ARTICLES

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Current Food Safety Issues of Home-prepared Vegetables and Herbs Stored in Oil

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ABSTRACT

Consumer interest in storing vegetables or herbs in oil or infusing oils with these products has grown over recent decades. Vegetables and herbs stored in oil provide several conditions necessary for botulinum toxin production, including an anaerobic environment. Studies of documented outbreaks of botulism have identified vegetables and herbs in oil as the food source, with most outbreaks traced to home-prepared versions. Implicated foods include peppers, garlic, mushrooms, and eggplant. Visual or other organoleptic clues do not provide adequate information to prevent botulism. Most Cooperative Extension resources have communicated the risks and hazards of storing these foods at room temperature and suggest refrigeration, freezing, drying, and acidifying as alternatives. The safest recommendation is to freeze vegetables or herbs stored in oil. If the product is not frozen, it should be refrigerated and then either consumed within four days or discarded. Future research is required to clarify the potential of additional hurdles to preparing and storing these foods safely. Possible research areas include the use of boiling water canning, acidification, and drying followed by an acid dip.

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INTRODUCTION

Vegetables and herbs in oil provide four conditions necessary for botulinum toxin production: (a) a likely natural presence of *Clostridium botulinum* spores, (b) an anaerobic environment, (c) a pH greater than 4.6, and (d) a water activity (a_w) greater than 0.85. Studies of documented outbreaks of botulism have identified vegetables and herbs in oil as the food source, with most outbreaks traced to home-prepared versions *(16, 28, 30–32)*. The U.S. FDA has prepared regulations for commercial processors who make vegetables and herbs in oils (21 CFR 114 – Acidified Foods), but there are no validated processes for home-prepared versions.

In 1973, seven persons contracted botulism after eating improperly canned vegetables in oil. Commercially canned peppers in oil were implicated epidemiologically, and type B toxin was identified in leftover peppers. The processor voluntarily recalled the pepper product, and no further cases were reported *(6)*. In 1985, 37 people were sickened with botulism after eating a garlic-in-oil preparation made in a restaurant *(30, 31)*. This was followed by a laboratory investigation indicating the survival of and toxin production by *C. botulinum* in garlic in oil preparations *(29)*. After a second botulism outbreak

TABLE 1. Growth inhibition and heat resistance of *C. botulinum (13, 26)*

Clostridium Group	Growth Inhibition[1]				Heat Resistance (min)	
	Temp	pH	A_w	NaCl[2]	$D_{90°C, 194°F}$	$D_{121°C, 250°F}$
Mesophilic/proteolytic	≤ 10°C (50°F)	≤ 4.6	≤ 0.93	≥ 10%	toxin 0.15	spores 0.2
Psychrotrophic/non-proteolytic	≤ 3.3°C (38°F)	≤ 5.0	≤ 0.97	≥ 5%	toxin 0.15	spores 1.5

[1]Under optimal conditions

[2]Water phase NaCl

from garlic-in-oil preparation in 1989, the FDA ordered the removal of commercial garlic-in-oil preparations that had no acidifying agent (phosphoric or citric acid) from store shelves and required that all future preparations be properly acidified before the garlic is added to oil *(22)*. Despite the initial FDA warning, home-bottled garlic in oil was associated with botulism in 1991 in California, 1999 in Florida *(28)*, and 2003 in Denmark *(21)*.

Other outbreaks of botulism have implicated home-prepared vegetables or herbs covered in oil. As recently as 1999, a botulism outbreak in Florida was linked to homemade garlic-infused oil, whose ingredients included cloves of garlic, rosemary, thyme, and olive oil *(24)*. In 1998, a case of botulism type A in the U.S. implicated home-prepared mushrooms covered in oil *(16)* and two cases in Britain implicated mushrooms covered in oil *(27)*. In Italy, where this method of home food preservation is popular, two separate incidents of foodborne botulism in 1993 were due to contaminated home-prepared eggplant stored in oil *(32)*. Between 1994 and 1998, more than 100 cases of botulism reported in Italy have been traced to home-prepared vegetables stored in oil or water *(4)*. These outbreaks collectively demonstrate the need for validated procedures specifically targeting consumers who preserve vegetables and herbs in oil. This paper reviews current food safety issues with regard to home-prepared vegetables and herbs in oil and discusses various hurdles available to consumers.

