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# Impacts Analysis Regarding Partially Hydrogenated Oils

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**June 2015**

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

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**ORNL/TM-2015/293**

Environmental Sciences Division

# IMPACTS ANALYSIS REGARDING PARTIALLY HYDROGENATED OILS

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# ABSTRACT

The U.S. Food and Drug Administration (FDA) has the responsibility under the Federal Food, Drug, and Cosmetic Act (FD&C Act) [21 *United States Code* (U.S.C) 301 et seq.] for assuring that the U.S. food supply is safe, sanitary, wholesome, and honestly labeled. Toward that end, FDA exercises approval authority over substances permitted for use as food additives. Substances that are generally recognized as safe (GRAS) are not subject to regulation as food additives under the FD&C Act.

Partially hydrogenated oils (PHOs), such as partially hydrogenated soybean and cottonseed oils, have been used in food for many years based on self-determinations by industry that such use is GRAS. However, based on new scientific evidence establishing the health risks associated with the consumption of *trans* fatty acids (also called *trans* fat), FDA has determined that there is no longer a consensus among qualified scientific experts that PHOs—which are the primary dietary source of industrially-produced *trans* fat—are safe for human consumption either directly or as ingredients in other food products. FDA therefore is issuing a declaratory order to revoke the GRAS status of PHOs for use in food, thus making PHOs subject to regulation as food additives.

Under the FDA Order, food manufacturers would no longer be permitted to sell PHOs, either directly or as ingredients in another food product, without prior FDA approval. Therefore, the U.S. food industry would be reasonably expected to use oils and fats from other sources as replacements for PHOs in all U.S. food products. One potential replacement would be palm oil imported from sources outside the United States (most likely from Southeast Asia).

This impacts analysis has been prepared by the staff of the Oak Ridge National Laboratory (ORNL) to assess and document the potential effects of the FDA Order on the environment of the United States. The purpose of this report is to provide input to FDA regarding an FDA determination as to whether the actions reasonably expected to result from the FDA Order may have significant environmental effects that would require preparation of an environmental impact statement or environmental assessment in accordance with FDA regulations for implementing the National Environmental Policy Act of 1969 (42 U.S.C 4321, et seq.).

The analysis considers the effects of the FDA Order revoking the GRAS status of PHOs on land use, water resources, air quality, waste management, transportation, and resources energy. An economic analysis of impacts to agriculture is included. Impacts to other environmental resources were judged to be either inconsequential or too local in nature to be anticipated in this analysis. No projected environmental impacts in the U.S. were judged to be significant.

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| µm | micrometers = 1 millionth of a meter |
| BOD | Biochemical Oxygen Demand |
| bu | bushel (60 pounds of soybeans) |
| | |
| °C | degrees Celsius |
| $^{14}C$ | a radioactive isotope of carbon with an atomic number of 14 |
| CAFOs | Concentrated Animal Feeding Operations |
| CDC | Centers for Disease Control and Prevention |
| CEQ | Council on Environmental Quality |
| CFR | *Code of Federal Regulations* |
| $CH_4$ | methane |
| CHD | coronary heart disease |
| CO | carbon monoxide |
| $CO_2$ | carbon dioxide |
| COD | Chemical Oxygen Demand |
| cwt | hundred weight |
| | |
| DHHS | Department of Health Human and Services |
| dL | deciliter = 1 tenth of a liter |
| DRINC | Dairy Research & Information Center |
| EPA | U.S. Environmental Protection Agency |
| | |
| °F | degrees Fahrenheit |
| FAO | Food and Agriculture Organization of the United Nations |
| FD&C Act | Federal Food, Drug, and Cosmetic Act |
| FDA | U.S. Food and Drug Administration |
| FMCSA | Federal Motor Carrier Safety Administration |
| FPEAC | Food Processing Environmental Assistance Center |
| FR | *Federal Register* |
| FRA | Federal Railroad Administration |
| | |
| g | gram |
| g/p/d | grams per person per day |
| gal | gallon |
| GRAS | generally recognized as safe |
| | |
| ha | hectare |
| HDL | high-density lipoprotein cholesterol |
| hr | hour |
| IFC | International Finance Corporation |

| | |
|---|---|
| IMO | International Maritime Organization |
| IOM | Institute of Medicine |
| kg | kilogram = 1 thousand grams |
| knot | nautical mile per hour |
| kW | kilowatt = 1 thousand Watts |
| kW-hr | kilowatt-hour |
| L | liter |
| lb | pound |
| LDL | low-density lipoprotein cholesterol |
| MARPOL | International Convention for the Prevention of Pollution from Ships |
| mg | milligram = 1 thousandth of a gram |
| Mg | megagrams = 1 million grams |
| mmol | millimole = 1 thousandth of a mole |
| MMT | million metric tons |
| MUFA | mono-unsaturated fatty acid |
| n.mi | nautical mile |
| N/A | not available or not applicable |
| NAAQS | National Ambient Air Quality Standards |
| NASS | National Agricultural Statistics Service |
| NCCA | National Cotton Council of America |
| NCPA | National Cottonseed Products Association |
| NEPA | National Environmental Policy Act |
| $NO_x$ | oxides of nitrogen |
| ORNL | Oak Ridge National Laboratory |
| PHO | partially hydrogenated oil |
| PHVO | partially hydrogenated vegetable oil |
| $PM_{2.5}$ | particulate matter with a diameter equal to or less than 2.5 µm |
| $PM_{10}$ | particulate matter with a diameter equal to or less than 10 µm |
| PUFA | poly-unsaturated fatty acid |
| $SO_x$ | oxides of sulfur |
| $SO_2$ | sulfur dioxide |
| SFA | saturated fatty acid |
| tC | tons of carbon |
| $tCO_2$ | tons of carbon dioxide |
| U.S. | United States |
| U.S.C. | *United States Code* |

| | |
|---|---|
| USB | United Soybean Board |
| USDA | U.S. Department of Agriculture |
| USDA/AMS | U.S. Department of Agriculture/Agricultural Marketing Service |
| USDA/ERS | U.S. Department of Agriculture/Economic Research Service |
| USDA/FAS | U.S. Department of Agriculture/Foreign Agricultural Service |
| USDA/NASS | U.S. Department of Agriculture/National Agricultural Statistics Service |
| USDA/OCE-WAOB | U.S. Department of Agriculture/Office of the Chief Economist and World Agricultural Outlook Board |
| yr | year |

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# 1. INTRODUCTION AND BACKGROUND

The U.S. Food and Drug Administration (FDA) has the responsibility under the Federal Food, Drug, and Cosmetic Act (FD&C Act) [21 *United States Code* (U.S.C) 301 et seq.] for ensuring that the U.S. food supply is safe, wholesome, sanitary, and properly labeled. Toward that end, FDA exercises premarket approval authority over substances that are food additives. Substances that are generally recognized as safe (GRAS) are not subject to regulation as food additives under the FD&C Act.

Partially hydrogenated oils (PHOs), such as partially hydrogenated soybean and cottonseed oils, have been used in food for many years. However, based on new scientific evidence and the findings of expert scientific panels establishing the health risks associated with the consumption of *trans* fatty acids (hereinafter called *trans* fat), FDA has determined that there is no longer a consensus among qualified scientific experts that PHOs—which are the primary dietary source of industrially-produced *trans* fat—are safe for human consumption.

**CHEMICAL HYDROGENATION**

Chemical hydrogenation is the process by which hydrogen atoms are added to unsaturated sites on the carbon chains of fatty acids, in the presence of catalysts, thereby reducing the number of double bonds. ‘‘Partial hydrogenation’’ describes an incomplete saturation of the double bonds, in which some double bonds remain but may shift to a different position along the carbon chain and alter their configuration from *cis* to *trans*. The *trans* arrangement of hydrogen atoms results in a relatively straight configuration of the fatty acids and increases the melting point, shelf life, and flavor stability of the hydrogenated oil. Because of these technical properties, PHOs have been used by the food industry in such products as margarine, shortening, and baked goods. The *trans* fatty acid content of PHOs can vary from approximately 10 to 60 percent of the oil, depending on how the oil is manufactured, with an average *trans* fatty acid content of 25 to 45 percent of the oil (Tarrago-Trani et al. 2006).

FDA is therefore preparing to issue a declaratory order stating that PHOs are not GRAS for use in human food.

## 1.1 WHAT IS FDA’s ACTION?

FDA is issuing a declaratory order stating that PHOs are not GRAS for use in human food. Thus PHOs, and food bearing or containing PHOs, introduced or delivered for introduction into interstate commerce in the United States on or after the effective date of the order will be adulterated under Section 402(a)(2)(C) of the FD&C Act unless the use of the PHOs is otherwise authorized (Action). Although all refined edible oils contain some *trans* fat as an unintentional byproduct of their manufacturing process, *trans* fats are an integral component of PHOs and are purposely produced in these oils to affect the properties of the oil and the characteristics of the food to which they are added. In addition, *trans* fat occurs naturally in meat and dairy products from ruminant animals; hence, naturally-occurring *trans* fat is unavoidable in ordinary, non-vegan diets.

Implementation of the Action is expected to result in the food industry using alternative ingredients as replacements for PHOs in U.S. food products. While FDA is determining that PHOs are not GRAS for use in human food, it is not mandating the specific replacement ingredients that may be used.

Data collected by FDA in 2009 and 2010 show that many foods (e.g., frozen potato products, most frozen breaded products) have been reformulated to remove PHOs (Doell et al. 2012). However, several foods made with PHOs remained on the market in 2012. These products fall into one of two categories:

- Foods for which consumers have the choice of an alternative containing lower levels of *trans* fat. These foods include cookies, baked goods, microwave popcorn, frozen pizza, frozen pies, and shortening.
- Foods for which consumers have limited or no choice of an alternative containing a lower level of *trans* fat. These foods include refrigerated biscuits, ready-to-use frostings, and stick margarine.

On November 8, 2013, FDA published a notice in the *Federal Register* and requested comments and scientific data and information on its tentative determination regarding the GRAS status of PHOs (78 FR 67169). Food industry groups commenting on the November 2013 tentative determination reported that small amounts of PHOs are also used in various flavoring agents, food coloring, and as stabilizing agents in foods.

## 1.2 WHY IS THIS IMPACTS ANALYSIS BEING PREPARED?

This analysis has been prepared by ORNL to assess and document the potential environmental effects of the FDA Action. ORNL's approach to the analysis of the impacts of the Action is generally consistent with the National Environmental Policy Act (NEPA) of 1969 (42 U.S.C 4321, et seq.), the Council on Environmental Quality (CEQ) Regulations implementing NEPA [40 *Code of Federal Regulations* (CFR) Parts 1500–1508], and with FDA regulations for implementing NEPA (21 CFR Part 25), except that it does not consider the impacts of alternatives to the Action.

Under CEQ regulations at 40 CFR 1508.8, agencies are directed to consider both the direct effects and the indirect effects of their proposed actions. Direct effects are those caused by the Action and occur at the same time and place. Indirect effects are those caused by the Action and are later in time or farther removed in distance, but are still reasonably foreseeable. Indirect effects may include growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems. This report analyzes primarily the indirect effects of the Action.

The following environmental concerns were identified in the comments received in response to FDA's November 8, 2013, *Federal Register* notice (78 FR 67169).

Commenters expressed concerns about the environmental impacts of substituting other fats and oils for PHOs. They stated that FDA should identify the potential impacts of the substitutes and replacements for PHOs and analyze the environmental consequences of those replacements.

Some commenters expressed the opinion that FDA's proposal may significantly affect the quality of the human environment and, therefore, require preparation of an environmental impact statement. The purpose of this report is to provide input to FDA regarding an FDA determination as to whether the Action may have significant environmental effects that would require preparation of an environmental impact statement or environmental assessment in accordance with FDA regulations for implementing NEPA.

Specific concerns mentioned in the public comments included the following:

- Use of imported palm oil and other tropical oils to replace PHOs may result in tropical rainforests being converted to palm oil plantations, thus contributing to the loss of tropical rainforests, increased greenhouse gas emissions, and the loss of orangutans and other endangered wildlife species that depend on the rainforests for habitat.
- Conversion of rainforests to palm oil plantations may adversely affect people who depend on the rainforest for sustenance and may expose plantation workers to undesirable working conditions.
- Increased use of imported palm oil as an alternative to PHOs may require trans-ocean shipments over long distances in cargo ships that burn bunker fuel, which one commenter described as "the most environmentally unfriendly fuel." Increased use of dairy products as an alternative to PHOs may increase environmental impacts from dairy farming, which one commenter called "one of the most inefficient uses of farmland."

As noted above, some commenters expressed concern that use of imported palm and other tropical oils to replace PHOs may result in tropical rainforests in other countries being converted to palm oil plantations, thus contributing to possible adverse effects such as deforestation, greenhouse gas emissions, harm to threatened or endangered species, harm to people who depend on rainforest for sustenance, and harm to plantation workers. Some of these comments stated that FDA should consider these potential environmental impacts.

In this report, ORNL did not analyze potential environmental impacts resulting from the possible sourcing of palm and other tropical oils in other countries because these are not within the scope of FDA's responsibilities under NEPA.

If persons in foreign countries take actions to produce palm oil or other tropical oils that have potential adverse environmental effects in these foreign countries, such actions would be subject to the independent oversight and authority of the relevant foreign government and would not be activities caused by FDA's Action. Consequently, the Action would not be the legally relevant "cause" of the potential adverse environmental impacts of these actions. Therefore, such impacts would not be "effects" within the meaning of 40 CFR 1508.8 that FDA would need to analyze. Because FDA would not consider the impacts of palm oil or other tropical oil production in foreign countries in a NEPA document, the analysis of activities in foreign countries is likewise beyond the scope of this analysis. FDA is considering potential effects on the global commons, including impacts from trans-ocean shipping of palm oil, in a separate document.

The issues raised by comments regarding potential impacts from domestic dairy farming are addressed in the analysis that follows.

## 1.3 WHAT RESOURCE ISSUES ARE CONSIDERED IN THIS DOCUMENT?

An interdisciplinary team of environmental scientists and analysts has performed this impact analysis. The team has identified resources and topical areas, analyzed the Action against the existing conditions, and determined the relevant beneficial and adverse effects to the human environment associated with the Action. The areas of assessment in Section 2 of this analysis include potential impacts to land use (Section 2.1); water resources (Section 2.2); air quality (Section 2.3); waste management (Section 2.4); transportation (Section 2.5); and use of energy and resources (Section 2.6). Cumulative impacts of the Action are also included (Section 2.7).

This analysis considers the potential environmental impacts of the Action on the environment in the United States and considers the potential impacts from increased importation of palm and palm kernel oil (see Section 2.3). The potential for impacts in the United States from increased use of dairy products is considered in Section 2.1.

## 1.4 WHAT RESOURCE ISSUES HAVE BEEN ELIMINATED FROM DETAILED ANALYSIS?

The FDA considered the potential for impacts to the resource categories of infrastructure (such as roads and bridges), ecological resources (including threatened and endangered species), socioeconomic resources, environmental justice, cultural resources, aesthetic resources, and the ambient noise environment, but eliminated these from detailed analysis. While the implementation of the Action could affect the resource categories listed above, any such impacts would be of a highly site-specific nature. It is unlikely that significant adverse impacts would occur to these resource categories at the nation-wide level as a result of the Action. Furthermore, it is difficult if not impossible to identify any site-specific impacts for these resources that might be definitively affected by activities associated with the Action.

For these reasons, and as explained in the following paragraphs, these resource categories are not discussed further in this Impact Analysis..

While current farming and industrial activities could create impacts to existing infrastructure, there would be no significant increase in the use of those infrastructure resources under the Action; therefore, no incremental adverse impacts to such resources would be expected to occur as a result of the Action.

The agricultural use of previously used farmland for growing crops in response to the Action would not be expected to adversely affect ecological or cultural resources; however, such resources could be discovered or adversely impacted during the clearing of any new farmland. However, as discussed in Section 2.1, crops grown to replace PHOs would not be expected to require the development of any new farmlands.

Agricultural activities in the United States primarily occur in rural areas characterized by low population density and low ambient noise levels. Neither the aesthetic characteristics nor the noise environment of those rural areas would be expected to be adversely impacted as a result of the Action.

The FDA is considering the economic impacts of the Action in a separate analysis. The action could affect local socioeconomic conditions in communities where oil crops are grown or where oils and fats are processed, but local-scale changes cannot be identified in this analysis. Because, as documented in Appendix A of this report, the Action is expected to result in little or no change in the overall mix of U.S. agricultural production, no changes in the U.S. agricultural workforce, including the utilization of migrant workers, would be expected. No potential has been identified for the Action to adversely affect environmental justice by creating disproportionately high and adverse impacts to minority or low-income populations in the United States.

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# 2. ENVIRONMENTAL IMPACTS

This chapter describes the potential impacts that might reasonably result from implementing the Action. Additionally, this chapter explains how those impacts are evaluated.

In order to analyze the indirect impacts that may occur as a result of the Action, FDA has developed a scenario for replacement of PHOs. The following discussion outlines the assumptions that were used to develop this scenario.

In response to the Action, the food industry would be reasonably expected to use alternative ingredients as replacements for PHOs in U.S. food products. However, while FDA is determining that PHOs are not GRAS for use in human food, it is not mandating the specific replacement ingredients that may be used.

Appendix A to this report presents an agricultural analysis of potential replacements for PHOs, considering the available options, economic costs, and potential impacts of replacements. A detailed list of potential PHO substitutes and replacements can be found in Table A-4 in Appendix A. The list of replacement ingredients includes: nontropical oils (such as corn, cottonseed, peanut, and rapeseed oils), tropical oils (such as palm, palm kernel, and coconut oils), animal fats (such as beef tallow, lard, and butter), and modified oilseed oils (such as high-oleic soybean, sunflower, and canola oils; mid-oleic soybean and sunflower oils; and low linolenic soybean and canola oils).

Additionally, in response to the Action, the U.S. food industry might alter its manufacturing processes to develop new products with similar characteristics to PHOs. These revisions might involve interesterification; modifications to the hydrogenation process; blending fully hydrogenated oils or tropical oils with liquid vegetable oils; separating tropical oils into hard fractions (for use in margarine and shortening, for example); and blending liquid and solid/semi-solid feedstocks (e.g., palm kernel oil) together with a catalyst to produce fats with different melting profiles and physical characteristics. Each of these PHO replacements has its own set of disadvantages, including limitations in supply, excessive saturated fat content, and/or price/cost.

It should be noted that the assumed implementation of any of the above changes or revisions to current manufacturing processes or techniques would be highly speculative in regard to the likelihood, as well as to the extent and environmental implications, of such changes.

The following scenario is evaluated in this Impacts Analysis. Because approximately 2.53 billion pounds (1.15 MMT) of PHOs are used annually in the United States (see Appendix A), the quantity of PHOs that are to be replaced by alternative ingredients for the scenario is also assumed to be 2.53 billion pounds (1.15 MMT).

- Under the scenario developed by FDA, PHOs are assumed to be replaced by a combination of fats and oils consisting of the following items and their percentages (Bruns 2014):
    - High-oleic soybean oil – 25 percent
    - Fully hydrogenated vegetable oils – 10 percent
    - Interesterified fats – 10 percent
    - Lard and tallow – 9 percent [1]
    - High-oleic sunflower oil – 5 percent
    - Other soybean oil – 5 percent
    - Cottonseed oil – 2.5 percent
    - Canola oils – 2.5 percent
    - Butter – 1 percent
    - Palm oil – 30 percent

For the purpose of analysis in this report, each of the PHO replacements in the above list is assumed to be produced domestically, except for the palm oil, which is assumed to be imported. The PHO replacements would require transport between producers, processors, and consumers.

## 2.1 LAND USE

### 2.1.1 Overview

The oils and fats in U.S. food are almost entirely derived from agriculture (the exceptions are oils obtained from fish and wild game). Overall, approximately 943 million acres (382 million ha) of land in the United States (15.6 percent of the nation's land area) is currently in agricultural use (EPA 2013). Of this total, 330 million acres (134 million ha) are used to grow crops (USDA/NASS 2014) and 613 million acres (248 million ha) are used for livestock production (EPA 2013).

