

Production and Marketing of Huitlacoche

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Ustilago maydis (Ustilaginaceae) has, perhaps, the unique distinction of being the causal organism of a highly prized edible delicacy and much reviled disease. The fungus causes common corn smut, a disease which can result in economic losses wherever maize (*Zea mays* L., Poaceae) is grown (Smith and White 1988). Common smut is especially a problem in processing sweet corn, where the galls and spores can foul the equipment and result in an unappetizing product. On the other hand, the very same galls (Fig. 1), which reduce the income of sweet corn producers, are edible and can be a more profitable crop than the corn itself. Huitlacoche (cuitlacoche), the Hispanicized version of the Nahuatl name for the edible galls, has been consumed by the people of central Mexico since pre-contact times (Valverde et al. 1993, 1995; Zepeda et al. 2005). Huitlacoche was also consumed by the Hidatsa people of the upper Missouri (Wilson 1987). During the rainy season, huitlacoche occurs naturally in maize fields of central Mexico where it is gathered by maize growers for sale in Mexico City and surrounding areas. Currently, 400 to 500 tonnes of huitlacoche are sold annually in Mexico City (Villanueva 1997). The popularity of huitlacoche is increasing rapidly in the US, due both to the increasing size of the Mexican-American community and an interest in new foods and fusion cooking especially in high-end restaurants. At least one chef in Madison, Wisconsin gathers huitlacoche from local farmers' fields for use in his restaurant. Other US restaurants pay as much as \$30 to \$40 kg⁻¹ for frozen huitlacoche produced by specialty growers (Pataky and Chandler 2003).

LIFE CYCLE AND INOCULATION METHODS

Ustilago maydis is a basidiomycete that infects meristematic tissue (Agrios 1997). The galls produce diploid teliospores, the overwintering stage of the fungus. The teliospores germinate and form promycelium, which undergoes meiosis forming haploid sporidia. The haploid sporidia are easily maintained in culture. Genetically compatible sporidia can mate and form dikaryotic infection hyphae. Infection hyphae are the pathogenic stage that infect corn. Mating and infection are control by two loci, *a* and *b* (Pataky and Chandler 2003). The *a* locus is the mating type locus and the *b* locus is the pathogenicity locus. Mating partners need different alleles at both the *a* and *b* loci (e.g., *a1b2* and *a2b1*) to be able to infect corn. The dikaryotic infection hyphae form appressoria that penetrate the host. Appressoria form only on rapidly elongating living cells. To form kernel galls, infection hyphae grow down the silk and infect individual ovaries.

Information on environmental conditions conducive to natural infection is contradictory (White 1999). Both excessively wet and excessively dry conditions have been anecdotally associated with enhancing infection (White 1999). The solution to this contradiction is revealed by the observation that successful pollination and fertilization decreases the susceptibility of individual ovaries to infection (du Toit and Pataky 1999a; Snetselaar et al. 2001). Following fertilization of the egg an abscission zone forms at the base of the silk (Heslop-Harrison et al. 1985; Bassetti and Westgate 1993a,b). The ovary is protected from infection because infection filaments cannot grow across the layer of dead cells (Snetselaar et al. 2001). Environmental conditions that disrupt or delay pollination increase the incidence of kernel galls. Both hot, dry weather and cool, wet weather can delay pollination thus

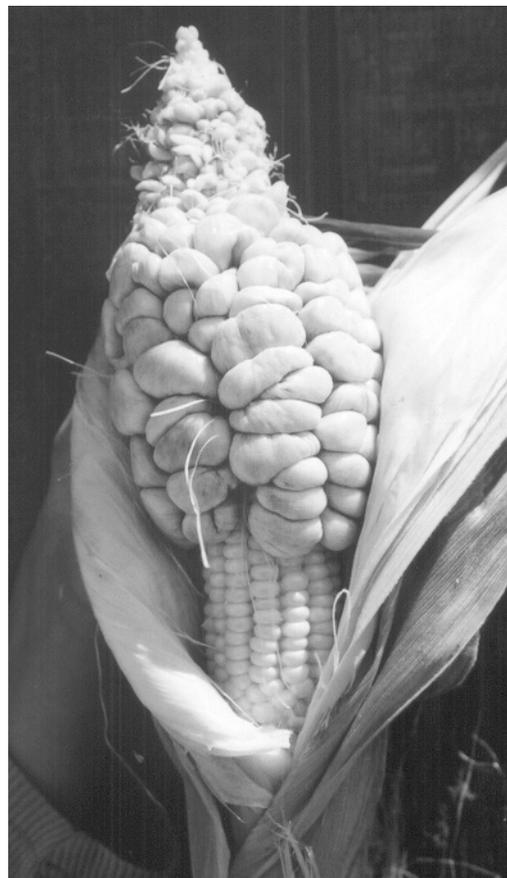


Fig. 1. Ear of sweet corn showing the galls of huitlacoche 15 to 17 days after inoculation.