CLOSTRIDIUM BOTULINUM

A summary of *C. botulinum* and botulism can be found online in the U.S. FDA-CFSAN Bad Bug book *(13)* and the ICMSF, *Microorganisms in Foods*, volume 5 *(26)*. There are numerous strains of *C. botulinum,* but they are commonly divided into two major groups (Table 1).

Group I – Mesophilic strains

C. botulinum strains A, and proteolytic strains of B and F, collectively have very heat resistant spores. Temperatures associated with home pressure canning would be required to kill these spores in a reasonable period of time. Mesophilic strains are inhibited by acid (pH ≤ 4.6) and salt concentrations greater than 10% *(13)*.

Group II – Psychrotrophic strains

C. botulinum strain E, and non-proteolytic strains B and F, can grow at refrigeration temperatures; however, their spores are much less heat resistant than those of Group I. Pasteurization temperatures that could be achieved in home boiling water canners could kill these spores. These strains are inhibited by acid (pH ≤ 5.0) and salt concentrations greater than 5% and are commonly associated with seafood products *(13)*. Non-proteolytic strains do not usually produce overt signs of food spoilage *(13)*.

SUMMARY OF RECOMMENDATIONS ON VEGETABLE OR HERBS IN OIL FOR CONSUMERS

In two bulletins for the commercial food processing industry, the U.S. FDA has outlined procedures for safely preparing vegetables and herbs in oil *(10, 20)*. In 1989, the FDA notified producers of the commercial products to review the formulation and labeling of their products. When refrigeration is needed, both shipping cartons and products sold at retail should be clearly and prominently labeled with statements such as "Requires Refrigeration for Safety" or "Refrigerate Both Before and After Opening *(20)*. If the manufacturer wanted to sell a shelf-stable product, they were required to add microbial inhibitors or acidifying agents and disclose these additives on their labels *(20)*. The FDA issued a second bulletin in 1993 *(10)*, in which it warned consumers not to prepare any homemade spices in oil, margarine or butter for extended storage, because the protective additives used in commercial mixes are not generally available for homemade products. Consumers were urged to refrigerate all such products and to dispose immediately of any products suspected to be spoiled or to have been stored unrefrigerated. By 1999, non-acidified garlic-in-oil mixtures were formally recognized as potentially hazardous in the FDA Food Code *(13)*.

The USDA *Complete Guide to Home Canning*, the most widely recognized source of validated processes for home food canning *(33)*, includes three procedures for preparing canned vegetables that have oil in the ingredient list. One is for marinated peppers *(34)*, the second for marinated whole mushrooms *(35)* and the third for pickled three-bean salad *(36)*. Each of these procedures includes acidulants as well as preparation steps to insure adequate reduction in pH of the vegetable tissue. Since the outbreaks in the 1980s and '90s, five Cooperative Extension publications outlining safe handling procedures for home-prepared vegetables and herbs in oil have been

TABLE 2. Cooperative Extension recipes outlining handling procedures for vegetables and herbs in oil