Soybean oil accounts for the great majority of domestic vegetable oil production and accounts for about two-thirds of total U.S. production of oils and fats. For example in 2013 total domestic edible oil and fat production was 28,570 million pounds, of which 19,720 million pounds were sourced from soybeans (see Table A-1 in Appendix A). Data collected and reported by the USDA National Agricultural Statistics Service (NASS) show that about one-quarter of U.S. crop land is planted in soybeans (USDA/NASS 2014).
In 2014, of the 330 million acres (134 million ha) total U.S. cropland, soybeans were planted on about 85 million acres (34 million ha) (USDA/NASS 2014). Production of sunflowers for oil and production of the oilseed canola used 1.3 million and 1.6 million acres (0.53 million to 0.65 million ha), respectively (USDA/NASS 2014). Corn oil is a secondary product from the production of corn for various purposes, and more U.S. crop land is planted in corn (for

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[1] 5% from lard + 4% from tallow

all purposes) than is planted in soybeans. In 2014, 91.6 million acres (37 million hectares) was planted in corn (USDA/NASS 2014). Cottonseed oil is produced as a secondary product of cotton production. During the decade 2004 to 2013 the U.S. land area planted in cotton ranged from 9.15 million to 15.3 million acres (3.7 million to 6.2 million ha; NCCA 2014).

Soybean production is a significant use of agricultural land in 31 U.S. states. Leading states for soybean acreage are Illinois, Iowa, Minnesota, North Dakota, Missouri, Indiana, Nebraska, South Dakota, and Ohio, with lesser production in other parts of the Midwest, the Great Plains and southeastern states (USDA/NASS 2014). More than 70 percent of the land used for canola production is in North Dakota and about 80 percent of the land used to grow sunflowers for oil is in North Dakota and South Dakota (USDA/NASS 2014).

Based on yield values in Table A-6 in Appendix A, production of the 2 billion pounds (0.9 million metric tons) of soybean oil that is currently converted into PHOs for domestic consumption is estimated to require 4 million acres (1.6 million ha) of soybean production (about 5 percent of land currently in soybean production and just over 1 percent of total U.S. cropland). The 255 million pounds estimated as produced from canola and the 28 million pounds estimated to come from sunflower require the output from about 380,000 acres (155,000 ha) and 47,000 acres (19,000 ha), respectively. At a crop yield of 122 bushels per acre and an oil yield of 1.6 pounds per bushel (University of Missouri 2015), the 214 million pounds of PHOs produced from corn oil represents the oil produced from 1.1 million acres (440,000 ha) of corn. At yields of 990 pounds of cottonseed per acre and 320 pounds of oil per ton of seed (NCPA 2002), the estimated 29 million pounds of cottonseed oil used annually for PHOs would represent the oil output from 183,000 acres of cotton (74,000 ha). Altogether, the 2.53 billion pounds (1.1 million metric tons) of vegetable oil produced into PHOs is estimated to represent output (often as one of multiple products from the crop) from 5.7 million acres (230,000 ha) of U.S. cropland, or 1.7 percent of the cropland in the United States.

Potential effects of the Action on agricultural land use within the United States, including the potential for changes in the amount of farmland allocated to production of specific oil crops and livestock, are described below. These discussions are based on the detailed analysis of how the Action could affect U.S. agriculture that is presented in Appendix A.

Impacts on the use of U.S. land for other phases of the production, processing, and utilization of oils and fats (e.g., oilseed storage, oil extraction, and hydrogenation) as PHO replacements would be minimal and are not considered further. These activities use far less land than is used in agricultural production of the raw materials, and there would be little or no net change in the amount of processing associated with PHO replacements.

## 2.1.2 Potential Impacts of the Action

In response to the Action, PHOs in the U.S. food supply would be expected to be replaced by other types of oils and fats. The FDA estimates that under the Proposed Action 60 percent of PHOs would be replaced by various forms of vegetable oils, while 40 percent (about 1 billion pounds, or 450,000 metric tons) would be replaced by imported palm oils and fats from animal sources.

Replacement of 60% of PHOs with various other types and forms of vegetable oils would have little net effect on U.S. agricultural land use. Lands currently used for oil crops for conversion into PHOs would continue to produce oil crops. For example, the land currently used to grow soybeans that are processed into partially hydrogenated soybean oil could be converted to the equivalent production of high-oleic-acid soybeans. Because high-oleic-acid soybeans have the same yields as conventional soybeans and can reasonably be expected to have the same growing requirements (Anon 2014; Bauer 2013; Graef et al. 2009; Shannon 2011, 2013; USB 2014), there would be no net change in the total acreage or location of soybean production. Some replacement oils are projected to come from different crops than the oils that are currently processed into PHOs. However, because the food industry uses different oils and fats interchangeably—generally choosing the least expensive combination of raw materials that is compatible with the required quality (FAO 1994)—such shifts are unlikely to lead to significant changes in production of particular oil crops. If PHO replacement requires oil from a particular oil crop to be used in greater quantities than in the current mix of PHOs, it is likely that other vegetable oils would substitute for that type of oil in some of the existing uses of that type of oil.

The 40 percent of PHOs that would be replaced by palm oil and animal-derived fats are equivalent to the production from 2.0 million acres (0.81 million ha) of soybean cropland (about 2.5 percent of U.S. land currently in soybean production There could be some reduction in production of soybeans and other oil crops, but any such reductions are expected to be small. As discussed in more detail in Appendix A, any changes in land use for soybean production are expected to be small because demand for soybean oil is not the primary determinant of the value of the U.S. soybean crop. The production of soybean oil is secondary to the production of soybean meal, and most of the price of soybeans (54 to 72 percent) is based on the value of soybean meal. Accordingly, relatively few farmers would be motivated to shift land out of soybean production. Thus, any reduction in the amount of farmland allocated to soybeans (vs. other crops) would be minimal; the estimated reduction of 63,000 acres presented in Section A.7.2 is less than 0.1% of total soybean cropland in the United States. Similarly, corn oil and cottonseed oil are produced as secondary products or byproducts from corn and cotton production, and a reduction in demand for edible corn or cottonseed oil would not be a major determinant of the land area allocated to growing corn or cotton. U.S. production of sunflower and canola oils is unlikely to be affected by a reduction in domestic demand because (as indicated by data in Table A-1) exports (of sunflower oil) and imports (of canola oil) are major factors in the market for these oils.

Fats from meat animals would replace about 9 percent of PHOs, with 5 percent of the replacement fats (about 127 million pounds annually) estimated to be lard (from pigs) and 4 percent (about 101 million pounds annually) estimated to be tallow (primarily from beef cattle). For lard, the estimated consumption for PHO replacement is about 15 percent of total U.S. production of lard (815 to 875 million pounds per year, based on data discussed in Appendix A) and about 40 percent of U.S. production of edible lard (300 to 340 million pounds per year). The estimated consumption of tallow for PHO replacement is about 5 percent of U.S. production of edible tallow. This increased consumption of meat fats is not expected to lead to significant increases in land use for meat-animal production. Because the value of fat is a very small component of the value of a cow, pig, or other meat animal, an increase in demand for animal fat as a PHO substitute is unlikely to be an important factor in farmers' decisions to raise more animals. Increased demand for edible meat fats would not necessarily require more meat-animal production, as more edible fats could be produced by increasing the fraction of animal carcasses that are rendered into edible products. Additionally, because the food industry uses different oils and fats interchangeably—generally choosing the least expensive combination of raw materials that is compatible with the required quality (FAO 1994)—substitution of animal fat for some current uses of PHOs can be expected to result in other types of fats and oils (probably vegetable oils) being substituted in other existing uses of these products. Economic analysis presented in Section A.7 indicates that the projected increases in demand for lard and tallow could increase production of both pork and beef by about 0.03 percent. This is a very small change, and much smaller than the changes that are likely to occur independent of the FDA action. Independent of any increase in demand for animal fat resulting from the action, U.S. pork production is projected to increase about 15 percent and beef production is project to increase about 2.6 percent from the averages of 2012 to 2014 (USDA/OCE-WAOB 2014).

The FDA estimates that butter would be substituted for 1 percent of the current uses of PHOs. Similar to animal fats, the supply of butter is linked to the production of other dairy products Dairy producers may respond to increased demand for butter by measures such as changing herd composition (favoring breeds of cows that produce milk with higher butterfat content) and changing the pricing of dairy products (for example, increasing the prices of whole milk relative to low-fat milk products) in order to shift more butterfat into the production of butter. If increased demand for butter increases dairy production by 0.07% (or 6700 cows), as is indicated in Section A.7.2, there would be some increase in land use for dairy production and production of crops for cattle feed, but these increased would be small in the context of U.S. agricultural land use.

In summary, the action could lead to small decreases in land use for crop production and small increases in land use for livestock production, but these changes would be very small in the context of U.S. agricultural land use.

## 2.2 WATER RESOURCES

### 2.2.1 Overview

Water is used throughout the current production and utilization of PHOs for U.S. food, including growing of oil crops, extraction of oil from seeds, refining, hydrogenation, and production of the food products that incorporate PHOs. Agricultural production is the largest consumer of water in the production cycle.

The production of vegetable oil has been estimated to use a worldwide average of 2,240 $m^3$ of water per metric ton of product (537,000 gal/ton). The growing of oil crops accounts for more than 90 percent (Mekonnen and Hoekstra 2010) of this water use.[2] Most oil crops are watered only by natural rainfall (Mekonnen and Hoekstra 2010), but rainfall is supplemented by artificial irrigation on some U.S. oil crops. In 2008, 7.04 million acres (2.85 million ha) of U.S. soybeans [less than one-tenth of the 75.7 million acres (30.6 million ha) of soybeans planted that year] were under artificial irrigation, receiving an average of 0.7 ft (0.2 m) of applied irrigation water during the year (USDA/NASS 2009). Almost all of the land used for growing irrigated soybean crops was in the five states of Nebraska, Arkansas, Mississippi, Missouri, and Kansas.

Estimated water requirements for livestock production (from which animal fats are derived) are typically higher than for production of plant products, with the water used in growing animal feed accounting for more than 90 percent of the total water input to meat and dairy products such as butter (Mekonnen and Hoekstra 2010). Analysis by Mekonnen and Hoekstra (2010) indicates that it takes 1,300 $m^3$ (343,000 gal) of water, on average, to grow the food consumed annually by a single U.S. dairy cow.

Steps in the post-harvesting production of vegetable oils typically include drying, cleaning to remove foreign matter, dehulling, milling or grinding, heat treatment (cooking), extraction of oil by mechanical means and/or with a solvent such as hexane, and refining (FAO 1994, Mag undated). Refining processes may include steam distillation; treatment with water or aqueous solutions such as citric acid, phosphoric acid, and sodium hydroxide; bleaching with clay; filtration; and centrifugation (FAO 1994, Mag undated). Water is used in steam production, process cooling, and various refining processes (IFC 2007). Hydrogenation and other fat modification processes such as interesterification do not require much water in the process, but are carried out at high temperatures (FAO 1994, Mag undated), and therefore are likely to employ water for process cooling. In 1991, a California vegetable oil processing facility reported using 2,100 gals of water per ton (8.8 $m^3$ per metric ton) of product (Mannapperuma et al. 1993). This is equivalent to 2.7 billion gal (10 million $m^3$) for the entire 2.53 billion pounds (1.15 million metric tons) of PHOs currently estimated to be consumed in U.S. food each year.

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[2] Water use estimates attributed to Mekonnen and Hoekstra (2010) are based on the “green” (rainwater) and “blue” (surface water and groundwater) components in their analysis of water footprint.

Within the existing PHO supply chain, the production of oil crops is also estimated to be the largest source of impacts to water quality. Crop production affects water quality by releasing sediment to surface water and releasing fertilizer and pesticide runoff to surface water and groundwater. Leakage and spills of lubricating oils, solvents, and fuel from farming equipment and implements also can reach surface water and groundwater, adversely affecting water quality (EPA 2014c). In 2000, nonpoint-source pollution from agriculture was estimated to be the leading source of water quality impacts on U.S. rivers and lakes, the second largest source of impairments to wetlands, and a major contributor to contamination of estuaries and ground water (EPA 2014c). Effluents from vegetable oil processing and refining may contain organic material (producing biochemical and chemical oxygen demand), suspended solids, organic nitrogen, and oil and grease that could adversely affect water quality if they were discharged without treatment (IFC 2007). Effluents from these processes are typically sent to municipal wastewater treatment plants where they are commingled with other wastewaters for treatment. Experience indicates that such treatment is generally effective in controlling pollutants present in wastewaters from vegetable oil processing, particularly when pretreatment measures such as removal of oil and glycerin are used to improve treatability of the wastewater effluent (McDermott 1976, EPA 2008). Water quality impacts from these effluents are controlled through municipal wastewater treatment, with implementation of industrial pretreatment standards established under Clean Water Act regulations at 40 CFR Part 403 and categorical standards for corn mills in 40 CFR Part 406 (EPA 2008).

In the supply chain for edible animal-derived fats (including butter, lard, and tallow), production of feed crops for agricultural livestock production is probably the largest source of impacts to water quality, but dairy processing and meat processing are also potentially important sources of impacts. Water quality impacts from producing crops for animal feed are similar to the impacts from producing crops for vegetable oils. Additionally, agricultural livestock production is a source of animal wastes, including fecal and urinary wastes and process water (such as from a milking parlor). Feedlots and other concentrated animal feeding operations (CAFOs) have been a particular source of concern due to the large quantities of manure and wastewater produced at a single site, and the potential for release of pollutants such as nutrients, organic matter, sediments, pathogens, heavy metals, hormones, antibiotics, and ammonia (EPA 2000). Water quality impacts from CAFOs are subject to controls under Clean Water Act regulations at 40 CFR 122.23 and 40 CFR Part 412. Control of water quality impacts from croplands and smaller-scale livestock production operations is encouraged through pollution-prevention programs that are largely voluntary (EPA 2000, EPA 2014c).

Most butter is produced in dairy processing facilities that process milk into a variety of products (FPEAC 2014). Wastewaters from dairy processing facilities contain organic acids and other components that can produce high levels of biochemical and chemical oxygen demand (BOD and COD). These wastewaters also can have high levels of fats, suspended solids, and dissolved solids such as the nutrients nitrogen and phosphorus (DRINC 2014, FPEAC 2014, Rodenburg 1998). Biologically based treatment technologies are generally effective, although some dairy effluent streams can present special challenges in treatment (Rodenburg 1998). Like most vegetable oil processors, most U.S. dairy plants discharge their effluents to municipal wastewater treatment plants for treatment (DRINC 2014, Rodenburg 1998). Water quality impacts from these effluents are controlled through the implementation of industrial pretreatment standards established under 40 CFR Part 403 and categorical pretreatment standards for dairy processors in 40 CFR Part 405, including standards specifically for butter manufacturing (40 CFR 405, Subpart D).

Rendering to produce edible animal fats from meat byproducts is typically conducted in rendering plants operated in conjunction with meat packing plants (EPA 2004). Wastewater from rendering operations can include washwater from the frequent cleaning of equipment and facilities, as well as condensed steam from cooking meat byproducts to separate fats from proteins. Wastewaters from meat packing and rendering are highly variable, but can have high levels of BOD and COD, as well as high concentrations of pollutants such as nutrients, ammonia, and oil and grease (EPA 2004). Water quality impacts from effluents from rendering facilities and meat packing plants are controlled through Clean Water Act permitting and industrial pretreatment standards established under 40 CFR 403 and categorical pretreatment standards for meat and poultry producers in 40 CFR Part 432, including standards specifically for rendering plants (40 CFR 432, Subpart J).

The potential effects of the Action on water use and water quality within the United States are described below.

### 2.2.2 Potential Impacts of the Action

In response to the Action, PHOs in the U.S. food supply are expected to be replaced by other types of oils and fats.

The FDA estimates that the Action would result in about 60 percent of PHOs being replaced by various forms of vegetable oils, while 30 percent (about 1 billion pounds, or 450,000 metric tons) would be replaced by imported palm oils, and 10% would be replaced by fats from animal sources.

Minimal effects on water use and water quality from oil crop production would be expected from the replacement of 60% of PHOs with various other types and forms of vegetable oil. For the 60% of PHOs that are expected to be replaced with other forms of vegetable oil, irrigation of oil crops to produce the replacement oils would use essentially the same quantity of water that is used to produce oil crops that are currently processed into PHOs. If lands currently used to grow irrigated soybeans for processing into partially hydrogenated soybean oil were converted to production of high-oleic-acid soybeans, no change in the total acreage of irrigated soybean production would be expected, because high-oleic-acid soybeans have the same yields and can reasonably be expected to have the same water requirements as conventional soybeans (Anon 2014; Bauer 2013; Graef et al. 2009; Shannon et al. 2011, 2013; USB 2014). Conversions to different oil crops would be unlikely to change the quantity of water used in irrigation because irrigated croplands that have been planted in one crop (e.g., soybeans) would be expected to be shifted to another irrigated crop with similar water needs. Any reductions in total oilcrop acreage, including irrigated acreage, from replacing 40% of PHOs, would logically translated into a reduction in water use in the U.S., but as discussed in Section 2.1, any changes in land use for oil crop production would be very small.

Water quality impacts from oil crop production also can be reasonably expected to be essentially the same as under current conditions, primarily because the total area dedicated to oil crop production is unlikely to change and because cultivation, fertilization, and pesticide application practices would not be affected by conversion to high-oleic crops. Conversion to different oil crops could result in changes in practices that may affect water quality, but the water-quality impact of such a shift is judged to be minimal because relatively little acreage would be converted.

Replacement of PHOs would involve some changes in processing technology for vegetable oils. The principal changes in processing that would accompany the replacement of PHOs would be changes in fat modification processes, such as replacing hydrogenation with interesterification or fat blending. Because processes such as hydrogenation, interesterification, and fat blending use relatively little water, any changes in water consumption would be very small, but reductions are possible. In 2005, the U.S. Environmental Protection Agency (EPA) estimated that if an enzymatic interesterification process were to replace partial hydrogenation for processing of 10 billion pounds (4.5 MMT) of soybean oil, water consumption would be reduced by 60 million gal (227,000 m$^3$) annually (EPA 2005). If enzymatic interesterification were to replace hydrogenation for the 10 percent of PHOs (253 million pounds or 115,000 metric tons) that FDA estimates would be replaced by interestified fats, the annual reduction in water consumption would be 1.5 million gal (5,700 m$^3$). This reduction in water use would be a positive impact, but it is a vanishingly small fraction of total use of water by U.S. industry, which uses 10,000 times that amount of water every day (Maupin et al. 2014 reported estimated daily industrial water use as 15.9 billion gal, or 60 million m$^3$).

There would be some potential for decreased U.S. production of oil crops and increased meat production, but as discussed in Section 2.1.2, any changes are expected to be small, so there would be very little change in the impacts of these activities on water quantity and quality. As indicated in Section A.7.2, increased demand for butter could increase U.S. dairy production by 0.07%, or about 6,700 cows. Production of feed for these cows could consume 8.7 million m$^3$ (2.3 billion gal) of water, but actual impacts would be less because some or all of their food supply would come from oil crops that would otherwise have been used to produce PHOs. Impacts to water quality from dairy production would also increase by about

0.07%. The action would result in reductions in U.S. processing of oil crops and oils, thus reducing the quantity of water used and the effluents produced by these industrial activities. Because these processes use relatively little water and because their effluents are assumed to be treated effectively, the resulting impact on water supply and water quality in the United States would be small, but the impact would be positive.

## 2.3 AIR QUALITY

### 2.3.1 Overview

Potential impacts to air quality can be gauged against the airborne concentrations of pollutants regulated by the U.S. EPA under the Clean Air Act as part of the National Ambient Air Quality Standards (NAAQS) (EPA 2014a). The NAAQS have been established to serve as thresholds below which no deleterious impacts to air quality would be expected to occur from exposure to selected “criteria pollutants.” The six NAAQS criteria pollutants include sulfur oxides ($SO_x$), nitrogen oxides ($NO_x$), ozone ($O_3$), carbon monoxide (CO), lead (Pb), and two types of particulate matter (PM): particulate matter with a diameter equal to or less than 10 µm ($PM_{10}$) and particulate matter with a diameter equal to or less than 2.5 µm ($PM_{2.5}$).

