energy sources, or excessive waste generation can compromise not only consumer health but also that of workers and nearby communities. In this sense, the values of justice and sustainability converge. A report from the **Nuffield Council on Bioethics** notes that an ethical approach to food sustainability must consider choice/autonomy, equity, health, the environment, and food security as interrelated values[30] and thus extends ethical responsibility to the complete life cycle of coffee, from the farm to the cup, and not just to the act of drinking it.

Bioethics of coffee research: transparency, conflicts of interest, and social responsibility

The scientific study of coffee, its composition, benefits, and risks, is also immersed in ethical considerations: researchers must ensure methodological transparency, declare conflicts of interest (e.g., funding from the coffee industry), and guarantee that their results benefit the common good. Furthermore, there is an ethical obligation to communicate results to the public understandably and without commercial distortion. Likewise, social responsibility implies that risk-benefit findings translate into recommendations that improve public health, consumer protection, and environmental sustainability. The ethics of food research also demand a fair distribution of the benefits of knowledge, especially when working with traditional products or vulnerable agricultural communities.[31]

MEXICAN COFFEE AND SOCIAL RESPONSIBILITY

Current situation of national production

Mexico is one of the countries with a coffee-growing tradition and possesses high-quality cultivation regions, such as Chiapas, Veracruz, Oaxaca, and Puebla. Even so, producers face structural challenges: low profitability, fluctuations in international prices, impacts of climate change (pests, temperatures, droughts), and competition from low-cost coffees. This situation highlights the need to value not only the final product but also the social, economic, and environmental sustainability of its cultivation.[31] From a social responsibility perspective, it is fundamental to consider that many small producers lack the infrastructure for optimized processing (e.g., for controlled roasts, monitoring of thermal contaminants), which can affect the coffee's quality, the roast's chemical profile, and, ultimately, consumer safety and benefits.[32]

Social and ecological implications of the cultivation and roasting model

The conventional coffee production model often drives monocultures, high inputs (fertilizers, pesticides), deforestation, and biodiversity loss—effects that impact rural producing communities and the surrounding environment. On the other hand, Mexican specialty coffee has promoted agroecological shade-grown practices, biodiversity, traceability, and short chains that favor social justice (better conditions for workers), as well as equity in the distribution of benefits among producers, roasters, and consumers.[33,34]

In processing, roasting is a critical phase that can involve energy consumption, emission of atmospheric pollutants, and generation of solid waste (husks, grounds). If these stages are not managed with sustainability criteria, coffee production, although valued by the consumer, may be contributing to hidden environmental impacts, which raises the need for industrial social responsibility.[33,34]

Public health perspective

Coffee consumption is so prevalent that its chemical profile, preparation method, and roast level have implications for public health. In Mexico, promoting specialty coffees that better preserve their functional compounds, reduce the formation of thermal contaminants, and come from responsible chains can contribute to a preventive health strategy. Likewise, ensuring that roasters and distributors inform about production practices, quality, and roasting is part of the public duty to protect consumers; this links to the bioethical principles of autonomy and information. For the productive and consumer sector to contribute positively to collective health, public policies must contemplate incentives for sustainable production, certification schemes that include monitoring of critical compounds (e.g., acrylamide, PAHs), and consumer education on how roasting processes affect the coffee's chemical profile.[33,34]

CONCLUSION

Evidence has been integrated on how the coffee roast level, particularly when contrasting specialty coffees against dark roast coffees, modifies the chemical composition of the bean and the beverage; how this chemical change can imply both benefits and risks for human health; and how these aspects have a bioethical dimension involving producers, consumers, regulators, and the environment, with a particular focus on the Mexican context.

The literature indicates that medium to light roast coffees may conserve a greater quantity of bioactive compounds, such as chlorogenic acids and antioxidants, while very dark roasts tend to degrade these compounds and may favor the formation of thermal contaminants, such as acrylamide or PAHs. Nonetheless, in the practice of human consumption, coffee has been mostly associated with protective effects for health when consumed moderately, making it clear that the risk/benefit profile does not depend solely on the roast, but on the system as a whole: bean origin, preparation method, quantity, consumer habits, among others.