Publication	Product in/with oil	Recommendations		
		Acidify	Storage	Shelf life
USDA 2009 *(34)*	Marinated peppers	Yes	Room temperature[1]	None listed[3]
USDA 2009 *(35)*	Marinated whole mushrooms	Yes	Room temperature[1]	None listed[3]
USDA 2009 *(36)*	Pickled three bean salad	Yes	Room temperature[1]	None listed[3]
Harris 1997 *(17)*	Garlic	No	Refrigerate	3 days
	Raw or cooked garlic	No	Refrigerate	3 weeks
	Dried garlic and herbs	No	Room temperature	None listed
	Unseasoned dried tomatoes	No	Room temperature	None listed
Raab and Woodburn 2009 *(25)*	Dried tomatoes with raw or cooked garlic added after drying	No	Refrigerate	3 weeks
	Mushrooms or chilies	No	Refrigerate	3 weeks
	Pesto	No	Refrigerate	3 weeks
Lamp 1998 *(19)*	Sun dried tomatoes with dried spices	Yes	Room temperature[1]	None listed
			Refrigerate	None listed
	Dried spices[2]	No	Room temperature	None listed
			Refrigerate	None listed
Andress 1998 *(2)*	Herbs	No	Refrigerate	3 days
	Pesto	No	Refrigerate	3 days
Kendall and Rausch 2006 *(18)*	Garlic	No	Refrigerate	10 days
	Herbs and vegetables	No	Refrigerate	10 days
	Dried tomatoes	No	Refrigerate	None listed

[1]Heat processed in a boiling water canner

[2]Simmered 120 min in hot oil

[3]No specific advice with the procedure; source states general advice in another chapter to use within one year for best quality

found (Table 2). While each publication highlights the hazards of vegetables and herbs stored in oil at room temperature, recommendations (particularly with regard to shelf life), were not consistent between the documents, and the handling instructions were on critical safety parameters not always clear.

An Oregon State University Extension Service fact sheet *(25)* presents instructions for the widest range of vegetables or herbs in oil products, including raw and cooked garlic, dried garlic and herbs, unseasoned dried tomatoes, dried tomatoes with raw or cooked garlic added after drying; mushrooms and chilies, and pesto. The authors recommend refrigeration for up to three weeks for all fresh herb or vegetable in oil mixtures. The document notes that if consumers place dried tomatoes or dried tomato-garlic-herb mixtures in oil, they may store them at room temperature. It is noted that the tomatoes, garlic, and herbs must be mixed fresh, and then dried before adding oil. The flavored oil recipes from this document are less clear. It appears to suggest that if consumers remove all of the flavoring solids (herbs or vegetables), they may store the flavored oil at room temperature; otherwise refrigeration for up to three weeks is advised.

The University of California Cooperative Extension provided a publica-

TABLE 3. Advice on refrigerated storage times for reduced oxygen foods *(1, 12, 23)*

Refrigeration	Storage Time	Treatment
< 3˚C	No limit specified	No additional hurdles are required
3–5˚C	< 10 days	No additional hurdles are required
5–10˚C	< 4 days	No additional hurdles are required
< 10˚C	> 10 days	At least one additional hurdle is required

tion on methods to safely preserve garlic *(17)* that stated that storing garlic in oil at room temperature was unsafe and that suggests storage in the freezer. No recommendations are listed for refrigeration. Although commercially prepared garlic is acidified, the publication did not recommend this method to consumers, citing its complexity.

A second publication by Lamp, from the University of California Cooperative Extension Service, was placed online in 1998 *(19)* and was available as recently as 2004, although it does not appear to be currently available. Similar to the OSU publication *(25)*, it recommends refrigeration for up to 3 weeks for flavored oils, pesto, and garlic in oil and storage at room temperature of dried tomatoes in oil. This document includes a recipe that calls for acidification of fresh tomatoes with a "sprinkle" of distilled vinegar, to which dried rosemary, basil or oregano may be added and recommends refrigeration or heat processing (canning) in pint jars for 20 minutes at 76.7–87.8 °C (170–190°F). There are no research citations, and the process does not adhere to the standards set by the USDA Complete Guide to Canning *(33)*. This publication also contains a recipe that calls for adding dried spices to oil and then heating on "low" for 120 minutes, after which the oil is sieved through multilayered cheesecloth into canning jars. The recommendation is to store this at room temperature or under refrigeration.