### 2.3.2 Potential Impacts of the Action

In regard to the replacement of PHOs with other resources originating within the United States, the planting, harvesting, processing, and transportation of these replacements would require the same general type of equipment that is currently used for growing, harvesting, processing, and transportation of the fats and oils used in PHOs, including farm machinery, transport vehicles, and factory processing/production equipment. Each of these would generate pollutants, including criteria pollutants regulated under the NAAQS, that could affect local air quality.

Because there would be no net change in the amount of domestic oil crops raised for the PHO replacements, there would be little or no net change in the total amount of pollutant emissions from the current farming practices, production, processing and transport of the PHO replacement oils within the United States. Likewise, any emissions associated with the solvent hexane (which is often used in extracting vegetable oils from oilseeds) would be unaffected because domestic vegetable oil production would not be expected to change. Therefore, within the United States the air quality impacts of atmospheric emissions associated with the domestic production of the PHO replacements would be negligible.

As discussed in the introduction to Section 2, this analysis assumes that 30 percent of the PHO replacement would be in the form of palm oil and/or palm kernel oil imported into the United States from foreign sources. It is therefore assumed that 0.76 billion pounds (0.34 MMT) would be imported into the United States and, furthermore, that the preferred method of importation would be by ocean-going vessels. The exact types of vessels that might be used for the international shipments of palm/palm kernel oil cannot be accurately predicted; however, both container-type vessels and bulk-cargo vessels have previously been used for such shipments of edible oils[3]. According to data from the Food and Agriculture Organization of the United Nations (FAO), the cargo-carrying capacity of ocean-going vessels that transport bulk edible fats and oils ranges from 15,000 to 40,000 metric tons (16,540 to 41,400 U.S. tons) (see Section 3.1.2 in FAO 2011). The use of the smaller of these values will result in the maximum total number of shipments, thereby contributing to the conservatism of this current analysis. The 0.76 billion pounds (0.34 MMT) of palm/palm kernel oil would thus require 23 annual shipments using vessels with a 15,000-metric ton (16,540-U.S. ton) capacity[4].

According to statistics available from the U.S. Department of Agriculture (USDA) for 2011, the Port of New Orleans region in Louisiana and the Port of Savannah in Georgia received the majority of the palm oil and palm kernel oil imported into the United States (Taylor 2013). The data for these two ports and for these two commodities are shown in Table 1.

**Table 1. Selected U.S. Waterborne Agricultural Imports in 2011**

| | **Palm Oil** | | **Palm Kernel Oil** | |
|---|---|---|---|---|
| **Port** | **Quantity Imported through Port (metric tons)** | **Port's U.S. Share of Commodity** | **Quantity Imported through Port (metric tons)** | **Port's U.S. Share of Commodity** |
| Port of New Orleans Region, Louisiana | 258,104 | 49% | 78,998 | 36% |
| Port of Savannah, Georgia | 141,207 | 27% | 73,523 | 34% |

*Source*: Taylor (2013).

From the data in Table 1, it can be inferred that the total quantity of palm oil plus palm kernel oil imported into the United States in 2011 was approximately 742,710 metric tons (816,980 U.S. tons)[5]. The combined amount of palm oil plus palm kernel oil imported through the Port of New Orleans region would therefore be 45 percent of the U.S. combined total, and the

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[3] Container-type vessels would transport palm oil or palm kernel oil contained within a bladder which would, in turn, be placed inside a rectangular steel shipping container similar to those routinely transported over U.S. highways by tractor-trailer rigs. Bulk-cargo vessels would transport palm oil or palm kernel oil inside one or more large compartments located within the hull of the vessel.

[4] 23 annual shipments = 340,000 metric tons of palm/palm kernel oil ÷ 15,000 metric tons per vessel (note that the answer is rounded upward).

[5] The calculation is as follows: Total palm oil = 524,870 metric tons {= [(258,104 ÷ 0.49) + (141,207 ÷ 0.27)] ÷ 2}. Total palm kernel oil = 217,840 metric tons {= [(78,998 ÷ 0.36) + (73,523 ÷ 0.34)] ÷ 2}. Combined total palm oil plus palm kernel oil = 742,710 metric tons (= 524,870 + 217,840).

amount imported through the Port of Savannah would be 29 percent of the U.S. combined total[6].

As discussed previously, a total of 23 annual trans-ocean shipments would be required to import 30 percent of the PHO replacements. Therefore, a total of 11 shipments (= 23 × 0.45)[7] would be received each year at the Port of New Orleans region, and 7 shipments (= 23 × 0.29)[7] would be received annually at the Port of Savannah, if the U.S. share received at each port is the same as documented in the USDA statistics for 2011 (Taylor 2013). The remainder of the imported palm oil and palm kernel oil that would replace PHOs (i.e., 5 shipments annually) would be received at one or more other U.S. ports.

A summary of the number of ocean-going vessel calls made in 2011 to U.S. ports (DOT/MA 2013) is presented in Table 2, along with the number of shipments for the imported PHO replacements as computed in the preceding paragraph.

**Table 2. Shipping Activity at U.S. Ports in 2011 for Ocean-Going Vessels**

| Location/Port | Total Vessel Calls (number of vessels per year) [a] | Equivalent Shipping Capacity for PHO Replacement (number of vessels per year) | Percent of Total Vessel Calls |
|---|---|---|---|
| All U.S. Ports Combined | 68,036 | 23 | 0.03 % |
| Port of New Orleans | 2,942 | 11 | 0.4 % |
| Port of Savannah | 2,731 | 7 | 0.3 % |
| Remainder | 62,363 [b] | 5 [b] | 0.01 % |

[a] *Source:* DOT/MA 2013
[b] Calculated difference

The above cited USDA data also state that U.S. agricultural cargo totaled 187.2 MMT (206 million U.S. tons) in 2011 (Taylor 2013). The estimated 0.34 MMT (363,000 U.S. tons) of PHO replacements therefore represent a negligible fraction of this total agricultural cargo by weight (0.34 × 100 ÷ 187.2 = 0.2 percent). From the data in Table 1, the equivalent shipping capacity for PHO replacement is also a negligible fraction of the total number of annual vessel calls at U.S. ports (23 × 100 ÷ 68,036 = 0.03 percent) and would represent only 0.4 and 0.3 percent of the number of annual vessel calls at the ports of New Orleans and Savannah, respectively.

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[6] The calculations are as follows: Fraction imported through Port of New Orleans region = 45 percent [= 100 × (258,104 + 78,998) ÷ 742,710]. Fraction imported through Port of Savannah = 29 percent [= 100 × (141,207 + 73,523) ÷ 742,710].

[7] Note the result is rounded upward.

Because these small numbers of shipments for the PHO replacements would easily be subsumed within the existing near-port and trans-ocean traffic, the increase in emissions resulting from near-port harboring activities or ocean-going transit of vessels carrying palm/palm kernel oil would be insignificant. Given that there would be no significant increase in the number of vessels, there would be no need to alter existing port capacities, nor would there be any need for additional near-port activities solely as a result of the importation of 0.34 MMT (363,000 U.S. tons) of palm/palm kernel oil. Therefore, local air quality would not be affected at or near U.S. ports as a result of importing PHO replacements.

Based on the discussion in the preceding paragraphs, it can be concluded that no significant impacts to air quality would be expected to occur as a result of the FDA's declaratory order regarding PHOs.

## 2.4 WASTE MANAGEMENT

### 2.4.1 Overview

Wastes are generated throughout the production of fats and oils for human consumption and are managed by a variety of methods. None of the principal waste streams generated in these production processes require management as hazardous waste.

The main waste produced by farm production of oil crops is crop residue, such as plant stalks. Manure is a principal waste produced in raising farm animals from which animal fats are obtained. Agricultural wastes such as these are often managed on the farm, for example by leaving crop residues in place in the fields or by incorporating manure into the soil as a soil amendment. Seed hulls and other detritus produced from cleaning of oil seeds can be managed in a similar fashion. Waste palm kernels produced as a waste in the production of tropical oils can be burned for energy recovery in properly equipped facilities (IFC 2007).

Wastes generated in vegetable oil processing include spent acids, solvents, and soap stock produced in chemical refining processes; spent bleaching earth (clay) that may contain gums, metals, and pigments; deodorizer distillate from the steam distillation of refined oils; mucilage from degumming; and wastewater processing sludge (IFC 2007). These wastes are managed by a combination of methods, including land application as soil amendments (particularly for organic wastes), recycling, incineration or burning for energy recovery, and landfill disposal (IFC 2007).

Hydrogenation of vegetable oil to produce PHOs is a catalytic process that uses hydrogen gas and solid nickel-based catalysts (FAO 1994, Mag undated); spent catalyst is an important waste stream from hydrogenation that can be managed by recycling or disposal (IFC 2007). Interesterification, an alternative to hydrogenation, is typically accomplished through a catalytic process that uses a solid alkaline catalyst such as sodium methoxide, producing spent catalysts that may need to be managed as waste (FAO 1994, Mag undated). Newer, enzyme-based interesterification processes do not employ catalysts (EPA 2005), thus avoiding the generation of spent catalysts.

The principal solid wastes associated with production of lard and tallow are the residues from slaughtering animals, meat packing, and byproducts, including bone, hide, hair, and inedible viscera. Most such residues are recovered for use in products such as animal feed and fertilizer (EPA 2004). Only small amounts of solid waste are generated from dairy processing activities that produce butter and other milk products (FPEAC 2014).

### 2.4.2 Potential Impacts of the Action

In replacing PHOs with various forms of vegetable oils, imported palm oils and fats from animal sources there would be some potential for a redistribution of U.S. production of oil crops and meat and dairy production within each sector, but any changes are expected to be negligible, so there would be very little change in the impacts of these activities on waste management. Domestic farming activities and vegetable oil production would continue to generate the same kinds of wastes as are generated currently and as described in the preceding paragraphs.

Because the new crops that would replace PHOs generally require the same acreage and the same farming techniques as the existing PHO crops, and because the processing of the resulting oil would be the same, there would be little change in the generation of waste from these activities. However, the elimination of the partial hydrogenation step for 90 percent [i.e., 2.3 billion pounds (1.0 MMT)] of the 2.53 billion pounds (1.15 MMT) of vegetable oil currently processed as PHOs would avoid the generation of some spent nickel catalysts as a waste requiring recycling or disposal. EPA (2005) has estimated that if partial hydrogenation were to be replaced by enzymatic interesterification, there would be additional reductions in the generation of sodium methoxide, soap, and clay wastes. Using the EPA (2005) data, for 2.3 billion pounds (1.0 MMT) of oil annually, the estimated annual reductions in waste generation would be 4.6 million pounds (2080 metric tons) of sodium methoxide, 26 million pounds (12 MMT) of soaps, and 11 million pounds (5 MMT) of clay. Because the wastes generated under the Action would be similar to the wastes currently generated by the production and processing of PHOs, there would be no changes in waste management techniques. Overall, there would be small positive impacts to waste management.

Some new waste generation would be associated with the at-port receiving of imported palm oil and/or palm kernel oil, as well as with the transportation and processing of those oils for use in food products. Nevertheless, the resulting wastes would be similar to those generated by the current production, transportation, and processing of PHOs in the United States, although there might be some differences in specific characteristics and quantities.

Based on the discussion in the preceding paragraphs, it can be concluded that the FDA's declaratory order regarding PHOs could result in small positive impacts on waste management, but that no significant adverse impacts on waste management would be expected to occur.

## 2.5 TRANSPORTATION

### 2.5.1 Overview

Transportation in the United States involves the modes of highway, rail, air, and barge. Highway and rail transportation are the primary modes associated with the production, distribution, and use of PHOs in food products.

### 2.5.2 Potential Impacts of the Action

Under the FDA Action, specialized crops would be grown and harvested in the United States, and the oils from these crops and other domestically produced oils and fats would be processed into forms suitable for replacement of PHOs. These PHO replacements would require transport between producers, processors, and consumers. However, the impacts of any new transportation under the Action would be negligible because the new crops that would replace PHOs generally require the same types of transportation as the existing PHO crops.

Also under the Action, the transport of imported palm oil from U.S. ports to food processors, as well as the transport of products made from palm oil from processors to consumers, would replace a portion of the current quantities of PHOs and/or PHO products transported between producers, processors, and consumers. The transport routes for imported palm oil once it arrives in the United States would likely be different than for the current PHOs. However, because food processing occurs at many U.S. locations and because food is consumed throughout the United States, there would be little or no change in either the total amount of transportation or the methods of transportation under the Action.

Furthermore, there is currently no concentration of such transportation in any one geographic area of the United States. Additionally, any new transportation within the United States under the Action would be a small fraction of the total amount of the current transportation of all U.S. food ingredients and food products, as discussed below.

Data available from the Federal Motor Carrier Safety Administration indicate that in 2012, a total of 10,659,380 large trucks were registered in the United States, and these vehicles traveled a total of 268 billion miles (see Table 4 in FMCSA 2014). The Federal Railroad Administration reports that in 2013 the amount of rail traffic in the United States totaled 748.7 million miles (FRA 2014). The routes traveled by the above highway vehicles and railcars cross every state in the nation.

The number of vehicles (truck or railcar) and/or the number of miles traveled annually that are associated with PHOs is unknown; however, the fraction of the total number of U.S. vehicles, as well as the total number of U.S. miles traveled, in the preceding paragraph that are associated with the production, processing and distribution of PHOs is extremely small given the huge amount of all types of commerce in the United States (of which PHOs are only a very small part). Therefore, the impacts to overall U.S. truck and/or railcar traffic, as well as the impacts to the associated transportation infrastructure, under the Action, would also be extremely small.

Based on the above considerations, it is concluded that there would be no significant impacts to transportation as a result of the FDA's declaratory order regarding PHOs.

## 2.6 USE OF RESOURCES AND ENERGY

### 2.6.1 Overview

The manufacture and processing of PHOs and their replacements—as well as the production, processing, and transportation of food products that contain those items—requires resources (such as land, water, manpower, fertilizer, and equipment/machinery) and energy/fuel.

### 2.6.2 Potential Impacts of the Action

The domestic crops that would be grown to create PHO replacements under the FDA Action would require similar types and amounts of resources and energy/fuel as are required for the PHOs currently being produced and used. As discussed in Section 2.4, elimination of the hydrogenation step for the 2.53 billion pounds (1.15 MMT) of vegetable oil currently processed into PHOs would reduce the use of nickel catalysts, which would somewhat reduce demand for this metal. Additionally, EPA (2005) estimates that substituting enzymatic interesterification for hydrogenation would reduce the quantity of soybean oil that is currently lost in processing; for the 2.53 billion pounds (1.15 MMT) of oil currently processed into PHOs, the potential savings would be 101 million pounds (46,000 metric tons) of oil, or about 4 percent of the quantity of oil processed. These reductions in resource consumption would be positive impacts. Overall, however, there would be little change under the Action in the use of resources and energy/fuel related to the production of domestic crop and fats/oils in comparison with the current situation regarding PHOs in the United States (see Section 2.1 in regard to land use and Section 2.2 in regard to water usage).

For those PHOs in the U.S. food supply replaced by imported palm oil or palm kernel oil, there would be marginal reductions in crops grown in the United States (see Section 2.1); therefore, marginal reductions in the use of land, water, other resources, and energy/fuel in agricultural production would be expected to occur. There would, however, be reductions in U.S. processing of oil crops and oils, which would cause commensurate reductions in the use of energy and other resources in these industrial processing activities.

The use of resources and energy/fuel would be associated with the transportation of palm oil and/or palm kernel oil from ports to processing facilities and with the manufacture of food products and the transportation of those products to consumers; however, there would be little net change in the use of such resources and energy because of the similarity of the activities associated with imported tropical oils in comparison with the current situation regarding PHOs produced in the United States.

Based on the discussion in the preceding paragraphs, it can be concluded that no significant impacts from the use of resources and/or energy would be expected to occur as a result of the FDA's declaratory order regarding PHOs.

## 2.7 CUMULATIVE IMPACTS

This impacts analysis includes consideration of the potential cumulative impacts of the FDA's declaratory order regarding PHOs. Cumulative impacts may result when the environmental effects of the Action are added to or overlaid upon the effects associated with other past, present, and reasonably foreseeable future activities in the same project area. Cumulative impacts can result from individually minor, but collectively significant, actions taking place over a period of time.

A principal source of potential environmental impacts of the Action within the United States, as identified in the previous sections, is the potential for changes in the amount of farmland allocated to soybeans (vs. other crops) and related changes in farming practices. Impacts of any such changes resulting from the Action would be combined with the impacts of other trends in crop selection and farming practices in the United States that occur in response to economics, introduction of new agricultural technologies, and other factors. For example, if projected improvements in soybean yield in the coming decades (see Table A-6 in Appendix A of this report) are not accompanied by an increase in demand, the crop yield improvements could result in reductions in U.S. soybean acreage comparable in magnitude to the reduction that might occur as a result of the Action. The cumulative effect from such changes would be small in the overall context of U.S. agriculture [i.e., the 4 million acres (1.6 million ha) of soybeans that are currently grown to produce PHOs is a very small fraction (i.e., about 0.4 percent) of the approximately 943 million acres (382 million ha) of land currently in agricultural use in the United States (EPA 2013)]; hence, such cumulative effects would not be considered significant.

Under the Action, cumulative impacts on air quality could occur in port cities that receive increased shipping activity related to increased importation of tropical oils. However, as discussed in Section 2.3, the increase in atmospheric emissions resulting from near-port harboring activities or ocean-going transit of vessels carrying palm oil and/or palm kernel oil would be insignificant and would, therefore, not make a meaningful addition to the cumulative impact to air quality in or near any U.S. port.

It is concluded that cumulative impacts within the United States occurring as a result of the FDA’s declaratory order regarding PHOs would not be significant.

# 3. REFERENCES

21 CFR (Code of Federal Regulations) Part 25; Food and Drug Administration, Department of Health and Human Services, Environmental Impact Considerations

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40 CFR (Code of Federal Regulations) Part 63; Environmental Protection Agency; Subchapter C—Air Programs: National Emission Standards for Hazardous Air Pollutants for Source Categories.

40 CFR (Code of Federal Regulations) Part 122; Environmental Protection Agency; EPA Administered Permit Programs: The National Pollutant Discharge Elimination System, Subpart B: Permit Application and Special NPDES Program Requirements, §122.23 Concentrated animal feeding operations.

40 CFR (Code of Federal Regulations) Part 403; Environmental Protection Agency; General Pretreatment Regulations for Existing and New Sources of Pollution.

40 CFR (Code of Federal Regulations) Part 405; Environmental Protection Agency; Effluent Guidelines and Standards for Dairy Products Processing Point Source Category.

40 CFR (Code of Federal Regulations) Part 406; Environmental Protection Agency; Effluent Guidelines and Standards for Grain Mills Point Source Category.

40 CFR (Code of Federal Regulations) Part 412; Effluent Guidelines and Standards for Concentrated Animal Feeding Operations (CAFO) Point Source Category.

40 CFR (Code of Federal Regulations) Part 432; Environmental Protection Agency; Effluent Guidelines and Standards for Meat Products Point Source Category.

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# APPENDIX A
# AGRICULTURAL ANALYSIS

This agricultural analysis has been prepared to investigate the options, economic costs, and potential impacts of replacing PHOs with other substances. In comparing options for replacing PHOs, one wants to look at health effects, costs and impacts.

## A.1 BACKGROUND

According to the United Soybean Board (USB 2013), because of growing consumer concerns about *trans* fats and the labeling regulations that went into effect in 2006, soybean oil has lost four billion pounds of market share. Domestic consumption (use) of soybean oil peaked in 2006 at 18.6 billion pounds, then decreased to 15.8 billion pounds in 2009 until returning to between 18.3 to 18.7 billion pounds in 2011 to 2013 (Table A-1). If one excludes the use of soybean oil to produce biodiesel (methyl esters), a nonfood use, then consumption peaked in 2002 at 17.1 billion pounds and was 13.6 billion pounds in 2013 (Table A-1). As this decline in consumption of (nonfuel) soybean oil has occurred, consumption of canola oil, palm oil, palm kernel oil, and corn oil have increased. Over all consumption of vegetable oils and fats has increased while the nonfuel consumption of soybean oil has decreased. Over half of the canola oil used by the U.S. food industry is high-oleic-acid canola oil (U.S. Canola Association 2013).