increasing the incidence of *U. maydis*-infected corn ears. Rapid pollination probably also contributes to the greater resistance to natural infection of US field corn relative to sweet corn. Breeding for stress resistance has greatly decreased the delay between pollen shed and silking in field corn.

For huitlacoche to be a dependable crop, artificial inoculation is required, as opposed to gathering the wild product opportunistically. A silk channel inoculation procedure results in significantly more kernel galls than natural infection (Pataky 1991; Valverde et al. 1993). But even with artificial inoculation, the amount of infection can be inconsistent (Pataky et al. 1995). Numerous causes of variation are now recognized including successful pollination, timing of inoculation, inoculum concentration, and differences among people's inoculation techniques (du Toit and Pataky 1999b; Pataky and Chandler 2003). Thus, when using the silk inoculation method, efficient and repeatable production of large numbers of kernel galls per ear requires standardization of inoculum concentration, control of pollination, and accurate timing of inoculation.

Within a few days of infection disfigured tissue can be observed. Small, white, firm galls covered with a semiglossy periderm form within 10 days and enlarge for 2 more weeks (Pataky and Snetselaar 2006). Fourteen to 15 days after infection, galls start to have a gray, silvery appearance as streaks of blackened tissues (teliospores) begin to form. By 16 to 18 days after infection, about 70% of the gall tissue is blackened and the galls have a semi-fleshy, mushroom-like integrity. The periderm ruptures 21 to 23 days after infection and the galls become a sloppy, wet, mass of teliospores. Eventually the galls dehydrate to form sooty, powdery masses of teliospores (Pataky and Snetselaar 2006).

Quality of huitlacoche as defined by color and flavor changes over time. As determined by a chef at a high-end restaurant (Pataky and Chandler 2003), the quality of galls harvested 12 to 14 d after inoculation is unacceptable due to lack of teliospores. Galls harvested 15 d after inoculation have marginal quality. Quality of huitlacoche harvested 16 or 17 d after inoculation was acceptable. Restaurants don't want huitlacoche in which the periderm has broken because the galls are sloppy and hard to handle. Restaurants also sometimes prepare huitlacoche in ways that the galls are presented intact. People who are used to consuming fresh huitlacoche prefer to harvest (or buy) huitlacoche when the periderm on some of the galls have split open and feel that the maximum flavor occurs at this stage. This stage presents a problem for producers and retailers as the galls are very fragile and if broken can foul grocery store display cases. Size of galls also is important. Galls of naturally-occurring huitlacoche often are very large because only a few kernels are infected per ear, thus allowing for unrestricted growth of galls. Galls produced by the silk channel method of inoculation tend to be smaller in size because nearly all kernels on an ear are infected and gall development is spatially restricted. Inoculation methods that result in infection of a lower percentage of ovaries might enhance production, marketing and quality of huitlacoche.

ECONOMICS

The economics of huitlacoche production begin with the cost of producing a corn crop. A crop of dent corn can be produced for approximately \$617/ha, while sweet corn can be more than \$3,703/ha. The increased costs for sweet corn include the costs of insecticides and fungicides and costs associated with harvesting and post harvest handling. The fact that huitlacoche must be harvested by hand means that the cost of sweet corn production would probably more accurately reflect the cost of huitlacoche production. Additional costs not included in standard sweet corn production would include the cost of detasseling, maintaining and preparing inocula, and inoculation. The largest additional costs are associated with removing the galls from the ear and bagging and freezing galls for sale. In 2006, we produced huitlacoche in relatively small lots. Based on what we thought our market could handle, we planted sequential plantings of 400 plants. Our costs were approximately \$4688 to produce a hectare of fresh market sweet corn based on a sweet corn budget from Michigan State University. If we assume the plant population would be 50,000 plants/ha and a 50% inoculation success rate, then it would cost \$0.19 to produce one ear of huitlacoche (Table 1). For 400 plants, it took less than 1 hr to prepare and maintain the inoculum, 30 minutes to detassel, 2 hr to inoculate, and 2 hr to harvest. Assuming an \$8.00/hr rate and extrapolating to a hectare the total cost to produce and harvest 25,000 ears would be \$10,188 or \$0.41 per ear. We estimate the cost of removing the galls from 400 ears was \$80 which extrapolates to \$5000 for 25,000 ears (Table 1). Assuming 130 g of galls per ear (Pataky and Chandler, 2003) the cost of producing a kilogram of huitlacoche would be \$5.92.