The University of Georgia Cooperative Extension Service (*2)* provided recommendations to county agents based on a review of other state Extension Service recommendations and the previous cautionary advice from FDA (*10*, *20)*. This publication provided recipes for infusing herb flavors in oil and for pesto. For the infusions, the oil is strained and refrigerated for up to three days. The recommendation for pesto is refrigeration for up to three days. Freezing is suggested for longer storage life.

The most recent publication, from Colorado State University Cooperative Extension Service (*18)*, has an original publication date of 2000 and an updated version publication date of 2006. Garlic-in-oil and vegetables (herbs)-in-oil recommendations are to refrigerate for up to 10 days or freeze. As the authors of some other publications have done, the authors recommend room temperature storage for dried tomatoes-in-oil mixtures, but they do not recommend storing dried herbs-in-oil mixtures at room temperature.

PRESERVATION HURDLES (BARRIERS)

In summary, the five Cooperative Extension Service publications offer as recommendations (a) freezing, with an indeterminate shelf life, (b) refrigeration for periods of 3–21 days, (c) acidification, using various methods, and (d) heat processing, using various methods. None of the publications cite research, although they do cite research-based information. Many recipes lack specificity for processes, such as weights of ingredients and times for acidification. It is clear, given the inconsistencies across these publications, that a consensus is needed on the storage practices and shelf life of home-prepared vegetable and/or herbs-in-oil mixtures. Individually validated processes are the gold standard but might not be practical, given the wide array of product combinations.

Cold storage

The best and current science-based recommendation for consumers is to store vegetable- and/or herbs-in-oil mixtures at or below 3.3°C (38°F). Outbreaks of botulism cited in this review were due to Group I (heat resistant) *C. botulinum* strains. These strains contaminated vegetables or herbs that were stored in oil at room temperature. No reported outbreaks have occurred because of products that were properly refrigerated. Storage temperatures below 10°C (50°F) will inhibit the growth of Group I strains of *C. botulinum*. However, to prevent the growth of Group II (psychrotrophic) strains of *C. botulinum,* refrigeration temperatures would have to be at or below 3.3°C (38°F). While these organisms are most commonly attributed to seafood, they may still be considered a concern in vegetable- and/or herbs-in-oil mixtures.

As already discussed, shelf-life guidelines vary widely, from three days *(2*, *10*, *17*, *20)* to three weeks *(19*, *25)*. It is believed that these shelf-life recommendations were determined from the minimum time required for the outgrowth of botulism at refrigeration temperatures. The report by Peck and others *(23)* states that with optimal circumstances, nonproteolytic *C. botulinum* can form toxin in 10 days or less at 8°C (46.4°F). Some research-based temperature-time barriers for *C. botulinum* are listed in Table 3. These range from 4 to 10 days for temperatures between 3 and 10°C (37.4–50°F). If refrigeration alone is to be used as a barrier to toxin production by *C. botulinum*, the question of home refrigerator performance must be addressed.

In an Audits International study *(3)* in which home refrigerator temperature was analyzed for 939 refrigerators in the U.S., 27.4% of the refrigerators had storage temperatures exceeding 5°C (41°F), with 1.4% of refrigerators exceeding 10.5°C (51°F). Additional data revealed

that 41% of retail food product temperatures were in the range of 5–10.5°C (41–51°F), while 6.7% of products were at temperatures > 10.5°C (51°C). These data show that refrigeration alone would not be a reliable hurdle in the U.S. The shelf life and safety of these products would depend on knowing the refrigerator temperature. Only freezing would accomplish the target temperature of ≤ 3°C (37.4°F) as a sole cold temperature hurdle or barrier to *C. botulinum* risk in these foods. The frozen mixture of vegetable or herb in oil would not support pathogen growth and would have a shelf life dictated by changes in quality. It is of interest to note that many oils will not solidify when stored in the freezer, making consumer access for portioning easier.