Eckel et al. (2007) estimated that partially hydrogenated oil comprised 35.5% (9.00 billion pounds), out of a total of 25.36 billion pounds of edible oils consumed in North America in 2006 (Table A-2). Eckel et al.'s estimate is based on edible oil consumption data from the Oil World Annual 2006 (ISTA Miekel GmbH 2006) and the percentage of each oil that was partially hydrogenated based on proprietary information from Dow AgroSciences.

It is estimated that 2.532 billion pounds of partially hydrogenated soybean, canola, corn, cottonseed, sunflower, peanut and palm kernel oil were used in the United States in 2012 (Table A-2). This estimate is based on the estimate made by Eckel at al. (2007) and the estimate QUALISOY (2013) made that 2 billion pounds of soybean oil was partially hydrogenated in 2012. The methodology used follows.

The North American vegetable oils consumption data used by Eckel et al. are similar to U.S. vegetable oil consumption reported for the same year by USDA/ERS (2014m). Therefore North American consumption trends developed using data from Eckel, et al. 2007 may be used to estimate U.S. consumption trends. For 2012, the only quantity of partially hydrogenated vegetable oil known is for soybean oil from QUALISOY. According to Eckel, et al., in 2006, 7.431 billion pounds of soybean oil was partially hydrogenated (see Table A-

2). This represents 83 percent of all partially hydrogenated oils.[1] In 2012, the amount of soybean oil, as reported by QUALISOY, that was partially hydrogenated was 2.0 billion pounds. This is 26.9 percent that of 2006.[2] Thus for oils other than soybean, it is assumed that the fraction of oil that is partially hydrogenated in 2012 is 26.9 percent of the fraction partially hydrogenated in 2006; and that this reduction in partially hydrogenated oils is the same as it is for soybean oil. For example, in 2006, 36.1 percent of the corn oil was partially hydrogenated, and in 2012, 26.9 percent of this fraction, or 9.7 percent. The estimated quantity of each oil that was partially hydrogenated in 2012 is shown in the last column of Table A-2, and the total for all the oils is 2.532 billion pounds.

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[1] 7.43 billion pounds soybean oil hydrogenated in 2006 ÷ 9.00 billion pounds oil from all sources hydrogenated in 2006 x 100; see Table A-2

[2] 2.0 billion pounds soybean oil hydrogenated in 2012 ÷ 7.431 billion pounds soybean oil hydrogenated in 2006 x 100; see Table A-2.

## Table A-1. Edible oil and fat use, import, and production in the United States (marketing year starting October, except peanuts starting August)
## (million pounds)

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Domestic use** | | | | | | | | | | | | | | |
| Coconut | 1,021 | 927 | 983 | 1,119 | 860 | 870 | 806 | 1,116 | 1,000 | 1,121 | 943 | 1,154 | 1,186 | 1,125 |
| Corn | 1,630 | 1,363 | 1,615 | 1,662 | 1,653 | 1,685 | 1,832 | 1,756 | 1,568 | 1,895 | 1,670 | 2,127 | 2,200 | 2,345 |
| Cottonseed | 672 | 780 | 639 | 691 | 935 | 860 | 714 | 623 | 502 | 552 | 600 | 572 | 599 | 420 |
| Lard | 630 | 663 | 638 | 556 | 614 | 720 | 732 | 799 | 780 | 791 | 790 | 821 | 820 | 815 |
| Olive | 458 | 474 | 477 | 534 | 536 | 516 | 559 | 579 | 603 | 590 | 641 | 697 | 647 | 669 |
| Palm | 262 | 330 | 385 | 471 | 378 | 515 | 722 | 1,244 | 1,461 | 2,090 | 2,116 | 2,267 | 2,734 | 2,945 |
| Palm kernel | 387 | 416 | 256 | 369 | 521 | 568 | 500 | 529 | 639 | 521 | 735 | 672 | 604 | 648 |
| Peanut | 244 | 260 | 269 | 250 | 210 | 260 | 274 | 219 | 194 | 199 | 226 | 218 | 200 | 245 |
| Canola | 1,862 | 1,542 | 1,333 | 1,567 | 1,660 | 1,919 | 1,985 | 2,923 | 2,833 | 2,854 | 3,669 | 3,851 | 3,554 | 4,297 |
| Safflower | 111 | 87 | 75 | 94 | 103 | 88 | 89 | 89 | 77 | 74 | 82 | 72 | 71 | 85 |
| Sesame | 17 | 20 | 21 | 22 | 24 | 20 | 24 | 27 | 22 | 30 | 26 | 25 | 28 | 29 |
| Soybean | 16,318 | 16,833 | 17,083 | 16,864 | 17,439 | 17,959 | 18,574 | 18,335 | 16,265 | 15,814 | 16,794 | 18,311 | 18,686 | 18,550 |
| Soybean minus methyl esters | 16,318 | 16,833 | 17,083 | 16,727 | 16,994 | 16,404 | 15,813 | 15,090 | 14,244 | 14,134 | 14,057 | 13,437 | 14,069 | 13,650 |
| Sunflower | 339 | 401 | 238 | 357 | 224 | 339 | 590 | 600 | 436 | 592 | 535 | 461 | 439 | 409 |
| Tallow, edible | 1,449 | 1,488 | 1,585 | 1,518 | 1,528 | 1,567 | 1,477 | 1,565 | 1,681 | 1,681 | 1,902 | 1,962 | 1,922 | 1,880 |
| ***Total usage*** | ***25,399*** | ***25,584*** | ***25,598*** | ***26,074*** | ***26,685*** | ***27,885*** | ***28,879*** | ***30,403*** | ***28,060*** | ***28,804*** | ***30,728*** | ***33,208*** | ***33,690*** | ***34,462*** |
| | | | | | | | | | | | | | | |
| **Net imports** | | | | | | | | | | | | | | |
| Coconut | 1,101 | 1,085 | 855 | 784 | 920 | 1,096 | 900 | 1,173 | 950 | 1,321 | 1,063 | 1,136 | 1,186 | 1,125 |
| Corn | -923 | -1,111 | -823 | -701 | -740 | -754 | -750 | -724 | -770 | -737 | -744 | -958 | -965 | -955 |
| Cottonseed | -131 | -150 | -89 | -111 | -55 | -66 | -137 | -186 | -192 | -94 | -163 | -248 | -201 | -210 |
| Lard | -90 | -83 | -107 | -217 | -160 | -67 | -71 | -69 | -71 | -53 | -57 | -52 | -47 | -60 |
| Olive | 456 | 472 | 475 | 529 | 532 | 510 | 557 | 574 | 598 | 584 | 633 | 688 | 638 | 661 |
| Palm | 398 | 471 | 382 | 619 | 767 | 1,311 | 1,545 | 2,095 | 2,278 | 2,187 | 2,157 | 2,273 | 2,831 | 2,998 |
| Palm kernel | 353 | 305 | 479 | 566 | 509 | 517 | 639 | 473 | 651 | 617 | 587 | 637 | 542 | 595 |
| Peanut 2/ | 65 | 30 | 28 | 99 | 45 | 54 | 94 | 63 | 45 | 62 | 44 | 13 | -3 | 40 |
| Canola | 1,006 | 853 | 821 | 945 | 865 | 1,126 | 938 | 1,892 | 1,766 | 1,798 | 2,620 | 2,625 | 2,285 | 2,952 |
| Safflower | 6 | -6 | -5 | -1 | 17 | 16 | 21 | 24 | -6 | -11 | 14 | 22 | 23 | 29 |
| Sesame | 17 | 20 | 21 | 22 | 24 | 20 | 24 | 27 | 22 | 30 | 26 | 25 | 28 | 29 |
| Soybean | -1,328 | -2,473 | -2,217 | -630 | -1,297 | -1,118 | -1,839 | -2,846 | -2,104 | -3,256 | -3,074 | -1,315 | -1,969 | -1,300 |
| Sunflower | -537 | -417 | -53 | -211 | -50 | -154 | -14 | -66 | -133 | -166 | 19 | 122 | 7 | 30 |
| Tallow, edible | -306 | -468 | -481 | -268 | -303 | -253 | -329 | -220 | -149 | -155 | -117 | -94 | -133 | -85 |
| ***Total*** | ***86*** | ***-1,474*** | ***-714*** | ***1,426*** | ***1,073*** | ***2,239*** | ***1,578*** | ***2,212*** | ***2,886*** | ***2,125*** | ***3,010*** | ***4,872*** | ***4,222*** | ***5,849*** |

## Table A-1. (continued)

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Production** | | | | | | | | | | | | | | |
| Corn | 2,403 | 2,461 | 2,453 | 2,396 | 2,396 | 2,483 | 2,560 | 2,507 | 2,418 | 2,485 | 2,515 | 3,010 | 3,165 | 3,300 |
| Cottonseed | 847 | 876 | 725 | 874 | 957 | 951 | 849 | 856 | 669 | 617 | 835 | 755 | 800 | 630 |
| Lard | 716 | 743 | 744 | 775 | 776 | 785 | 801 | 876 | 864 | 835 | 850 | 868 | 867 | 875 |
| Olive | 2 | 2 | 2 | 4 | 4 | 7 | 2 | 4 | 4 | 7 | 9 | 9 | 9 | 9 |
| Peanut | 179 | 231 | 286 | 173 | 126 | 181 | 166 | 158 | 143 | 140 | 190 | 188 | 211 | 205 |
| Canola | 759 | 631 | 535 | 638 | 832 | 928 | 932 | 1,015 | 1,105 | 1,078 | 1,154 | 1,115 | 1,221 | 1,430 |
| Safflower | 91 | 81 | 83 | 108 | 73 | 76 | 71 | 69 | 87 | 81 | 67 | 49 | 49 | 57 |
| Soybean | 18,420 | 18,898 | 18,430 | 17,080 | 19,360 | 20,387 | 20,489 | 20,580 | 18,745 | 19,615 | 18,888 | 19,740 | 19,820 | 19,720 |
| Sunflower | 855 | 704 | 295 | 581 | 256 | 524 | 610 | 632 | 653 | 731 | 493 | 329 | 432 | 379 |
| Tallow, edible | 1,764 | 1,932 | 2,068 | 1,781 | 1,833 | 1,833 | 1,798 | 1,789 | 1,846 | 1,821 | 2,021 | 2,051 | 2,054 | 1,965 |
| ***Total production*** | ***26,036*** | ***26,560*** | ***25,621*** | ***24,411*** | ***26,613*** | ***28,155*** | ***28,279*** | ***28,487*** | ***26,534*** | ***27,410*** | ***27,021*** | ***28,114*** | ***28,628*** | ***28,570*** |
| Methyl Ester | | | | | | | | | | | | | | |
| Corn | | | | | | | | | | 102 | 261 | 575 | 918 | 662 |
| Canola | | | | | | | | | | 475 | 645 | 964 | 429 | 487 |
| Soybean | | | | 137 | 445 | 1555 | 2761 | 3245 | 2021 | 1680 | 2737 | 4874 | 4617 | 4900 |
| Net production for food | | | | | | | | | | | | | | |
| Corn | | | | | | | | | | 2,383 | 2,254 | 2,435 | 2,247 | 2,638 |
| Canola | | | | | | | | | | 603 | 509 | 151 | 792 | 943 |
| Soybean | | | | 16,943 | 18,915 | 18,832 | 17,728 | 17,335 | 16,724 | 17,935 | 16,151 | 14,866 | 15,203 | 14,820 |

*Source*: USDA/ERS (2014n), for corn and canola used for methyl esters USDOE/EIA (2014)

**Table A-2. Consumption of partially hydrogenated oil 2006 and 2012**

| | Vegetable oil consumed | | Partially hydrogenated | | Vegetable oil consumed | Partially hydrogenated | |
|---|---|---|---|---|---|---|---|
| | Bil lb | Bil lb | Fraction | Bil lb | Bil lb | Fraction | Bil lb |
| | Eckel[a] | USDA[b] | Eckel[a] | Eckel[a] | USDA[b] | Estimated | |
| **Type of Oil** | Year | | | | | | |
| | 2006 | 2006 | 2006 | 2006 | 2012 | 2012 | 2012 |
| Soybean | 17.820 | 18.574 | 0.417 | 7.431 | 18.686 | 0.107 | 2.000[c] |
| Canola | 2.609 | 1.985 | 0.267 | 0.697 | 3.554 | 0.072 | 0.255 |
| Corn | 1.722 | 1.832 | 0.361 | 0.622 | 2.200 | 0.097 | 0.214 |
| Coconut | 0.895 | 0.806 | 0 | 0 | 1.186 | 0 | 0 |
| Cottonseed | 0.695 | 0.714 | 0.177 | 0.123 | 0.599 | 0.048 | 0.029 |
| Palm kernel | 0.529 | 0.500 | 0.004 | 0.002 | 0.604 | 0.001 | 0.001 |
| Palm | 0.434 | 0.722 | 0 | 0 | 2.734 | 0 | 0 |
| Sunflower | 0.423 | 0.590 | 0.235 | 0.099 | 0.439 | 0.063 | 0.028 |
| Peanut | 0.233 | 0.274 | 0.116 | 0.027 | 0.200 | 0.031 | 0.006 |
| ***Total*** | ***25.360*** | ***25.997*** | | ***9.001*** | ***30.202*** | | ***2.532*** |

[a] Eckel = Eckel at al. (2007)

[b] USDA = USDA/ERS (2014n) (see Table A-1)

[c] QUALISOY (2013)

## A.2 SOURCES OF VEGETABLE OILS, FATS, OR OTHER OIL PROCESSING METHODS FOR USE AS PHO REPLACEMENTS

Vegetable oils are made up of a variety of fatty acids: saturated, monounsaturated, and polyunsaturated. The fatty acid profiles vary among fats and oils (Table A-3). Saturation is a measure of the number of carbon double bonds in the fatty acid molecule. Saturated fats have no carbon double bonds, monounsaturated fats have one carbon double bond, and polyunsaturated fats have more than one carbon double bond. The most prevalent fatty acids in vegetable oils include: palmitic (16:0), stearic (18:0), oleic (18:1), linoleic (18:2) and linolenic acid (18:3), where the first number in parentheses indicates the number of carbon atoms in a fatty acid and the second number indicates the number of carbon double bonds.

Vegetable oils containing unsaturated fatty acids, and in particular, linolenic acid (18:3), are prone to oxidation, which leads to rancidity. Some vegetable oils are partially hydrogenated to improve their stability, resistance to oxidation, and shelf life and to raise the melting temperature of the vegetable oil for use in certain cooking, frying, and baking applications. Generally the more saturated fats an oil contains, the more solid the fat will be at room temperature. Hydrogenation converts oils into solid or semisolid fats and allows them to be used in the manufacture of shortenings and margarine.

### Table A-3. Fatty acid profiles of fats and oils (percentage)

| | Type of fatty acid | | | |
|---|---|---|---|---|
| | Saturated | Monounsaturated | Polyunsaturated | Linolenic[a] |
| Beef tallow | 49.8 | 41.8 | 4.0 | 0.6 |
| Butter | 51.4 | 21.0 | 3.0 | 0.3 |
| Canola | 7.4 | 62.3 | 28.1 | 9.1 |
| Canola, high-oleic | 6.8 | 72.7 | 15.8 | 2.4 |
| Coconut | 86.5 | 5.8 | 1.8 | 0 |
| Corn | 12.9 | 27.6 | 54.7 | 1.2 |
| Cottonseed | 25.9 | 17.8 | 51.9 | 0.2 |
| Lard | 39.2 | 45.1 | 11.2 | 1.0 |
| Palm | 49.3 | 37.0 | 9.3 | 0.2 |
| Palm kernel | 81.5 | 11.4 | 1.6 | 0 |
| Peanut | 16.9 | 46.2 | 32.0 | 0 |
| Soybean | 15.6 | 22.8 | 57.7 | 6.8 |
| Sunflower, high-linoleic | 10.3 | 19.5 | 65.7 | 0 |
| Sunflower, high-oleic | 9.9 | 83.7 | 3.8 | 0.2 |

[a] Linolenic acid is one of a number of polyunsaturated fats
*Source:* USDA (2014)

As described earlier, soybean oil is the most widely used vegetable oil in the United States. Traditional soybean oil is high in polyunsaturated fats (58 percent, including 7 percent as linolenic acid), which is why for certain uses it is partially hydrogenated.

Fats and oils that are suitable to replace partially hydrogenated oils are those that are low in polyunsaturated fats and in particular, linolenic acid (18:3). These include: animal fats (beef tallow, butter, and lard), tropical oils (coconut, palm, and palm kernel oils), and certain domestically produced oils (high-oleic canola, peanut, high-oleic/low linolenic soybean, and high-oleic sunflower).

Fats and oils for human consumption can be divided into three categories: salad and cooking oils, frying oils, and solid fats. PHOs are not known to be used for salad and cooking oils. For frying oils fatty acid composition typically includes 20 to 30 percent linoleic acid (to produce fried food flavor), 50 to 65 percent oleic acid, and less than 3 percent linolenic acid. Possible alternatives to PHOs for commercial frying include naturally stable oils including corn, cottonseed, palm, and peanut oils, and modified fatty acid oils including high-oleic/low-linolenic canola, mid-oleic corn, low-linolenic soybean, mid-oleic/low-linolenic soybean, high-oleic sunflower and mid-oleic sunflower oils. For solid fats (spreads and shortenings), PHOs have been effective in meeting the functionality (melting point, lubricity, moisture, and creaming ability) and stability requirements, but to meet these requirements, current replacement options for PHOs have often increased saturated fatty acids. There are *trans* fat-free options for margarines and shortenings (Eckel et al. 2007).

There are a number of strategies for replacing PHOs (see Table A-4). It is likely that a combination of a number of these replacement strategies will be utilized to replace PHOs. Possible replacements for PHOs include stable nontropical oils (e.g. corn, cottonseed oils). Corn oil production is increasing as corn-to-ethanol facilities install front-end corn oil extraction technology. Tropical oils (e.g. palm, coconut, palm kernel oils) are another possibility, but are high in saturated fats and coconut oil is at a price disadvantage to other oils. Animal fats such as lard and tallow are available but are produced as by-products from meat production and have limited scope for increased production. Prices of animal fat are relatively favorable. Modified oilseeds are considered a good possibility to replace PHOs and to some extent have already done so (e.g. high-oleic/low-linolenic canola oil). Blends of hard (high in saturated fats) and soft oils (e.g. soybean, canola oil) and fractionated tropical oils are possibilities. The hydrogenation process might be changed to produce less *trans* fats. Interesterification is an alternative that can be used to modify oils to obtain desired melting profiles and physical characteristics (Eckel et al. 2014).