From a bioethical perspective, this panorama highlights that actors in the coffee chain have an obligation to guarantee both product quality and transparency of information for the consumer. Consumer autonomy demands access to truthful information about the roast, origin, and potential risks of consumption; the principle of non-maleficence and beneficence implies reducing exposure to contaminants and promoting the product's positive effects; while the principle of justice demands that producers, roasters, and consumers equitably share the benefits and that environmental and social harms associated with cultivation, processing, and commercialization are minimized.

Finally, in the Mexican context, where specialty coffee production has growing value, promoting sustainable cultivation and processing models, encouraging informed consumption, and aligning academic innovation with an integrated bioethical framework can become a public health and social development strategy. It is recommended that future studies conduct more detailed analyses of the chemical profile according to roast in Mexican coffees, include contaminant evaluation, and explore consumer perception of roasting and the information they receive. Similarly, public policies must incentivize traceability, certification of sustainable practices, and consumer education to maximize both the quality and safety of the coffee that reaches the cup.

REFERENCIAS

[1] Secretaría de Agricultura y Desarrollo Rural. Café mexicano [Internet]. Ciudad de México: Gobierno de México; 2016.

[2] Guenther H, Anklam E, Wenzl T, Stadler RH. Acrylamide in coffee: review of progress in analysis, formation and level reduction. Food Addit Contam. 2007;24(Suppl 1):60–70.

[3] DiNicolantonio JJ, O'Keefe JH. Coffee is not a carcinogen. Mo Med. 2018;115(3):197–198.

[4] Nehlig A, Cunha RA. The coffee–acrylamide apparent paradox: an example of why the health impact of a specific compound in a complex mixture should not be evaluated in isolation. Nutrients. 2020;12(10):3141.

[5] Fanzo J. Ethical issues for human nutrition in the context of global food security and sustainable development. Glob Food Secur. 2015;7:15–23.

[6] Ferrari R. Writing narrative style literature reviews. Med Writing. 2015;24(4):230–235.

[7] Melese YY, Kolech SA. Coffee (Coffea arabica L.): methods and strategies of breeding. Sustainability. 2021;13(19):10814.

[8] Alberto NJ, Niquisse JA, Ferreira A, Ribeiro-Barros AI, Aoyama EM, Silva LO, Rakocevic M, et al. Plant morphological and anatomical traits in Coffea arabica cultivars. Horticulturae. 2024;10:1002.

[9] da Costa DS, Albuquerque TG, Costa HS, Bragotto AP. Thermal contaminants in coffee induced by roasting: a review. Int J Environ Res Public Health. 2023;20(8):5586.

[10] Cwiková O, Komprda T, Šottníková V, Svoboda Z, Simonová J, Slováček J, et al. Effects of processing methods on coffee composition. Foods. 2022;11:3295.

[11] Santanatoglia A, Angeloni S, Bartolucci D, Fioretti L, Sagratini G, Vittori S, et al. Effect of brewing methods on acrylamide content and antioxidant activity: studying eight different filter coffee preparations. Antioxidants (Basel). 2023;12(10):1888.

[12] Olechno E, Puścion-Jakubik A, Zujko ME, Socha K. Influence of various factors on caffeine content in coffee brews. Foods. 2021;10(6):1208.

[13] Kocadağlı T, Gökmen V. Formation of acrylamide in coffee. Curr Opin Food Sci. 2022;45:100842.

[14] Strocchi G, Rubiolo P, Cordero C, Bicchi C, Liberto E. Acrylamide in coffee: what is known and what still needs to be explored: a review. Food Chem. 2022;393:133406.