Heat treatment

A common resource available to consumers for heat-treating foods is canning. Pressure canning at 115–121°C (239–250°F) would be required for low acid foods *(33)* to ensure destruction of all types of *C. botulinum*. However, pressure canning garlic and similar vegetables adversely affects texture and significantly alters palatability *(17)*. Most herbs or vegetables are placed fresh into oil for preservation, but no research-based processes are available for pressure canning unacidified garlic or vegetables in oil. In fact, a 1990 outbreak of botulism was attributed to home-canned garlic in oil that was heated to a temperature insufficient to inactivate *C. botulinum* spores *(22)*.

One publication lists a recipe that calls for simmering dried herbs for 120 minutes in oil, followed by filtration through cheesecloth into a clean canning jar *(19)*. Unfortunately, the publication does not cite research-based references or give the scientific rationale for choosing this heat-based method. An oven heating method for producing herb or vegetable flavored oil found online from a non-Extension related source *(7)* in 2004 does not appear to be currently available online. This document recommends that herbs and vegetables be heated in one cup of canola oil in a 150°C (302°F) oven until the temperature of the oil reaches 120°C (248°F). The hot oil is then strained into a suitable thermal resistant, dry container. The document recommends refrigeration for up to one month. With boiling points over 121°C (250°F), most oils could be cooked to sufficient heat lethality temperatures for all *C. botulinum* types, but this approach has not been scientifically validated. It is also not clear whether heating oil to temperatures greater than 100°C (212°F) would boil off any moisture present in the vegetables or herbs and thus preclude *C. botulinum* growth. Further research must be done before methods of heating herbs or vegetables in oil are recommended.

Acidification

Using acid, naturally present or added, to prevent *C. botulinum* growth is commonly done by consumers *(33)*. The three existing procedures of canning vegetables in oil available in the USDA *Complete Guide to Canning (33)* rely on adding lemon juice and vinegar to acidify the low-acid foods to a pH value below 4.6. A boiling water canning process is used to destroy spoilage organisms and non-sporeforming pathogens.

Several of the publications from Cooperative Extension sources reviewed in this publication (Table 2) recommend storing dried tomatoes in oil at room temperature. While fresh tomatoes are considered a borderline acid food *(33)*, the drying process concentrates the available acid, making dried tomatoes an acidic food with a pH of approximately 4.0 *(9)*. Sun-dried tomatoes stored in oil are considered low risk as long as sufficient moisture is removed in the drying process *(9)*.

A few of the recipes reviewed (Table 2) mix low-acid foods with tomatoes, either before or after drying, and are not clear with regard to potential hazards of these foods when they are stored in oil. One recipe *(19)* assumes that mixing fresh tomatoes with low-acid spices before drying will acidify the spices, but no evidence or peer-reviewed citations support this claim.

One publication reviewed recommends adding 1 teaspoon of lemon juice or vinegar per 1 cup of oil to vegetable- or herb-in-oil mixtures that are to be refrigerated *(5)*. The Commonwealth Scientific and Industrial Research Organisation of Australia *(9)* recommends that consumers add vinegar to the vegetable component before any oil is added so that the ratio proportion of vegetable to vinegar by weight is not greater than three to one. The resultant mixture will then contain approximately one percent acetic acid, which would ensure a final pH below 4.6.

Drying (control of A_w)

Controlling the amount of moisture available in the product in a manner sufficient to prevent the growth of all types of *C. botulinum* that might be present in the product could be difficult *(13)*. Because water forms droplets in oil, even very small amounts can be sufficient to allow microbial growth *(8)* and botulism toxin formation *(29)*. Using dried rather than fresh vegetables and herbs in oil has been recommended as a way to allow for room temperature storage *(19, 25)*.