**Table A-4. Sources of replacements for the use of partially hydrogenated oils (adapted from Eckel et al., 2007)**

| Strategy/Use of | Description | Examples | Advantages | Disadvantages |
|---|---|---|---|---|
| Stable nontropical oils | Oils naturally low in linolenic acid (18:3) | Corn oil<br>Cottonseed oil | Functionality<br>Increasing supply of corn oil | Limited supply of cottonseed oil |
| Tropical oils | | Palm oil<br>Palm kernel oil<br>Coconut oil | Price Functionality<br>Availability<br>User experience | High in saturated fats<br>Availability<br>Price of coconut oil |
| Animal fats and tallow | Fats from animals | Beef tallow<br>Lard<br>Butter | Functionality<br>User experience<br>Price of tallow, lard | High in saturated fats<br>Price of butter |

## Table A-4. (Continued)

| Alternative | Description | Examples | Advantages | Disadvantages |
|---|---|---|---|---|
| Modified oilseeds | Oil seeds that produce stable oils without hydrogenation | High-oleic soybean, sunflower, canola oils;<br>Mid-oleic soybean, sunflower oils;<br>Low-linolenic soybean and canola oils | Acceptable for frying | Some are new and still limited availability;<br>Cost of improved varieties |
| Modified hydrogenation process | Increase pressure, decrease temperature and/or change catalyst | Company-specific products | Reduce amount of *trans* fats (<11%)[b] | Extremely high pressures and concentrations of catalysts can reduce commercial viability |
| Blends of hard and liquid oils | Blending fully hydrogenated oils, or tropical oils with liquid vegetable oils | Company-specific products, | Can be formulated to provide differing fatty acid compositions and melting profiles;<br>Various combinations can be used for frying or baking | May be high in saturated fats |
| Fractionation of tropical fats | Separating tropical oils into hard fractions for use in margarine and shortening | Company-specific products | Different fractions have different solid fats and melting point curves | High in saturated fat |

**Table A-4. (Continued)**

| | | | | |
|---|---|---|---|---|
| Interesterification | Blend a liquid (e.g. soybean oil) and a hard feed (e.g. palm kernel oil, solid fraction of palm oil) together and treated with an excess of glycerol in the presence of a catalyst (chemical or enzymatic), producing fats with differing melting profiles and physical characteristics | Company-specific products | Does not change degree of unsaturation<br>Does not convert *cis* in *trans* fats<br>Enzymatic catalyst provides better functionality and few unidentified byproducts | Expense of enzymes |

[a] Bunge Oils Inc. (2013)
[b] Tarrago-Trani et al (2006)
*Source*: Adapted from Eckel et al. (2007)

## A.3 REPLACEMENT OILS AND FATS – PRODUCTION

There are a number of vegetable oils and fats that could be substituted for traditional soybean oil. The major world vegetable oils with their quantities produced are shown in Table A-5. As can also be seen in Table A-5, the 2.53 billion pounds of partially hydrogenated vegetable oils currently used in the United States represents less than 1 percent (0.007) of the total USDA Economic Research Service (USDA/ERS) forecast 2013/14 world vegetable oil production and is equivalent to, or greater than, 16 percent of world production of coconut (32.4 percent), cottonseed (22.5 percent), olive (35.0 percent), palm kernel (16.7 percent), and peanut (20.2 percent) oils. The 2.53 billion pounds represents less than 8 percent of the production of rapeseed (canola) (4.5 percent) and sunflower (7.3 percent) oils and 2.6 percent or less of the production of palm (2.0 percent) and soybean (2.6 percent) oils.

Soybean oil accounts for about two-thirds of U.S. production of oils and fats (Figure A-1). Individually, production of other oil crops and fats are small relative to soybeans. Some oils are imported, such as palm oil, coconut oil, and canola, in quantities greater than 1 billion pounds (Table A-1).

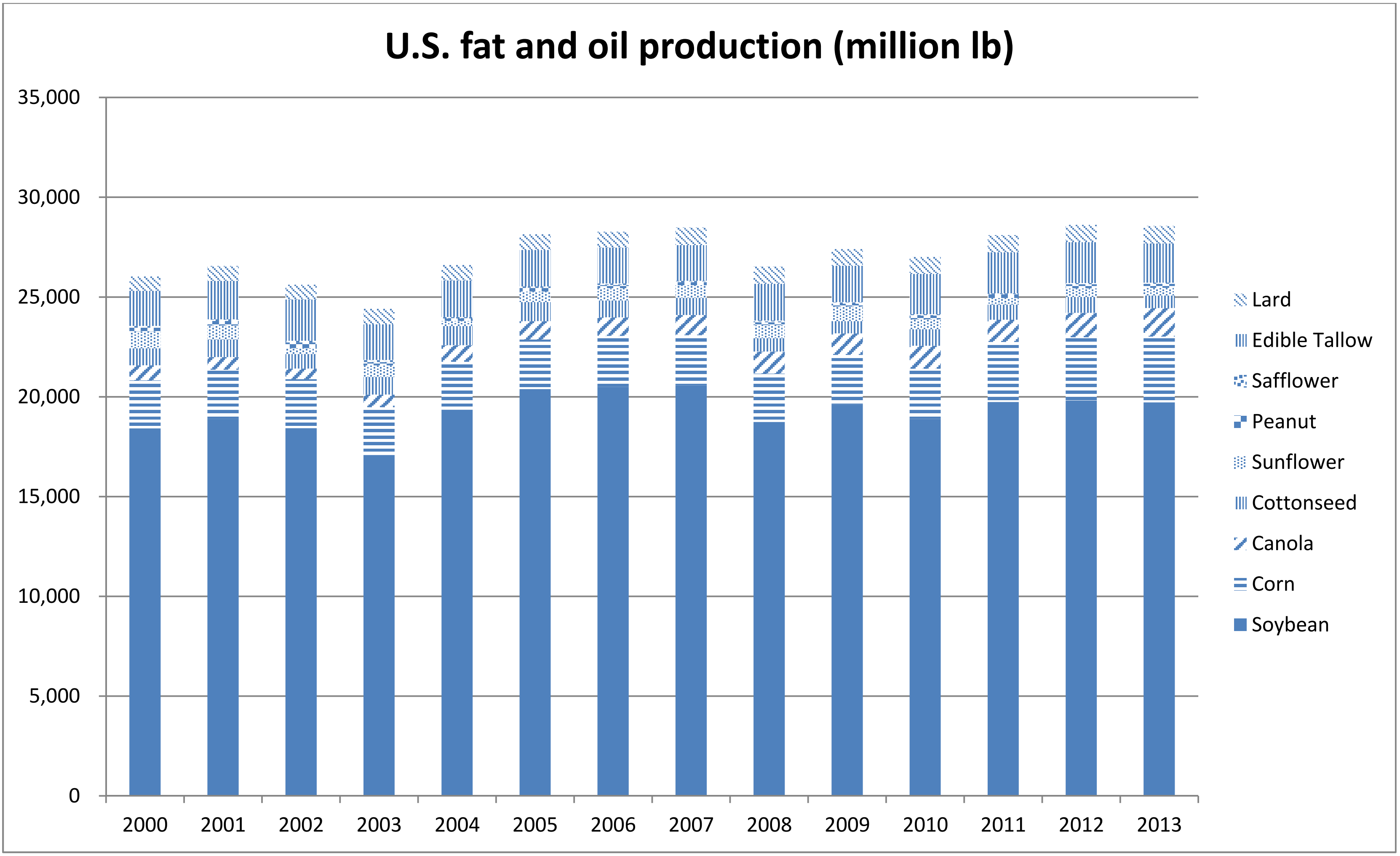

**Figure A-1. U.S. vegetable oil and fat production 2000-2013 (year beginning October 1, except peanuts beginning August 1)**

*Source*: USDA/ERS (2014n)

**Table A-5. World vegetable oil production (billion pounds)**

| Type of Oil | Year |  |  |  |  | 2.532 billion lb as fraction of 2013/14 |
|---|---|---|---|---|---|---|
|  | 2009/10 | 2010/11 | 2011/12 | 2012/13[a] | 2013/14[b] |  |
| Coconut | 7.76 | 8.16 | 7.52 | 8.05 | 7.80 | 0.324 |
| Cottonseed | 10.12 | 10.93 | 11.57 | 11.62 | 11.27 | 0.225 |
| Olive | 6.79 | 7.16 | 7.14 | 5.89 | 7.23 | 0.350 |
| Palm | 101.50 | 107.43 | 114.53 | 122.95 | 128.81 | 0.020 |
| Palm kernel | 12.35 | 12.63 | 13.54 | 14.35 | 15.12 | 0.167 |
| Peanut | 10.78 | 11.75 | 11.73 | 12.24 | 12.50 | 0.202 |
| Rapeseed | 49.74 | 51.85 | 53.40 | 54.89 | 56.79 | 0.045 |
| Soybean | 85.54 | 91.05 | 93.89 | 94.38 | 98.46 | 0.026 |
| Sunflower | 27.07 | 27.38 | 33.82 | 29.83 | 34.55 | 0.073 |
| ***Total*** | ***311.64*** | ***328.35*** | ***347.14*** | ***354.19*** | ***372.53*** | ***0.007*** |

[a] Preliminary
[b] Forecast
*Source:* USDA/ERS (2014n)

In Table A-1 historic data, from 2000/01 to 2013/14, on domestic use, domestic production, and net imports are shown. Net imports are imports minus exports. A minus sign indicates that the United States was a net exporter of an oil. For example, in 2013 the United States produced 19.7 billion pounds of soybean oil, consumed domestically (domestic use) 18.6 billion pounds, and was a net exporter of 1.3 billion pounds. The net import number is used because the United States exports and import quantities of many oils. For example, in 2013/14 the United States imported 0.2 billion pounds of soybean oil and exported 1.5 billion pounds of soybean oil, for net exports of 1.3 billion pounds (or net imports of -1.3 billion pounds). The United States actually exported 165,000, 300,000, and 75,000 pounds of coconut, palm, and palm kernel oil, respectively, in 2013, even though it did not produce any of those oils. For most oils and fats used domestically, the vast majority of the quantities used are either produced domestically or imported, but not both. Canola is an exception.

Domestic use of soybean oil [excluding its use for methyl esters (biodiesel, a nonfood use)] peaked in 2001/02 to 2004/05, with the highest year being 2002/03 at 17.1 billion pounds (Table A-1). In 2013/14 use (excluding methyl esters) was 13.6 billion pounds. This decline can be attributed in part to the reduction in the use of partially hydrogenated oils and substitution of other oils (e.g. palm and canola) as a result of the 2006 labeling requirements, and also the increased use of canola oil in general.

For domestic U.S. production, compared to the 2.53 billion pounds of PHOs, the only vegetable oil other than soybean or corn that approaches that quantity is canola. Including both domestically produced and imports, more than 4 billion pounds of canola is used in the United States. Just based on quantities produced and imported, the only vegetable oils that would make a major contribution toward replacing 2.2 billion pounds of PHO would be modified soybean (19.7, 0.2), palm (0, 3.0), coconut (0, 1.2), and canola (1.4, 3.3), and possibly corn oil (3.3, 0)[4] (Table A-5). Corn oil is a byproduct of corn milling. Dry mill ethanol facilities are now producing corn oil in addition to wet mills, but some of the oil from dry mill ethanol facilities (back end extraction) is inedible corn oil and is used to make biodiesel and in animal feeds.

For tropical oils, if 2.53 billion pounds of palm, palm kernel, or coconut oil is used to replace 2.53 billion pounds of partially hydrogenated soybean oil, then this would constitute 2.0 percent, 16.7 percent, and 32.4 percent, respectively, of 2013/14 their world production (Table A-5).

The two prime candidates to supply vegetable oil to replace PHOs are high-oleic-acid/low-linolenic-acid soybean oil and palm oil, based on production levels and price. Palm and soybean oil accounted for 34 percent and 26 percent of world vegetable oil production (Table A-5), respectively, and soybean oil accounted for 69 percent of U.S. vegetable oil production in 2013/14 (Table A-1). World production of palm oil and soybean oil were 129 and 98 billion pounds, respectively, in 2013/14 (Table A-5), which are far greater than the amount of partially hydrogenated oil used in the United States.

QUALISOY (2013) estimates that 1.3 billion pounds of high-oleic-acid soybean oil will be available by 2016 to substitute for partially hydrogenated vegetable oils that do not require "solid fat functionality," and that by 2023, approximately 23 million acres of high-oleic-acid soybeans will be planted, producing 9 billion pounds of high-oleic-acid soybean oil.

Palm oil is relatively high in saturated fats, but a new cross has been developed that is higher in oleic acid (43 to 54 percent) and lower in saturated fats (less than 31 percent) (Thin Oil Products 2012). Two other crops grown in the United States that have favorable oil characteristics (high in oleic acid, low in linolenic acid) that could be utilized are canola (high-oleic-acid varieties) and sunflower (high-oleic-acid varieties). [If canola oil is to be substituted for PHOs, it would have to be the high-oleic-acid oil type, as ordinary canola oil is higher in linolenic acid than soybean oil.]

## A.4 REPLACEMENT OILS AND FATS – LAND AND RESOURCE REQUIREMENTS

There are three large-production tropical oils that could be used in place of PHOs: palm oil, palm kernel oil, and coconut oil. Production of these oils takes place mainly in Southeast Asia. For palm oil and palm kernel oil, Indonesia and Malaysia are the major producers, together producing 86 percent and 85 percent of the world's palm oil and palm kernel oil. Palm oil and palm kernel oil are produced together.

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[4] First number in parenthesis is billions of pounds produced in United States and second number is billions of pounds imported (not net imports)

## Table A-6. Land area required to replace 2.53 billion pounds of PHOs with alternative oils

| | Crop yield | | Oil yield | | Land requirement | | Land currently planted | |
|---|---|---|---|---|---|---|---|---|
| **Region/Oil crop** | **per acre** | **per hectare** | **lb/ac** | **Mg/ha** | **million acres** | **million hectares** | **million acres** | **million hectares** |
| Soybeans[b] | | | | | | | | |
| Current average crop yield[c] | 43.4 bu | 2.917 Mg | 505 | 0.566 | 5.01 | 2.03 | 78.4 | 31.7 |
| USDA 2023 long-term forecast crop yield[d] | 49.2 bu | 3.307 Mg | 573 | 0.642 | 4.42 | 1.79 | | |
| USB 2025 goal[e] | 60 bu | 4.033 Mg | 698 | 0.782 | 3.62 | 1.47 | | |
| Sunflower[f] | 1431 lb[g] | 1.603 Mg | 590 | 0.661 | 4.29 | 1.74 | 1.42 | 0.58 |
| Canola[h] | 1588 lb[i] | 1.779 Mg | 665 | 0.745 | 3.80 | 1.54 | 1.41 | 0.57 |

[a] 2-year average for Indonesia and Malaysia (USDA/FAS 2014a,b)

[b] Assumed oil yield is 11.64 lb/bu (0.194 Mg/Mg), 4-year average 2011/12-2014/15 (USDA/ERS 2014d,f)

[c] 4-year average (USDA/NASS 2014a,2015)

[d] Projected soybean yield in USDA long term projection for 2023(USDA/OCE-WAOB 2014)

[e] United Soybean Board yield goal for 2025 (USB 2014a)

[f] Assumed oil fraction is 0.4121(USDA/ERS 2014h,j)

[g] 4-year average USDA/ERS (USDA/ERS 2014g)

[h] Assumed oil fraction is 0.41894 (USDA/ERS 2014k,l)

[i] 4-year average USDA/ERS (USDA/ERS 2014k)

If traditional soybeans are replaced by high-oleic-acid soybeans, the high-oleic-acid soybeans may be either transgenic (e.g. from DuPont Pioneer or Monsanto) or nontransgenic (Pham et al. 2012, Shannon et al. 2011). According to information available, there is no difference in yields between traditional soybean varieties and high-oleic-acid varieties (Anon 2014; Graef et al. 2009; Shannon et al. 2011, 2013; USB 2014b). According to USDA/ERS (2014a), from 2010 to 2014, between 93 and 94 percent of the soybeans planted have been genetically engineered (primarily for resistance to the herbicide glyphosate) (USDA/ERS 2014a). If high-oleic-acid soybeans replace all PHOs and have the same yield as the traditional soybean varieties they replace, then the impact on agriculture would be negligible.

Two other possible candidates to replace PHO that can be domestically produced are canola and sunflower oil. However, to replace 2.53 billion pounds of PHOs would require approximately three times greater acreage than is currently grown of either of these crops (see Table A-6)[6] making unrealistic their sole use as PHO replacement options.

Lard, tallow, and butter can also be substituted for PHOs. Lard is a byproduct of pork production. Tallow is a byproduct of beef production. Butter is produced from the butter fat in milk. USDA reported lard production at 875 million pounds (USDA/ERS 2014n) and pork production at 23.17 billion pounds (USDA/OCE-WAOB 2014) in 2013, for a lard-to-pork ratio of 0.0378. USDA reports edible tallow production at 1.965 billion pounds (USDA/ERS 2014n) and beef production at 25.592 billion pounds (USDA/OCE-WAOB 2014) in 2013, for an edible tallow-to-beef ratio of 0.0768. Pork and beef production require 6.5 and 7.0 pounds of feed per pound of meat produced (Leibtag 2008). Assuming that corn is the source of feed, based on an average corn yield of 150 bushels per acre (four-year average 2011-2014, USDA/NASS 2014a, 2015). To produce a pound of lard and tallow require 0.0205 and 0.0109 acres)[7]. USDA/NASS (2014b) reported milk production, butter fat production, butter fat used to produce butter, and butter production of 201.2 billion, 7,558 million, 1,511 million, and 1,862 million pounds, respectively. A pound of milk produces 0.03756 pounds of butter fat, and 0.811 pounds of butter fat are needed to produce a pound of butter). Therefore, 21.6 pounds of milk are required per pound of butter[8]. The feed efficiency of milk production is 1.5 pounds of milk produced per pound of feed (de Ondarza 2001), which means that 14.4 pounds of feed are required per pound of butter production. EPA reports that

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[6] Sunflower: 4.29 million acres ÷ 1.42 million acres x 100 = 302.1%; Canola: 3.80 million acres ÷ 1.41 million acres x 100 = 269.5%

[7] Lard: 3.07 bushels corn per pound lard = (6.5 pounds feed per pound meat/0.0378 pounds lard per pound of pork)/(56 pounds per bushel corn), 0.0205 acres per pound of lard = 3.07 bushels corn per pound lard/56 pounds per bushel of corn; Tallow: 1.63 bushels corn per pound tallow = (7.0 pounds feed per pound beef/0.0768 pounds tallow per pound of meat)/(56 pounds per bushel corn), 0.0.109 acres per pound of lard = 1.63 bushels corn per pound tallow/56 pounds per bushel of corn

[8] 0.3756 pounds of butter fat per pound of milk = 7,558 million pounds butter fat/2.012 billion pounds of milk; 0.811 pounds of butter fat per pound of butter = 1,511 million pounds of butter fat for butter/1,862 million pounds butter; 21.6 pounds of milk per pound of butter = 0.811 pounds of butter fat per pound of milk/0.03756 pounds of butter fat per pound of milk

typical dairy rations in the Midwest include a number of feeds, including corn and alfalfa hay (USEPA 2012).

## A.5 REPLACEMENT OILS AND FATS – ECONOMIC CONSIDERATIONS

Price will also be a significant determinant of which vegetable oils are utilized to replace PHOs. Prices of vegetable oil are presented in Figure A-2 and can be found in tabular form in Table A-7. As can be seen in Figure A-2, sunflower oil price has been significantly higher than other vegetable oils for much of the 2001 to 2014 time period. Canola and edible corn oil have been slightly higher than soybean oil.