USES AND CHALLENGES

As part of a University Community partnership funded by the Kellogg Foundation a group of researchers from the University of Wisconsin-Madison worked with the farmer at Troy Community Farm, an urban non-profit, certified organic CSA (community supported agriculture) farm to do a trial production of huitlacoche and determine the feasibility of adding huitlacoche to the farm's line of products.

We used the method of inoculation outlined in Pataky and Chandler (2003) to produce the huitlacoche. Sweet corn was detasseled to eliminate pollination, fertilization, and subsequent abscission of the silks. Sporidial suspensions were injected down the silk channel of unpollinated ears of maize. Ears were harvested 14 to 20 days after inoculation, depending on the temperature during development. Huitlacoche was marketed fresh on the ear still enclosed in the husks or as frozen galls that had been cut from the cob. We looked at the consumer acceptance of the different products, the consumer price, and whether huitlacoche production fit the farmer's management system and business objectives.

The Pataky and Chandler (2003) inoculation method was highly effective and gave good yields of galls (Fig. 1). For the average farmer, there is a limitation in obtaining and culturing the inoculum. It is not a difficult process but it is not part of most farmers' standard techniques. This could be handled by a biological supply company, however, APHIS regulations would need to be followed.

When harvested at peak quality, as defined by flavor, the galls are highly perishable and delicate. The galls are gray with a black interior and they split easily. The galls need to be consumed within a few days of harvest. Ears sold at a Madison Wisconsin Latino grocery and deli sold rapidly. However, when the galls split open the wet sloppy teliospores fouled the refrigerated display cases and the owner was not happy. Ultimately the ears were displayed in field crates and much of the production was used by the proprietor to make foods to be sold through the deli case.

Earlier harvest, when the galls are smaller with a grey interior, resulted in galls that can be removed from the ear either by plucking or cutting and these galls can be frozen. Freezing results in some loss of quality, but can be more attractive to chefs who have to plan menus in advance and require a dependable and consistent product. Pataky and Chandler estimated that based on an estimated price of \$25/kg, the value of huitlacoche harvested 15 to 17 days after inoculation ranged from \$0.70 to \$1.68/ear.

Table 1. Activity and estimated cost of producing 400 ears, extrapolated to cost per hectare (50,000 plants/ha) and per ear assuming 50% success rate of inoculation.

Activity	Estimated cost (\$)		
	Per 400 ears	Per ha ^y	Per ear (25,000 ears)
Cost of producing sweet corn (MSU budget ^z)	37	4,688	0.19
Preparation of inoculum: 1 hr × \$8/hr	8	1,000	0.04
Inoculation: 2 hr × \$8/hr	16	2,000	0.08
Detasseling: 0.5 hr × \$8/hr	4	500	0.02
Harvest: 2 hr × \$8.00/hr	16	2,000	0.08
Total	65	10,188	0.41
Freezing (removing from ear): 10 hr × \$8/hr	80	5000 ^x	0.40
			Per kg (130 g/ear)
Total production and freezing	145	15,188	5.92

^zwww.msu.edu/~blackj/2002%20MSU%20Sweet%20Corn%20Budget.xls

^y50,000 plants/ha

^x25,000 ears

While there was a receptive market for huitlacoche in the Madison area, huitlacoche did not fit the system of the Troy Gardens farmer. This was primarily due to lack of control of resources needed for inoculation and the highly perishable nature of the product. Removing the galls and freezing them required a food processors permit, a dedicated facility and inspections, all of which were beyond the resources of our cooperating farmer. There are farmers in the US successfully producing and marketing huitlacoche and demand is increasing, however the technical and marketing requirements may make huitlacoche a better crop for a farm devoted to highly specialized crops.

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