Multiple hurdles (barriers)

Table 3 summarizes some scientific sources for reduced oxygen food shelf life maximums based on refrigeration temperature. These times are based on refrigeration as the only hurdle. However, maintaining a refrigeration temperature below 3°C (37.4°F) or even below 10°C (50°F) could be difficult for consumers, as many do not have thermometers and apparently do not routinely monitor refrigeration temperatures *(3, 14)*. In 1992, the ACMSF published a report that made multiple hurdle recommendations on the safe production of reduced oxygen foods *(1)*. Refrigeration is the first barrier, followed by one or more additional barriers: (a) heat treatment to attain a temperature of 90°C (194°F) for 10 min or equivalent lethality (e.g. 80°C (176°F) for 129 min, 85°C (185°F) for 36 min), (b) pH ≤ 5.0 throughout the food, (c) salt concentration ≥ 3.5% throughout the food, or (d) $a_w \leq 0.97$ throughout the food. It is important to emphasize that temperatures below 10°C (50°F) inhibit group I *C. botulinum*, and the additional listed hurdles inhibit growth of the psychrotrophic group II *C. botulinum*. Sub-inhibitory levels of pH, NaCl, or acid hurdles combined may provide inhibition of *C. botulinum (11)*.

Labeling

If consumers fail to achieve the recommended hurdles or barriers employed, herbs and vegetables stored in oil present a risk for foodborne illness. If temperature or storage time is critical to the safety of the product, then proper warning labels must be placed on packages of such foods. Labels should include statements similar to those required of industry: "keep frozen", "refrigeration required" and "discard after [date]". It must be noted however, that labeling should be a choice of last resort, as it may not always be effective *(15)*.

CONCLUSIONS

The consumer recommendation that best ensures the safety of vegetables or herbs stored in oil is to freeze the product. The safety of frozen products does not change over the shelf life of the food, although quality changes will eventually occur. If consumers cannot or will not freeze the product, it should be recommended that it be refrigerated for no more than 4 days based on the recommendations in Table 3. Consumers must label their vegetable or herbs in oil accordingly to prevent confusion with other preserved products.

Future research is required to clarify the potential of additional hurdles. Heat and acid are the most common barriers employed in consumer canning. Boiling water canning would most likely achieve the required psychrotrophic *C. botulinum* lethality, but this outcome would need to be scientifically validated. Heating vegetables or herbs in oil would certainly achieve lethal temperatures, but again research is needed to determine exact recommendations. Standardized recipes, like those already published in the USDA *Complete Guide to Canning (33),* have been created to achieve a safe level of acidification when the food is prepared as described in the procedures with the canning process. Acidification of vegetables and/or herbs in oil is a hurdle employed by commercial food processors to inhibit *C. botulinum* outgrowth. No published research has been found that studied acidification and subsequent room temperature storage in the home environment; therefore, it is not recommended to consumers. More research is necessary.

Acidification of home-dried vegetables or herbs could be employed, using an ascorbic or citric acid dip. This hurdle might reduce the risk for botulism if the vegetables or herbs were incompletely dried and adequate moisture was present for botulinum growth. Likewise, dipping commercially dried herbs in an acid solution might provide an additional barrier to botulism in the event that commercially dried herbs absorbed moisture during storage. At this time, the parameters for acid dip concentrations and submersion times are not known, and research is needed before a recommendation can be made.

The salt and water activity hurdles (except drying) are not generally employed as consumer food safety hurdles and would not be recommended. Salted butter inhibits the growth of *C. botulinum* because it has 18% NaCl in its water phase (7 CFR 58). However, there is no research-based information for consumers indicating that adding herbs or vegetables to butter results in a product that is safe at room temperature or under refrigeration.

This review has attempted to draw some consensus through a review of the literature on the acceptable shelf life of refrigerated vegetable- and/or herbs-in-oil mixtures with regard to reducing the risk of botulism poisoning. A need for future research to determine the added hurdles and specific procedures that could make these foods safer has been identified. The safety risk presented by people choosing to make up their own procedures for preserving herbs or garlic in oil is documented. This material is based upon work supported by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, under Agreement No. 00-51110-9762.

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