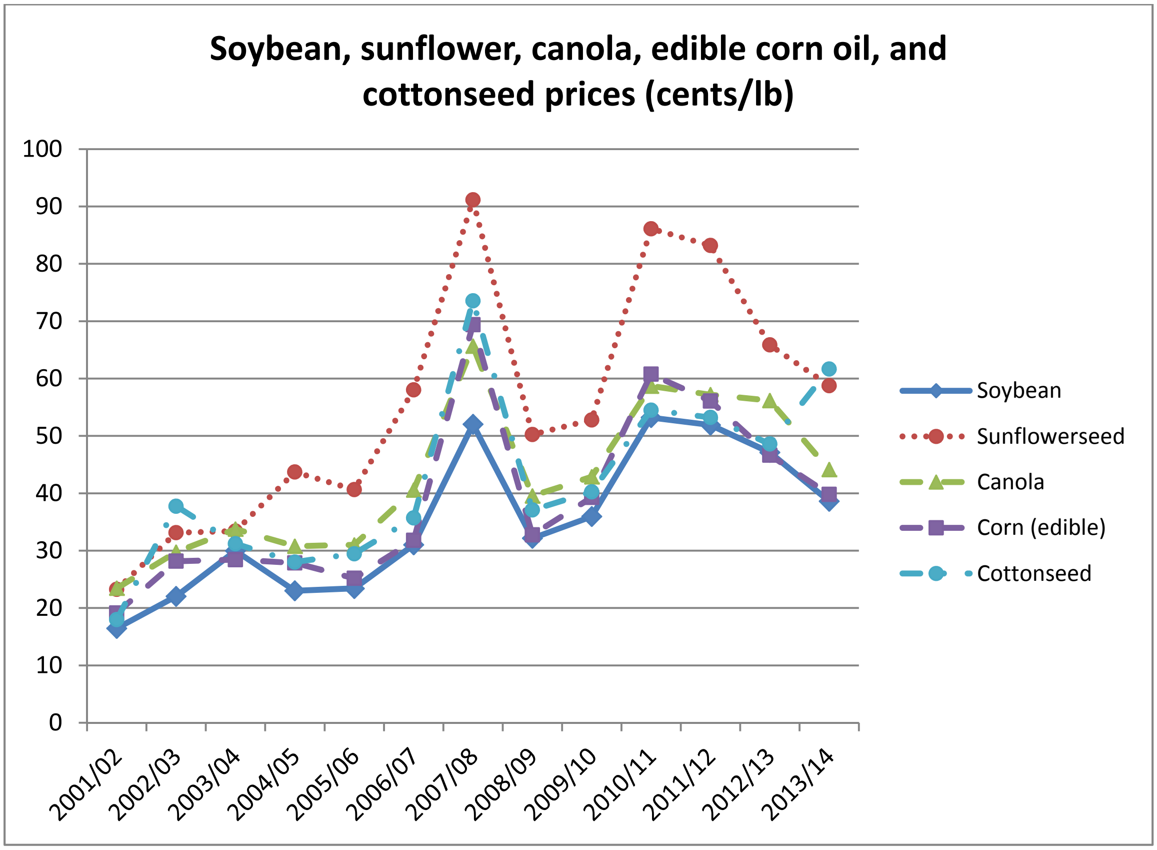

**Figure A-2. Soybean, sunflower, canola, edible corn oil, and cottonseed oil prices**
*Source:* USDA/ERS (2014c)

## Table A-7. Vegetable oil and fats prices (U.S. cents/lb)

| Market year | Soybean | Cottonseed | Sunflower | Canola | Peanut | Corn (edible) | Lard | Edible tallow | Butter |
|---|---|---|---|---|---|---|---|---|---|
| 2001/02 | 16.46 | 17.98 | 23.25 | 23.45 | 32.23 | 19.14 | 13.55 | 13.87 | 155 |
| 2002/03 | 22.04 | 37.75 | 33.13 | 29.75 | 46.70 | 28.17 | 18.13 | 17.80 | 100 |
| 2003/04 | 29.97 | 31.21 | 33.42 | 33.76 | 60.84 | 28.43 | 26.13 | 22.37 | 101 |
| 2004/05 | 23.01 | 28.01 | 43.71 | 30.78 | 53.63 | 27.86 | 21.80 | 18.48 | 171 |
| 2005/06 | 23.41 | 29.47 | 40.64 | 31.00 | 44.48 | 25.18 | 21.74 | 18.16 | 143 |
| 2006/07 | 31.02 | 35.70 | 58.03 | 40.57 | 52.99 | 31.80 | 28.43 | 27.32 | 111 |
| 2007/08 | 52.03 | 73.56 | 91.15 | 65.64 | 94.53 | 69.40 | 40.85 | 41.68 | 124 |
| 2008/09 | 32.16 | 37.10 | 50.24 | 39.54 | 78.49 | 32.75 | 26.72 | 25.47 | 131 |
| 2009/10 | 35.95 | 40.27 | 52.80 | 42.88 | 59.62 | 39.29 | 31.99 | 32.26 | 105 |
| 2010/11 | 53.20 | 54.50 | 86.12 | 58.68 | 77.24 | 60.76 | 51.52 | 51.34 | 155 |
| *Tentative determination that PHOs are not GRAS* | *Tentative determination that PHOs are not GRAS* | *Tentative determination that PHOs are not GRAS* | *Tentative determination that PHOs are not GRAS* | *Tentative determination that PHOs are not GRAS* | *Tentative determination that PHOs are not GRAS* | *Tentative determination that PHOs are not GRAS* | *Tentative determination that PHOs are not GRAS* | *Tentative determination that PHOs are not GRAS* | *Tentative determination that PHOs are not GRAS* |
| 2012/13 | 47.13 | 48.60 | 65.87 | 56.17 | 87.71 | 46.66 | 51.80 | 43.24 | |
| 2013/14[a] | 38.62 | 61.66 | 58.76 | 44.13 | 65.14 | 39.82 | 43.19 | 40.09 | |

[a] Through August

*Sources:* USDA/ERS (2014c), butter: USDA/ERS (2012)

If lard and edible tallow replace 9 percent of PHOs (based on 2.53 billion pounds to be replaced), this would require 228 million pounds. Lard production in the United States was 875 million pounds in 2013, and annual production has been between 835 and 876 million pounds between 2007 and 2013. Lard is pig fat, and is a byproduct of pork production, so the quantity produced depends on the quantity of pork production. The U.S. Department of Agriculture projects an increase in pork production by 2024 of about 15 percent from the average of 2012 to 2014, which would result in about an additional 130 million pounds of lard supply (USDA/OCE-WAOB 2014). Replacing 9 percent of PHOs with lard would require 26 percent of the lard supply. Up until the 2010/11 marketing year the price of lard was less than soybean oil. From the 2011/12 marketing year to the present the price of lard has been above that of soybeans (Figure A-3). For the 2013/14 marketing year (October to July) the price of lard averaged $0.439/lb versus a soybean oil price of $0.382/lb (USDA/ERS 2014e). If lard is substituted for partially hydrogenated oils then the demand for lard may increase which would increase the value of the lard produced jointly with pork.

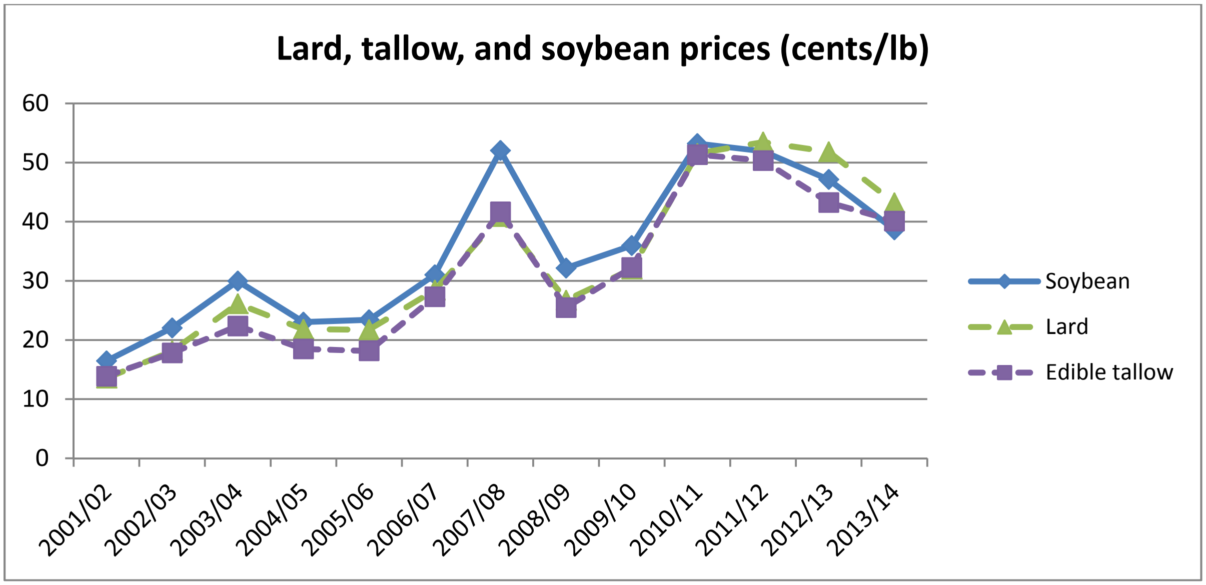

**Figure A-3. Lard, tallow, and soybean prices 2001/02 to 2013/14**
*Source:* USDA/ERS (2014c)

Tallow is a byproduct of beef production, so the quantity produced depends on the quantity of beef production. The U.S. Department of Agriculture projects an increase in beef production by 2024 of about 2.6 percent from the average of 2012 to 2014 (USDA/OCE-WAOB 2014), which would result in about an additional 51 million pounds of edible supply. Replacing 228 million pounds of PHOs with lard would require 12 percent of the edible tallow production in 2013. [Note that there is also inedible tallow produced at a quantity similar to edible tallow, but would have to be upgraded to be edible]. Up until the 2013/14 marketing year the price of edible tallow was less than the price of soybean oil. From the 2013/14 marketing year the price of edible tallow was above that of soybean oil (Figure A-3). For the 2013/14 marketing year (October to September) the price of edible tallow averaged

$0.398 per lb versus a soybean oil price of $0.382 per lb (USDA/ERS 2014e). If tallow is substituted for partially hydrogenated oils the demand for tallow may increase which would increase the value of the tallow produced jointly with beef. There are characteristics of tallow that may not make it suitable to be used in applications for which lard can be used.

In 2013 butter production was 1,862 million pounds (USDA NASS 2014b) and for the 12 months from July 2013 to June 2014 butter production was 1,837 million pounds (USDA/ERS 2014b, USDA/NASS various dates). Replacing 1 percent of PHOs with butter would require 25.3 million pounds, or 1.4 percent of butter production. Over the recent period of 12 July to 6 September 2014 the price of butter averaged $2.50/lb (USDA/AMS 2014a, 2014b) and during the period 2000 to 2011 was 2 to 9 times as expensive as soybean oil (Table A-6). Butter is priced at a considerable premium over any vegetable oil or fat.

The price of soybean oil has historically been the lowest amongst domestically produced vegetable oils (Figure A-2) and, while soybean oil has historically been priced at a slight premium to edible tallow and lard, recently it has been lower than edible tallow or lard (Figure A-3). As of October 2014, prices for palm and soybean oil as reported by Indexmundi (2014b) were $0.305 and $0.327 per pound, respectively, and soybean oil price as reported by USDA/ERS (2014e) was $0.341 per pound.

A disadvantage that sunflower oil has is price. Over the last five years the price of sunflower oil has been between $0.17/lb and $0.33/lb higher than soybean oil. At current yields, (soybeans at 42.9 bu/acre), canola and sunflower require less land than soybeans to produce 2.2 billion pounds of vegetable oil (but they produce less meal to feed livestock than soybeans). However, soybeans are a higher-value crop because they produce more meal to feed livestock.

Prices of sunflower and canola oil have been higher than soybean and palm oil (Indexmundi 2014a). Palm kernel and coconut oil have been higher priced for 67 percent and 74 percent of the 121 months between June 2004 and June 2014, averaging $0.043/lb and $0.056/lb higher than soybean oil, respectively. Palm oil has been $0.069/lb less than soybean oil (Figure A-4).

Vegetable oils trade in a world market, and trade is large. Not all vegetable oils and fats are perfect substitutes for each other, as they have differing characteristics. For the 2.53 billion pounds of soybean oil that are partially hydrogenated, the two major vegetable oils that are the most likely candidates to replace the traditional soybean oil (7 percent linolenic acid) are palm oil from Indonesia and Malaysia and high-oleic-acid soybean oil produced in the United States. The least impact on agriculture would be in a scenario in which high-oleic-acid soybean oil replaces the traditional soybean oil and the yields are the same for both traditional and high-oleic-acid soybeans.

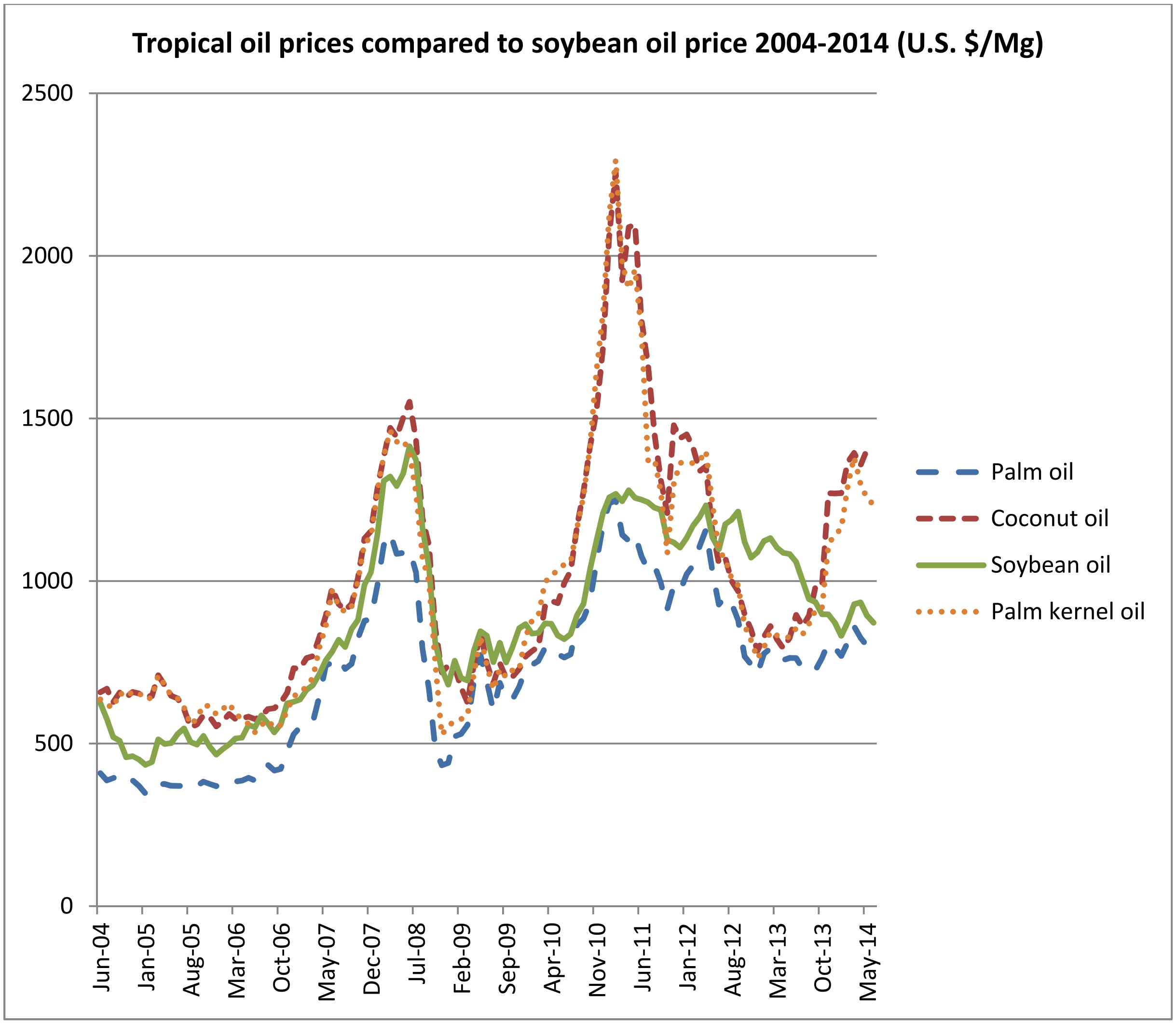

**Figure A-4. Tropical oil prices compared to soybean oil prices, 2004-2014**
*Source:* Indexmundi (2014a)

## A.6 PRODUCTION AND CRUSHING OIL SEEDS (AND HOW THAT MAY AFFECT PRODUCTION OF SUBSTITUTE OILS TO REPLACE PARTIALLY HYDROGENATED OILS)

Vegetable oils come from oilseeds, which produce two primary products: vegetable oil and meal. The ratios of these two products vary greatly. Cottonseed and corn oil come from crops from which the oil component is a by-product, so the oil is produced based on the amount of a primary product that is processed, namely cotton and corn for ethanol. At the other extreme is oil palm. Most of its value is from the oil, and a small amount of the value comes from the meal.

The oil palm produces a fresh fruit bunch. Palm oil is extracted from the pulp and palm kernel oil from the kernel. After palm oil extraction palm kernel meal remains. Palm kernel meal is moderate in protein content (about 15 percent). Another aspect of oil palm production is that the oil palm is a perennial with a useful life of about 25 years and no harvestable production occurs until year 3 (Figure A-5). It takes a substantial investment to get an oil palm plantation started, so there has to be enough confidence that there will be markets for the additional production is oil palm acreage is increased.

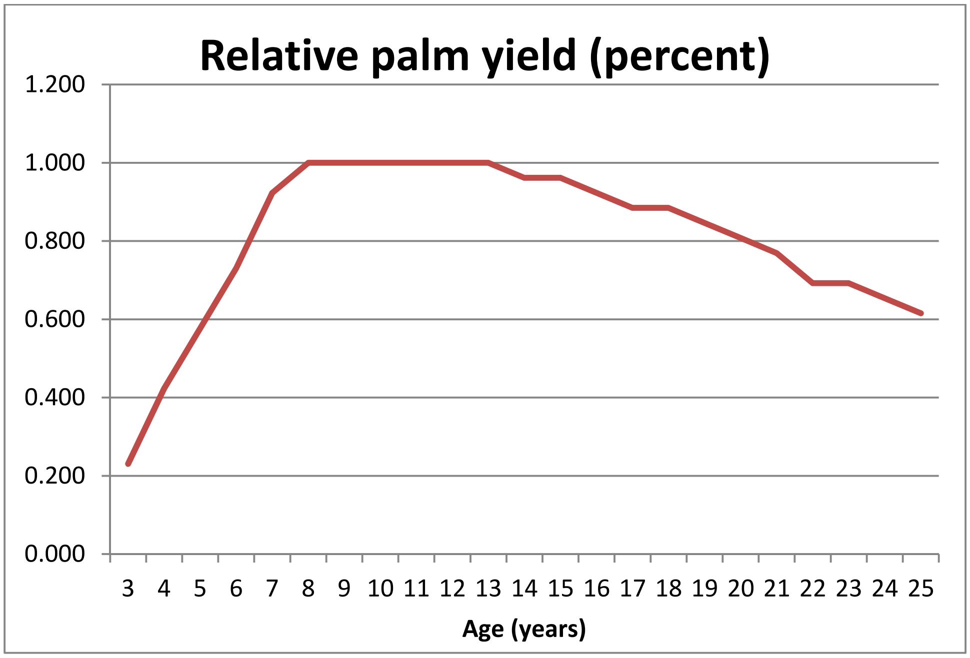

**Figure A-5. Oil palm production profile**
*Source*: Maybank (2012)

For soybeans, the majority of the value is in the meal, ranging from 54 to 72 percent over the 1990-2010 timeframe. In contrast to palm kernel meal, soybean meal is 48 percent protein. Oil palm production is mostly influenced by palm oil price, while for soybeans the price of soybean meal is generally has the most important impact on soybean production. For canola, the oil fraction has comprised between 64 and 79 percent of the value of canola over the 1990 to 2013 timeframe.

In the United States, soybeans are produced primarily in the Corn Belt[9] with lesser production in the Great Plains and Southeast. About 80 percent of canola production is in North Dakota and about 80 percent of sunflower production is from South Dakota and North Dakota. There could be some shifts in regional production patterns of oilseeds in response to replacement of partially hydrogenated vegetable oils, but the effect on soybean production will be somewhat dampened by the fact that the meal provides about two-thirds of the value of soybeans. While canola and sunflower provide more oil per acre, they provide less meal per acre than soybeans. The impact of replacing PHOs on domestic oilseed production

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[9] The Corn Belt is the highly productive agricultural region that we define as including: Iowa, Illinois, Indiana, Ohio, southern Michigan, southern Wisconsin, southern Minnesota, eastern Nebraska, and northern Missouri.

depends on the interplay of the vegetable oil and oilseed meal markets. The 2.0 billion pounds of soybean oil (at current yields) requires 4.0 million acres (1.6 million ha) of production, but even if there is a 2.0 billion pound drop in the demand for soybean oil, it is unlikely that soybean production would be reduced by 4.0 million acres (1.6 million ha) because meal is a more important driver of soybean production than soybean oil.