[15] European Commission. Commission Regulation (EU) 2017/2158 establishing mitigation measures for acrylamide in food. Off J Eur Union. 2017;L304:24–44. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32017R2158

[16] European Food Safety Authority (EFSA). Scientific opinion on acrylamide in food. EFSA J. 2015;13(6):4104. doi:10.2903/j.efsa.2015.4104

[17] Binello A, Cravotto G, Menzio J, Tagliapietra S. Polycyclic aromatic hydrocarbons in coffee samples: enquiry into processes and analytical methods. Food Chem. 2021;344:128631.

[18] Santanatoglia A, Angeloni S, Bartolucci D, Fioretti L, Sagratini G, Vittori S, et al. Effect of brewing methods on acrylamide content and antioxidant activity: studying eight different filter coffee preparations. Antioxidants (Basel). 2023;12(10):1888.

[19] Aktağ IG, Hamzalıoğlu A, Kocadağlı T, Gökmen V. Dietary exposure to acrylamide: a critical appraisal on conversion mechanisms and digestion. Curr Res Food Sci. 2022;5:1118–1126.

[20] Li Z, Zhao C, Cao C. Production and inhibition of acrylamide during coffee processing. Molecules. 2023;28(8):3476.

[21] Poole R, Kennedy OJ, Roderick P, Fallowfield JA, Hayes PC, Parkes J. Coffee consumption and health: umbrella review of meta-analyses. BMJ. 2017;359:j5024.

[22] Ding M, Bhupathiraju SN, Satija A, van Dam RM, Hu FB. Long-term coffee consumption and cardiovascular disease risk: systematic review and meta-analysis. Circulation. 2014;129(6):643–659.

[23] Ungvari Z, Kunutsor SK. Coffee consumption and cardiometabolic health. GeroScience. 2024;46:6473–6510.

[24] Nila IS, Villagra Moran VM, Khan ZA, Hong Y. Effect of daily coffee consumption on Alzheimer's disease risk: systematic review and meta-analysis. J Lifestyle Med. 2023;13(2):83–89.

[25] Wikoff D, Welsh BT, Henderson R, Brorby GP, Britt J, Myers E, et al. Systematic review of adverse effects of caffeine consumption. Food Chem Toxicol. 2017;109:585–648.

[26] Haghighatdoost F, Hajihashemi P, de Sousa Romeiro AM, Mohammadifard N, Sarrafzadegan N, de Oliveira C, et al. Coffee consumption and hypertension risk: systematic review and meta-analysis. Nutrients. 2023;15(13):3060.

[27] Resnik DB. Paternalistic food and beverage policies: a response to Conly. Public Health Ethics. 2014;7(2):170–177.

[28] Secretaría de Economía. NOM-255-SE-2022, Café Pluma—Denominación—Especificaciones—Información comercial y métodos de prueba [Internet]. Ciudad de México: DOF; 2022 [citado 2025 oct 20]. Disponible en: https://www.dof.gob.mx/nota_detalle.php?codigo=5674083&fecha=30/11/2022

[29] Johns Hopkins Berman Institute of Bioethics. Public health and community well-being [Internet]. 2020 [citado 2025 oct 8]. Disponible en: https://bioethics.jhu.edu/

[30] Nuffield Council on Bioethics. Unpacking the ethics of food sustainability [Internet]. 2024 [citado 2025 oct 8]. Disponible en: https://www.nuffieldbioethics.org/

[31] Cullerton K, Adams J, Forouhi NF, Francis O, White M. Avoiding conflicts of interest in food research. BMJ. 2024;384:e077908.

[32] International Labour Organization. Workers in coffee cultivation: Mexico profile [Internet]. 2023 [citado 2025 oct 8]. Disponible en: https://www.economia.gob.mx/

[33] Rosales-Martínez V. Coffee agroecosystem in Mexico. Agroproductividad. 2020;13(9):29–38.

[34] Medina-Meléndez JA, Ruiz-Nájera RE, Gómez-Castañeda JC, Sánchez-Yáñez JM, Gómez-Alfaro G, Pinto-Molina O. Study of the production system of coffee (Coffea arabica L.) in the Frailesca region, Chiapas. 2014;10(2):33–43.