Another factor that affects (at least in the short-term) the choice of oilseed production is crushing capacity. [Crushing of oilseeds is used to separate the oil from the meal.] Soybeans are relatively low in oil content (about 20 percent), while the other oilseeds of interest are higher in oil content (greater than 40 percent). There are three different types of crushing facilities: mechanical, prepress-solvent (mechanical-solvent), and solvent extraction. Solvent extraction is used for soybeans and prepress-solvent would be used for canola and sunflower. While canola and sunflower can be crushed using solvent extraction, solvent extraction is not as efficient for oil extraction of these higher oil content oilseeds. If there is a shift in where oilseeds are produced, it may take time for the appropriate type of crushing facilities to become available and existing facilities may not be in the same geographical locations as production. These factors may slow down shifts in oilseed production.

## A.7 EVALUATION OF THE FDA ACTION FOR EXTERNAL COSTS

As discussed in Section 2 of this report, replacements for PHOs have been identified for detailed analysis of their potential environmental impacts.

- **FDA Action:** PHOs are replaced by a combination of fats and oils consisting of the following items and their percentages (Bruns 2014):
  - High-oleic soybean oil – 25 percent
  - Fully hydrogenated vegetable oils – 10 percent
  - Interesterified fats – 10 percent
  - Lard – 5 percent and tallow – 4 percent
  - High-oleic sunflower oil – 5 percent
  - Other soybean oil – 5 percent
  - Cottonseed oil – 2.5 percent
  - Canola oils – 2.5 percent
  - Butter – 1 percent
  - Palm oil – 30 percent

  For the purpose of analysis in this appendix, each of the PHO replacements in the above list is assumed to be produced domestically, except for the palm oil, which is assumed to be imported.

The external costs of agricultural production are discussed in the following subsections.

### A.7.1 External costs of agricultural production

External costs (also called externalities or social costs) are costs that are imposed on a third party. An example would be sediment that comes from soil erosion from crop production that requires a downstream drinking water provider to remove the sediment from before providing drinking water to its customers.

Fats are byproducts of livestock production (lard as a byproduct of pork production from hogs and tallow as a byproduct of beef production from cattle) and butter comes from dairy cattle. Costs need to be estimated for crops, and for beef, pork, and dairy. Tegtmeier and Duffy (2004) and Pretty et al. (2001) have estimated external costs of agricultural production in the United States. Schaffer et al. (c. 2007) have estimated the costs for pork production.

Tegtmeier and Duffy (2004) provide a range of costs for crops ($4,969 – $16,151 million) and livestock ($714 – $739 million) (in 2002$). Pretty et al (2001) estimate costs for agriculture in the aggregate for the United Kingdom, United States, and Germany. Their total estimated cost for the United States is £21,022 million (in 1996£). They do not differentiate between costs from livestock and crop production. Schaffer et al (c. 2007) estimate the external costs for pork production. They estimate costs for a variety of hog production systems and estimate monetized externalities and subsidies. Pretty et al.'s estimate are converted costs are converted to U.S. dollars and the costs of Tegtmeier and Duffy and Pretty et al. are indexed to 2013 dollars using the GDP price deflator (Federal Reserve Bank of St. Louis 2015)[10]. These costs are then converted to a dollar per acre cost for crops and dollar per pound of beef and pork by indexing the costs of Tegtmeier and Duffy. Costs for beef and pork consist of direct costs for livestock production as well as crop costs for feed.

Tegtmeier and Duffy 2004 costs are converted to a per acre, per pound of crop, and per pound of meat cost. Per acre costs are based on the crop acreage of principal crops reported by USDA/NASS (2004, 2014a), which were 326.3 and 300.2 million acres in 2013 and 2002, respectively. We make a gross estimate of crop production in 2002 using USDA/NASS data for grains, forages, and oilseeds produced. This is the sum of grains, 30% of silages, and two-thirds of hay. The factors applied to silages and hay are to account for moisture and relative feeding value, respectively. Total crop production used to determine external costs per acre of crop production are 503.8 million Mg, or 555.3 million tons (Table A-8). Meat production is shown in Table A-9. Meat production does not include milk, so to try and account for dairy cattle, an adjustment was made based on the stocks of beef and dairy cattle. Beef cattle were 88.60 and 96.70 million head in 2013 and 2002, respectively. Dairy cattle were 9.12 and 9.22 million head in 2013 and 2002, respectively. For 2002, the beef number

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[10] The Federal Reserve Bank of St. Louis provides quarterly data for January 1, April 1, July 1, and October 1 for a given year. To determine the GDP price deflator for a given year, say 2002, we average January 1, 2002, April 1, 2002, July 1, 2002, October 1, 2002 and January 1, 2003.

for the total calculation was adjusted upward by 9.43% [(9120 + 96704)/96704]. Data for the dairy cattle adjustment is shown in Table A-10.

**Table A-8. Grain, hay, silage, and oilseed production 2002 and 2013**

| | **Production (Mg)** | | **Factor** | **Adjusted production (Mg)** | |
|---|---|---|---|---|---|
| | **2013** | **2002** | | **2013** | **2002** |
| Barley | 4,682,770 | 4,933,040 | 1 | 4,682,770 | 4,933,040 |
| Corn for grain | 353,715,030 | 228,805,080 | 1 | 353,715,030 | 228,805,080 |
| Corn for silage | 106,912,630 | 95,235,350 | 0.300 | 32,073,789 | 28,570,605 |
| Alfalfa | 52,236,600 | 66,972,010 | 0.667 | 34,824,400 | 44,648,007 |
| All other | 71,091,530 | 69,978,420 | 0.667 | 47,394,353 | 46,652,280 |
| Oats | 956,230 | 1,721,880 | 1 | 956,230 | 1,721,880 |
| Proso millet | 418,120 | 62,480 | 1 | 418,120 | 62,480 |
| Rice | 8,613,080 | 9,568,990 | 1 | 8,613,080 | 9,568,990 |
| Rye | 194,800 | 176,670 | 1 | 194,800 | 176,670 |
| Sorghum for grain | 9,882,220 | 9,392,290 | 1 | 9,882,220 | 9,392,290 |
| Sorghum for silage | 4,916,940 | 3,048,140 | 0.300 | 1,475,082 | 914,442 |
| Winter | 41,755,520 | 31,178,180 | 1 | 41,755,520 | 31,178,180 |
| Durum | 1,685,000 | 2,162,270 | 1 | 1,685,000 | 2,162,270 |
| Other spring | 14,520,280 | 10,721,530 | 1 | 14,520,280 | 10,721,530 |
| Total grains/hay/silage | 671,580,750 | 533,956,330 | 1 | 552,190,674 | 419,507,744 |
| **Oilseeds** | | | | | |
| Canola | 1,002,670 | 704,210 | 1 | 1,002,670 | 704,210 |
| Cottonseed | 3,997,060 | 5,609,940 | 1 | 3,997,060 | 5,609,940 |
| Flaxseed | 85,250 | 319,270 | 1 | 85,250 | 319,270 |
| Mustard seed | 16,660 | 56,000 | 1 | 16,660 | 56,000 |
| Peanuts | 1,893,380 | 1,506,150 | 1 | 1,893,380 | 1,506,150 |
| Rapeseed | 880 | 2,050 | 1 | 880 | 2,050 |
| Safflower | 95,010 | 135,160 | 1 | 95,010 | 135,160 |
| Soybeans for beans | 89,507,370 | 74,824,770 | 1 | 89,507,370 | 74,824,770 |
| Sunflower | 922,030 | 1,129,270 | 1 | 922,030 | 1,129,270 |
| Total oilseeds | 97,520,310 | 84,286,820 | 1 | 97,520,310 | 84,286,820 |
| Total | 769,101,060 | 618,243,150 | | 649,710,984 | 503,794,564 |

Sources: USDA/NASS (2004, 2014a)

### Table A-9. Meat production

| | 2013 | 2002 |
|---|---|---|
| | billion pounds | |
| Beef | 25.592 | 27.192 |
| Dairy adjustment | 2.665 | 2.564 |
| Beef (adjusted dairy) | 28.257 | 29.756 |
| Pork | 23.167 | 19.685 |
| Chicken | 37.387 | 31.895 |
| Turkey | 5.783 | 5.638 |
| Total meat production, with adjustment for dairy | 94.594 | 86.974 |

Sources for beef, pork, chicken, and turkey: USDA/OCE (2004), USDA/OCE-WAOB (2014)

### Table A-10. Equivalent meat production from dairy cattle used to calculate total meat production

| | 2013 | 2002 | 2013 | 2002 |
|---|---|---|---|---|
| | 1000 head | | meat (million pounds) | |
| Dairy cattle | 9225 | 9120 | 2.665 | 2.564 |
| Beef cattle | 88600 | 96704 | 25.592 | 27.192 |
| Total | 97825 | 105824 | 28.257 | 29.756 |

Sources for beef cattle and dairy cattle number, and beef cattle production: USDA/OCE (2004), USDA/OCE-WAOB (2014)

For crops, the per acre and per pound of crop (for livestock feed) external costs which Tegtmeier and Duffy (2004) calculated for 2002 are based on 2002 acreages and 2002 crop production (Tables A-11, A-12).

### Table A-11. External costs for livestock (excluding feed) and crop costs per acre based on Tegtmeier and Duffy and per acre costs based on Pretty et al

| **Livestock** | **million 2013$** | **million 2002$** |
|---|---|---|
| Low | 895.3 | 714 |
| High | 926.6 | 739 |
| | **$/lb meat** | **$/lb meat** |
| Low | 0.01029 | 0.00821 |
| High | 0.01065 | 0.00850 |
| **Crops** | **million 2013$** | **million 2002$** |
| Low | 6230.6 | 4969 |
| High | 20251.7 | 16151 |
| **Crops** | **2013$ per acre based on 2002 acreage** | |
| | **Tegtmeier and Duffy 2004** | **Pretty et al 2001** |
| Low | 20.75 | |
| High | 67.46 | 146.10 |

Pretty et al. (2001) give a total external cost of £21.02 billion in 1996, which based on the British pound U.S. dollar exchange rate of 1.569 $ per £ in 1996 is $32.99 billion, and is $45.87 billion in 2013 dollars (based on the GDP price deflator 76.885 in 1996 and 106.915 in 2013) (Federal Reserve Bank of St. Louis 2015). Because Pretty et al do not distinguish between crops and livestock, but only give a total number, the total of Pretty et al is compared to the high estimate of Tegtmeier and Duffy, for a ratio of 2.61658 (45,868/(926.6+20,251.7)). Pretty et al.'s total cost is 2.62 times higher than Tegtmeier and Duffy. This gives the per acre cost of $146.10 per acre in Table A-11.

For livestock production there is the added cost of the external costs from crop production used to feed livestock. Beef cattle and hogs require 7.0 and 6.5 pounds of feed per pound of meat produced and for milk production 1 pound of feed produces 1.5 pounds of milk.

**Table A-12. External cost of crops and total (livestock plus crops) used to produce 1 pound of beef and pork based on Tegtmeier and Duffy and 2002 crop production levels**

| **Crops** | **million 2013$** |
|---|---|
| low | 6230.6 |
| high | 20251.7 |
| | **tons** |
| 2002 crop production | 555,332,748 |
| | **2013$/lb crops** |
| low | 0.0056 |
| high | 0.0182 |
| **Beef** | **2013$ per pound meat** |
| Low | 0.0393 |
| High | 0.1276 |
| **Pork** | |
| Low | 0.0365 |
| High | 0.1185 |
| **Livestock plus crop cost** | **2013$ per pound meat** |
| **Beef** | |
| Low | 0.0496 |
| High | 0.1383 |
| **Pork** | |
| low | 0.0468 |
| high | 0.1292 |

Schaffer et al. (c. 2007) estimate external costs for pork production as $11.93 per hundredweight (cwt) ($2003) of gain in hogs. We assume that this is per cwt of pork production. Indexing this to 2013 dollar and converting to a per pound basis this is $0.1466 per pound. (GDP price deflator of 87.004 in 2003 and 106.915 in 2013 (Federal Reserve Bank of St. Louis 2015)).

To calculate the external costs of the animal (livestock) part of milk production we take the dairy fraction of total meat production for 2002 and 2013 of 0.0295 and 0.0282, respectively, and multiply this by the total livestock impact from Tegtmeier and Duffy of $895.3 (low) and $926.6 (high) and obtain a range of $26.40 to $27.32 using 2002 data and $25.22 to $26.10 million (2013 dollars) using 2013 data. Using milk production for 2002 of 169.9 billion pounds, livestock portion of external cost per pound of milk ranges from $0.0227 to $0.0235.

### A.7.2 Use of a mixture of domestically-produced and imported palm oil and lard, tallow, and butter to replace PHOs

There are a number of oils/fats that could replace PHOs (Table A-13). Bruns (2015) estimated the breakdown of such PHO replacements as shown in Table A-13.

**Table A-13. Replacement of PHOs**

| oil/fat | fraction | million pounds |
|---|---|---|
| Soybean oil-high oleic | 0.25 | 633.0 |
| Fully hydrogenated oil | 0.1 | 253.2 |
| Interesterified fats | 0.1 | 253.2 |
| Sunflower oil-high oleic | 0.05 | 126.6 |
| Butter | 0.01 | 25.3 |
| Soybean oil | 0.05 | 126.6 |
| Cottonseed oil | 0.025 | 63.3 |
| Canola oil | 0.025 | 63.3 |
| Palm oil | 0.3 | 759.6 |
| Lard/tallow | 0.09 | 227.9 |
| Total | | 2532.0 |

The change that would occur in vegetable oil/fat use that would occur by implementing the oil/fat replacements of PHOs from Table A-13, are shown in Table A-14. We assume that the interesterified fats and fully hydrogenated oils use soybean oil as their feedstocks. The net effect on soybean oil use is a reduction of 733.5 million pounds.

## Table A-14. Change in oil/fat production according to Table A-13

| oil/fat | change<br>million pounds | Notes |
|---|---|---|
| Soybean oil | -1240.1 | |
| Cottonseed oil | 34.3 | |
| Sunflower oil | 98.7 | |
| Canola oil | -191.7 | |
| Corn oil | -214 | |
| Palm oil | 759.9 | |
| Palm kernel oil | -1 | |
| Peanut oil | -6 | |
| Butter | 25.3 | |
| Lard/tallow | 228.0 | |
| Interesterified fats | 253.3 | assume soybean oil |
| Fully hydrogenated oils | 253.3 | assume soybean oil |
| Soybean oil – net change | -733.5 | |

Table A-15 shows the effects of these changes. In this case, there is a net reduction in farmed acreage of 1.57 million acres and a decrease in soybean meal equivalents of 1.56 million tons, which is equivalent to 3.6% of current soybean meal production. Replacement of PHOs according to Table A-3 causes soybean meal equivalents to decrease. If no reduction in soybean meal equivalents is desired (i.e. there is soybean production above what is needed to provide the oil), then the net reduction in acreage is 63,000 acres.

## Table A-15. Change in oilseed production

| oil/fat | units | yield[b] | oil fraction | oil lb/acre | change million acres | meal fraction | meal lb/acre | meal change 1000 tons | protein % | soybean meal equivalent[a] 1000 tons |
|---|---|---|---|---|---|---|---|---|---|---|
| Sunflower | lb/ac | 1431 | 0.4121[c] | 590 | 0.167 | 0.4687[d] | 671 | 56.1 | 34 | 39.7 |
| Canola | lb/ac | 1588 | 0.41893[e] | 665 | -0.288 | 0.579[f] | 919 | -132.5 | 36 | -99.3 |
| | | | lb/bu | | | lb/bu | lb/acre | | | |
| Soybeans | bu/ac | 43.4 | 11.64[g] | 505 | -1.452 | 47.57[g] | 2065 | -1,499 | 48 | -1,499 |
| Total | | | | | -1.573[h] | | | | | -1,558[h] |

[a] Soybean meal equivalent calculated based on protein content

[b] 4-year averages, calculated from data in USDA/ERS (2014f) and crop yields from USDA/NASS (2014a, 2015)

[c] 4-year averages, calculated from data in USDA/ERS (2014h, 2014i, 2014k)

[d] Calculated from data in USDA/ERS (2014h, 2014i, 2014j)

[e] 4-year averages, calculated from data in USDA/ERS (2014l, 2014m)

[f] 4-year averages, calculated from data in USDA/ERS (2014l, 2014n)

[g] 4-year averages, calculated from data in USDA/ERS (2014f)

[h] to replace 1,558 thousand tons of soybean meal at the least number of acres (with soybeans) would require 1.573 million acres of soybeans, for a net decrease of 0.535 million acres.

Based on per acre external costs from Tegtmeier and Duffy (2004) of $20.75 (low) and $67.46 (high) and from Pretty et al. (2001) $146.10, results in external costs ranging from -$1.39 to -$229.8 million (Table A-16). External costs from crops are reduced because palm oil imports (for which any crop costs are out of scope), lard/tallow, and butter replace vegetable oil based partially hydrogenated oils. The costs from the animal fats (lard/tallow) portion are calculated below.

**Table A-16. External costs from crops of replacing partially hydrogenated oils according to Tables A-13 and A-14**

| | | | **External cost factors from** | |
|---|---|---|---|---|
| | **millions of acres cropped** | **external cost estimates** | **Tegtmeier and Duffy** | **Pretty et al** |
| | | | $/acre | |
| | | Low | 20.75 | |
| | | High | 67.46 | 146.10 |
| | | | **total external costs from crop change (million 2013$)** | |
| minimum change (no net meal change) | -0.063 | Low | -1.31 | |
| | | High | -4.26 | -9.22 |
| maximum change (no meal replacement) | -1.590 | Low | -32.64 | |
| | | High | -106.10 | -229.79 |

## ***Lard and edible tallow***

Lard and edible tallow are potential replacements for PHOs. They can be readily substituted.

The National Renderers Association recognizes and defines categories of animal fats (Alm 2013):

- Lard: Edible grease, the process and parameters of which are the same as for edible beef tallow, but with pork as the raw material.
- Edible tallow: Exclusively beef, this product is rendered from fat trimmings and bones taken from further processing at a slaughterhouse. The product is of light color and low moisture, insolubles, unsaponifiables, and free fatty acids. The tallow may be further refined, polished, and deodorized to become a cooking fat. The pet food industry generally uses the crude product not shipped under seal, often referred to as technical tallow.
- Choice white grease: A specific grade of mostly pork fat defined by hardness, color, fatty acid content, moisture, insolubles, unsaponifiables, and free fatty acids.
- Edible: Fats and proteins produced for human consumption, which are under the inspection and processing standards established by the U.S. Department of Agriculture, Food and Safety Inspection Service (USDA/FSIS).

- Inedible: Fats and proteins produced for animal, poultry, and fish consumption or for other non-edible uses.

The specifications of pig fat defined as lard and choice white grease, and edible tallow are shown in Table A-17. Definitions for the terms in the table are shown below. [Note: For edible tallow, Table a, note *, in the National Renderers Association (2003) lists maximum moisture as 0.20%. Table b in this reference shows moisture and volatiles as 0.1% maximum.]

**Table A-17. Specifications for lard, choice white grease, and edible tallow**

| | **Lard** | **Choice white grease** | **Edible tallow** |
|---|---|---|---|
| Titer (minimum) (˚C) | 38.0 | 36.0 | 41.0 |
| Free fatty acids (FFA) (maximum) (%) | 0.5 | 4 | 0.75 |
| Color (Fat analysis committee (FAC) (maximum)) | 39 | 13-11E | 3 |
| Lovibond color (5 ¼ inch cell) (maximum) | 1.5 red | | |
| Moisture (maximum) (%) | 0.2 | | 0.2 |
| Insoluble impurities (maximum) (%) | 0.05 | | 0.05 |
| Moisture, unsaponifiables, and impurities | | 1 | |
| Peroxide value (maximum) (meq/kg) | 4 | | 1.0 |

Source: National Renderers Association (2003).

Additional edible tallow specifications: maximum iodine value: 40-45, soap: 5 ppm (maximum); moisture and volatiles: 0.1% (maximum); Wiley melting point 107-114˚F; FAC color index: 10 yellow, 1 red; smoke point: 435˚F (minimum); flash point 600˚F (minimum)

Definitions (Rothsay, 2014):

- Titer: Temperature at which fat becomes a solid. Tallow and lard have titers at 40˚C or higher, and greases have a titer below 40˚C
- Color (FAC): color of a fat is compared to the Fat Analysis Committee Standard (FAC) ranging from 1 (lightest) to 45 (darkest)
- Color, Lovibond: Matches a sample of a fat with standard red and yellow colors
- Free fatty acids (FFA): Fatty acids split from the triglyceride or fat molecule and dissolved in the fat
- Insoluble impurities: The amount of sediment
- Rendering: Process using high temperature and pressure to convert animal byproducts into “safe, nutritional, and economically valuable products.”

The total amount of fat produced from hogs (pigs) is around 870 million pounds. Lard is defined differently by the U.S. Department of Agriculture/Economic Research Service (USDA/ERS) and the U.S. Census Bureau. Fat from hogs (pigs) is defined by the USDA as lard, whereas the Census Bureau separates fat from pigs into two categories: lard (which qualifies as edible) and under Inedible tallow and grease the subcategory of inedible products, feed, other grease. These inedible fats from hogs are called white grease or choice white grease. The Census Bureau category that includes pig fat (other than what is defined as lard) may also include other greases. The Census Bureau discontinued collection of data for fats, with the last full year of data collection being 2010.

Edible and inedible lard, and edible and inedible tallow are chemically similar. To be edible, lard and tallow must be from USDA inspected and approved carcasses and be processed (rendered) under sanitary conditions, and meet specifications defined in Table A-17. Some fats that could potentially be edible are thus not considered to be edible. The price differential between edible and inedible fats is limited. Price incentives could be effective in shifting supply from inedible to edible fats (Meeker 2015).

For 2009 and 2010 the Census Bureau (2011) reported consumption of lard at 340 and 296 million pounds, respectively, with consumption for edible and inedible products being 138 and 158 million pounds, respectively in 2010 (Table A-18). In 2009 most of the inedible consumption was for methyl esters (biodiesel) (146 million pounds out of a total of 166 million pounds for total inedible products). Biodiesel would be price sensitive as many fat and oil feedstocks can be used, so it is likely that if lard is needed for replacing partially hydrogenated oils this could be bid away biodiesel. Under inedible tallow and grease, inedible products other grease consumption in 2009 was 560 and 222 million pounds for feed and methyl esters, respectively. Choice white grease, which also comes from hogs, in the Census Bureau data, falls under this other grease category. Lard plus other grease used for feed and methyl esters adds up to 1.12 million pounds in 2009. Production of other grease was 1.21 and 1.32 million pounds in 2009 and 2010 respectively.

## Table A-18. Fat consumption and production (Census Bureau, 2009 and 2010)

| Product description | 2010 | 2009 |
|---|---|---|
| Edible tallow | million pounds | |
| Consumption: | | |
| Selected edible and inedible products | 675.5 | 1499.2 |
| Edible products | 161.4 | 261.3 |
| Baking or frying fats | (D) | 256.4 |
| Margarine | (D) | (D) |
| Other edible products | (D) | (D) |
| Inedible products | 514.1 | 1,237.9 |
| Inedible tallow and grease: | | |
| Consumption: | | |
| Selected edible and inedible products | 3,341.5 | 3,642.5 |
| Edible products | - | - |
| Inedible products | 3,341.5 | 3,642.5 |
| Fatty acids | 771.3 | 650.0 |
| Feed | 1,665.0 | 1,842.0 |
| Inedible tallow | 331.7 | 396.6 |
| Grease | 1,333.3 | 1,445.4 |
| Yellow grease | 809.3 | 885.6 |
| Other grease | 524.0 | 559.8 |
| Methyl esters | 529.5 | (D) |
| Inedible tallow | (D) | (D) |
| Yellow grease | (D) | (D) |
| Other grease | (D) | 222.5 |
| Other inedible products | (D) | (D) |
| Lard: | | |
| Consumption: | | |
| Selected edible and inedible products | 296.2 | 340.1 |
| Edible products | 138.0 | 173.7 |
| Baking or frying fats | (D) | (D) |
| Margarine | (D) | (D) |
| Other edible products | - | - |
| Inedible products | 158.2 | 166.4 |
| Lubricants | (S) | (D) |
| Methyl esters. | (D) | 145.9 |
| Other inedible products | (D) | (D) |
| Production: | | |
| Edible tallow | 1,859.3 | 1,837.3 |
| Inedible tallow and grease | 6,021.9 | 6,220.3 |
| Inedible tallow | 3,299.0 | 3,375.6 |
| Grease | 2,722.9 | 2,844.7 |
| Yellow grease | 1,403.6 | 1,632.1 |
| Other grease | 1,319.4 | 1,212.6 |
| Lard | 312.1 | 346.1 |
| Poultry fat | 1,417.6 | 1,378.8 |
| Tall oil, crude | 1,344.0 | 1,217.2 |

Source: U.S. Census Bureau (2011); (D) - Withheld to avoid disclosing data of individual companies; (S) - Withheld because estimates did not meet publication standards

In 2013 The Energy Information Administration of the U.S. Department of Energy reported 468 million pounds of white grease and 48 million pounds of other animal fats were used for biodiesel (USDOE/EIA 2014).

USDA-ERS reports lard consumption and production were 815 and 875 million pounds in 2013, respectively (USDA/ERS 2014m). Production has been relatively stable and annually averaged 870 million pounds over 2011-2013. For market year 2009, which covers October 2008 to September 2009, USDA-ERS reported lard production was 864 million pounds and lard consumption was 780 million pounds.

For 2009 and 2010 the Census Bureau reported consumption of edible tallow at 1499 and 676 million pounds, respectively, with consumption for edible (inedible) products being 261 (1238) and 161(514) million pounds in 2009 and 2010, respectively (Table A-18). [Note that USDA reported edible tallow consumption of 1,681 and 1,902 million pounds in 2009 and 2010, respectively (USDA/ERS 2014n).] In 2009, of the edible tallow used for edible products, 256 million pounds was for baking or frying fats.

USDA-ERS reports edible tallow consumption and production were 1,880 and 1,965 million pounds in 2013, respectively (USDA/ERS 2014n). Production annually averaged 2,023 million pounds over 2011-2013. For market year 2009, which covers October 2008 to September 2009, USDA-ERS reported lard production was 864 million pounds and lard consumption was 780 million pounds.

In this analysis, 9% of PHOs be replaced by lard and edible tallow. Based on 2.53 billion pounds of PHO, 9% is 228 million pounds. If one based the allocation between lard and edible tallow on production, based on USDA data for 2013, with lard production at 875 million pounds and edible tallow production at 1,965 million pounds, the allocation would be 70 million pounds of lard and 158 million pounds of tallow. However, there are characteristics of lard and tallow that make lard preferable for some uses. Tallow has a higher level of saturation than lard, higher melting point, and a "waxy mouth feel," but is suitable for sausage products (Ockerman 2015). A fat with a high melting point can result in a waxy or greasy taste (Ghotra et al. 2002). Ockerman and Basu (2006) state that when lard is substituted for vegetable oils in baking the amount should be reduced by 25%. In this analysis it is assumed that lard substitutes for PHOs on a 1- for 1-basis. In this analysis, lard replaces 5% (127 million pounds) and tallow 4% (101 million pounds) of PHOs.

The Census Bureau data indicated that lard that meets edible specifications (even if used for inedible purposes) is around 300 to 340 million pounds, and of this 140 to 170 million pounds is used in edible products. If 127 million pounds of additional lard is needed, this is a large fraction of the edible lard in the Census Bureau data. Based on USDA/ERS data total hog derived fat is around 870 million pounds, this would be 14% of lard production. A majority of the USDA reported lard production is choice white grease, which does not meet edible specifications.

Lard is a byproduct of pork production, so the quantity produced depends on the quantity of pork production. The U.S. Department of Agriculture projects an increase in pork production by 2023 of about 15 percent from the average of 2012 to 2014 (USDA/OCE-WAOB 2014), which would result in about an additional 120 million pounds of lard supply. Replacing 127 million pounds of PHOs with lard would require 14 percent of the lard production in 2013. Up until the 2010/11 marketing year the price of lard was less than soybean oil. From the 2011/12 marketing year to the present the price of lard has been above that of soybean oil (Figure A-3). For the 2013/14 marketing year (October to September) the price of lard averaged \$0.439/lb versus a soybean oil price of \$0.382/lb (USDA/ERS 2014e).

If lard is substituted for partially hydrogenated oils the demand for lard may increase which would increase the value of the lard produced jointly with pork. Nelson (2010) estimated that 433,000 tons of lard was produced (and we assume this was in 2009). Pork production was 23.0 million pounds in 2009 (USDA/OCE-WAOB 2011), thus 0.0377 pounds of lard is produced per pound of pork. USDA estimates lard production at 875 million pounds and pork production at 23.17 billion pounds in 2013, and also a very similar lard-to-pork ratio of 0.0378. Valuing pork at \$61/cwt (\$0.61 per pound) live equivalent (USDA/OCE-WAOB 2014), lard at \$0.40/lb, and 0.0377 pounds lard per pound of pork, then value of lard is \$350 million, or 2.5 percent that of pork. Kaiser (2012) reports the supply elasticity of pork to be 0.296 (i.e. a 1 percent increase in pork price causes a 0.296 percent increase in pork production). [Kaiser (2012) reports a retail price supply elasticity of 0.203). Koo et al. (1988) report a long-run supply elasticity of 0.199 to 0.149.

Yen and Chern (1992) estimate an own price elasticity for lard for a number of models, -0.862, -0.807, -0.887, and -0.080 and report much lower estimates by Goddard and Glance (1989) and Gould et al. (1991), of -0.17 and -0.277, respectively. Yen and Chern dismiss their low estimate of -0.080.

Based on a starting lard price of \$0.40 per pound the value of lard is \$350 million. If an additional 127 million pounds of lard is required, this is a 14.4 percent increase in lard demand. Applying a price elasticity of 0.862 (from Yen and Chern), the price of lard increases by 12.5 percent (0.144 * 0.862). Lard price increases by \$0.050 per pound and the total value of lard increases to \$394 million. If one of the lower price elasticities is applied (e.g. Gould et al. 1991), say 0.277, then lard price increases by \$0.0160 per pound and the total value of lard is \$364 million.

If lard price increases by \$0.050 per pound, then the value of the hog (pork meat plus lard) increases by 0.302 percent [=lard@875 million lb * \$0.050/lb/(lard@875 million lb * 0.40/lb + pork@23 billion lb * 0.61/lb) * 100]. Using a supply elasticity of 0.296, the supply of pork increases by 0.0895 percent, or 20.7 million pounds. Using the lower elasticity estimates of Koo et al. would lead to a lower projected increase in pork production. If lard price only increases by \$0.0160, using Kaiser's supply elasticity of 0.0296 results in a 0.029 percent increase in pork production, or 6.6 million pounds.

Tallow is a byproduct of beef production, so the quantity produced depends on the quantity of beef production. The U.S. Department of Agriculture projects an increase in beef production by 2024 of about 2.6 percent from the average of 2012 to 2014 (USDA/OCE-WAOB 2014), which would result in about an additional 51 million pounds of edible supply. Replacing 101 million pounds of PHOs with lard would require 5.2 percent of the edible tallow production in 2013. Up until the 2013/14 marketing year the price of edible tallow was less than the price of soybean oil. From the 2013/14 marketing year the price of edible tallow was above that of soybean oil (Figure A-3). For the 2013/14 marketing year (October to September) the price of edible tallow averaged $0.398 per lb versus a soybean oil price of $0.382 per lb (USDA/ERS 2014e).

Nelson (2010) estimated edible tallow production of 1,492,300 tons, or 2,985 million pounds. USDA/OCE-WAOB 2011) estimates beef production of 27.6 billion pounds in 2009, giving a ratio of 0.1082 pounds of edible tallow per pound of beef. For 2013 USDA/ERS (2014n) estimates edible tallow production of 1,965 million pounds and beef production of 25,592 million pounds, or 0.0768 pounds pound of edible tallow per pound of beef. Valuing beef at farm price of $130 per cwt ($1.30 per pound) (USDA/OCE-WAOB 2014), edible tallow at $0.40/lb, and 0.0768 pounds edible tallow per pound of beef, then value of edible tallow is $786 million, or 2.4 percent that of beef.

Supply elasticities estimated for beef are relatively low. Skold et al. (1988) and Langmeier and Thompson (1967) estimate 0.16, Ospina and Shumway (1979) estimate 0.14, and Folwell and Shapouri (1977) estimate 0.04. We use 0.16.

Yen and Chern (1992) estimate an own price elasticity of demand for edible tallow for a number of models, -1.7380, -1.5962, -1.7629, and -0.0873 and report a much lower estimates by Goddard and Glance (1989) of -0.41. Yen and Chern dismiss their low estimate of -0.080. We use an average of the first three elasticities from Yen and Chern of -1.7 as well as -0.41 from Goddard and Glance for a low number.

Based on a starting edible tallow price of $0.40 per pound the value of edible tallow is $786 million. If an additional 101 million pounds of edible tallow is required, this is a 5.16 percent increase in edible tallow demand. Applying a price elasticity of 1.7 (from Yen and Chern), the price of edible tallow increases by 8.8 percent (0.0516 *1.7). Edible tallow price increases by $0.0351 per pound and the total value of edible tallow increases to $855 million. If the lower price elasticity from Goddard and Glance is applied, 0.41, then edible tallow price increases by $0.0085 per pound and the total value of edible tallow is $803 million.

If edible tallow price increases by $0.0351 per pound, then the value of the beef cattle (beef meat plus edible tallow) increases by 0.202 percent [=edible tallow @1965 million lb * $0.0351/lb/( edible tallow @1965 million lb * 0.40/lb + beef@25.59 billion lb * 1.30/lb) * 100]. Using a supply elasticity of 0.16, the supply of beef increases by 0.032 percent, or 8.3

million pounds. Using the lower demand elasticity estimate of Goddard and Glance for tallow would lead to a lower projected increase in beef production of 2.0 million pounds.

It can be argued that the mere substitution of lard and tallow for a partially hydrogenated vegetable oil would not increase the price of lard and tallow that much because oils and fats can be substituted for each other in many applications, resulting in primarily a reshuffling of the uses of fats and oils (Sommerville 1993). It can be argued that the above estimates of changes in pork and cattle supply represent maximum impacts.

## *External costs for lard and tallow*

External costs for substituting lard and tallow for PHOs are summarized in Table A-19 based on the ranges changes in pork and beef production calculated above and the costs from Table A-12.

**Table A-19. Total external costs from changes in beef and pork production resulting from increased lard and tallow use**

| **External cost factors from:** | **Tegtmeier and Duffy** | | **Schaffer et al.** | | **Pretty et al.**[a] | |
|---|---|---|---|---|---|---|
| **Tallow (beef)** | **2013$/lb meat (Table A-13)** | | | | | |
| low | 0.0496 | | | | | |
| high | 0.1383 | | | | | |
| **Lard (pork)** | | | | | | |
| low | 0.0468 | | | | | |
| high | 0.1292 | | 0.1466 | | | |
| | **Supply change (million pounds)** | | | | | |
| | low | high | low | high | low | high |
| Beef | 2.00 | 8.29 | 2.00 | 8.29 | 2.00 | 8.29 |
| Pork | 6.65 | 20.73 | 6.65 | 20.73 | 6.65 | 20.73 |
| **Tallow (beef)** | **External costs (millions of 2013 dollars)** | | | | | |
| low cost | 0.10 | 0.41 | | | | |
| high cost | 0.28 | 1.15 | | | 0.60 | 2.48 |
| **Lard (pork)** | | | | | | |
| low cost | 0.31 | 0.97 | | | | |
| high cost | 0.86 | 2.68 | 0.97 | 3.04 | 1.86 | 5.80 |

[a] multiply Tegtmeier and Duffy costs by 2.1658

## *Butter*

Butter production was 1.863 and 1.860 million pounds in 2013 and 2012, respectively (USDA/NASS 2014b). For butter to replace 1% of PHOs would require 25.3 million pounds of butter, or 1.36% of total butter production. Yen and Chern (1992) (4 estimates), Goddard and Glance (1989) (1 estimate) and Gould et al. (1991) (1 estimate), estimated elasticities of demand for butter as: 0.6711, 0.5745, 0.5365, 0.7193, 0.53, and 0.662. The average of these elasticities is 0.616. Using the average demand elasticity of 0.616, a 1.36% increase in butter production leads to a 0.84% increase in butter price. Meyers et al. (1992) estimated that a 1% increase in butter price leads to a 0.087% increase in milk utilization. We assume that 1% increase in butter price leads to a 0.087% increase in milk production. Therefore a 0.84% increase in butter price leads to a 0.0727% increase in milk production, or 146 million pounds.

Milk production was 200.5 and 201.2 billion pounds in 2013 and 2012, respectively (USDA/NASS 2014b). For milk production a typical feed efficiency (pounds of milk per pounds of feed) is 1.4 or higher (de Ondarza 2001). Based on 2013 production and using a feed efficiency of 1.5, 97.6 million pounds of feed is required. Average milk production per cow in 2013 was 21,685 pounds (USDA/OCE-WAOB 2014). To produce the additional milk 6,700 cows are needed.

As with beef and pork production there the two components of the external costs: for the livestock impact and the feed impact. The sum of the external costs for butter is low, ranging from \$0.57 to \$3.9 million, depending on assumptions made about supply and demand elasticities and which studies of external costs of livestock and feed are used (Table A-20).

**Table A-20. External costs of increased butter use**

| | | **million pounds** | |
|---|---|---|---|
| increase in milk production | | 146 | |
| increase in feed use | | 97.59 | |
| External cost factors from: | | Tegtmeier and Duffy | Pretty et al.[a] |
| | | 2013$ per pound of feed | |
| external feed cost | low | 0.0056 | |
| | high | 0.0182 | |
| | | 2013$ per pound of milk | |
| livestock cost | low | 0.0227 | |
| | high | 0.0235 | |
| | | millions of 2013 dollars | |
| external feed cost | low | 0.547 | |
| | high | 1.779 | |
| external livestock cost | low | 0.0227 | |
| | high | 0.0235 | |
| total external cost | low | 0.570 | 1.235 |
| | high | 1.803 | 3.905 |

[a] multiply Tegtmeier and Duffy costs by 2.1658

### *Summary of costs*

External costs for crops and animal products are summarized in Table A-21. Because of imported palm oil replacing domestically produced vegetable oils, domestic crop acreage would decrease and crop external costs are negative as a result. If in the world market vegetable oils demand simply shifted between uses (e.g. palm oil used for biodiesel is now used for food and partially hydrogenated soybean oil formerly used for food is now not partially hydrogenated and used for biodiesel). The impact of the increased use of lard, tallow, and butter is shown on the last line of Table A-21 (Livestock cost) (the sum of beef, pork, and milk) ranging from $1.0 to $12.7 million.

**Table A-21. External costs estimated**

| External cost factors from: | Tegtmeier and Duffy | | Pretty et al. | |
|---|---|---|---|---|
| | low | high | low | high |
| | external costs (million 2013 dollars) | | | |
| Crops | -1.31 | -106.10 | -9.22 | -229.79 |
| Beef (tallow) | 0.10 | 1.15 | 0.60 | 2.48 |
| Pork (lard) | 0.31 | 2.68 | 1.86 | 5.80 |
| Milk (butter) | 0.57 | 1.81 | 1.24 | 3.91 |
| Total | -0.33 | -100.47 | -5.53 | -217.60 |
| Livestock cost | 0.98 | 5.63 | 3.69 | 12.19 |

## A.8 CONCLUSIONS

Replacing partially hydrogenated vegetable oils does not create additional demand over the entire market for vegetable oil/fats. It may shift demand for various vegetable oils/fats, reducing some and increasing others. Therefore, in general, one would expect minimal impacts.

This analysis examines a combination of potential substitutes for PHOs (Table A-13). These options include domestically produced oils, domestically produced fats, and imported palm oil. Because of the imported palm oil, total estimated domestic external costs range from -$0.33 to -$218 million. The portion of the external costs from use of fats (lard, tallow, butter) to replace 10% of PHOs are modest, having a range of $1.0 to 129 million (as an upper bound).Some oils that were previously partially hydrogenated may replace palm oil either domestically or internationally, or lard and tallow used for biodiesel, and this would reduce the overall impacts.

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