Polycyclic Aromatic Hydrocarbon (PAH) Composition of Mesquite (*Prosopis fuliflora*) Smoke and Grilled Beef

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The major component of mesquite wood was lignin (63.96%) whereas hickory only contained 17.66% lignin. A total of 31 individual PAH having a composite concentration of 1250 μg/kg of wood was measured in condensed mesquite wood smoke. Corresponding values for condensed hickory wood smoke were 22 and 688 μg/kg, respectively. Beef patties containing 30% fat and grilled over mesquite wood had 24 PAH at a total concentration of 549 μg/kg of meat while the same beef cooked over hardwood charcoal had 16 PAH representing 68 μg/kg. Decreasing the fat content also decreased the number and amount of measurable PAH.

INTRODUCTION

The presence of both carcinogenic and noncarcinogenic PAH in smoked/grilled foods and wood smoke has been well documented (Lijinsky and Shubik, 1964, 1965; Lijinsky and Ross, 1967; Rhee and Bratzler, 1968; Tilgner and Daun, 1969; Rusz et al. 1971; White et al., 1971; Toth and Blaas, 1972; Potthast and Eigner, 1975; Panalaks, 1976; Steinig, 1976; Borys et al., 1977; Obiedzinski, 1977; Obiedzinski and Borys, 1977; Potthast, 1978, 1979; Lo and Sandi, 1978; Doremire et al.,, 1979; Lintas et al., 1979; Binnemann, 1979; Fretheim, 1983; Larsson et al., 1983; Colmsjo et al., 1984; Lawrence and Weber, 1984). Numerous factors can contribute to the formation of PAH in smoke and foods, with several important ones being wood composition, temperature of pyrolysis (Tilgner, 1977), and meat lipid content (Doremire et al., 1979).

Recently, mesquite, which is a leguminous plant of the American Southwest, has become quite popular as a fuel source for grilled foods. Its advocates claim that its high combustion temperature gives food a unique flavor and results in a moist product. However, no published information on mesquite composition is available.

Therefore, this study was designed to determine the general composition of intact mesquite and to measure the types and amounts of PAH generated in both model smoke generation systems and with grilled beef patties containing varying amounts of fat.

MATERIALS AND METHODS

Wood Source and Preparation. Commercial mesquite wood approximately 5–10 cm in size was obtained. This was used as such for the grilled meat portion of the study. Another portion of wood was manually split into smaller pieces and processed through a Wiley Mill equipped with a 2-mm screen to produce a sawdust that was used in the smoke generation portion of the study.

Meat Source and Preparation. Commercially available beef patties, averaging 115 g in weight, advertised as being 90, 80, or 70% lean and verified in duplicate (AOAC, 1975), were obtained. Approximately 1 kg of mesquite wood was ignited in a hometype open barbecue grill. After 40 min, four patties of the same composition were placed flat on a wire rack situated 10 cm from the surface of the spread coals. They were cooked 3 min on one side and then turned to cook for an additional 2 min. Upon removal from the grill, products were placed in foil and stored at −20 °C until analysis the following week. To serve as a control, patties were also prepared under identical conditions using commercially available hardwood charcoal.

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Table I. Composition (%) of Mesquite and Hickory Sawdusts

	mesquite	hickory		mesquite	hickory
moisture	5.1	4.0	lignin	64.0	17.7
nitrogen	0.18	0.13	hemicellulose	8.1	7.1
cellulose	8.0	53.6			

Wood Analyses. Duplicate analyses for moisture (AOAC, 1975), nitrigen (AOAC, 1975), cellulose, hemicellulose, and lignin (Browning, 1967) contents were determined using mesquite and hickory sawdusts.

Smoke Generation. An all-glass laboratory smoke generator was constructed consisting of a 2-holed 500-mL round-bottom flask, which was placed into a rheostat-controlled heating mantle, and a water-cooled condenser. One port was fitted with a thermometer that was positioned in the center of a 150-g charge of sawdust. The other port was fitted with the condenser. Initial studies indicated that the maximum amount of smoke was obtained at 600–650 °C. The resulting smoke was condensed and collected for 10 min in 100 mL of distilled water. Smoke condensates were stored overnight at room temperature before PAH analyses were performed. To serve as a control, commercially available hickory sawdust was also subjected to the same smoke generation conditions.

PAH Analysis. One-hundred-gram quantities of cooked patties or 100 mL of well-shaken smoke condensate were extracted, purified, and analyzed for PAH composition by capillary gas chromatography as described by Larrson et al. (1983). Duplicate lots of each variable were analyzed.

RESULTS AND DISCUSSION

Wood Composition. Structurally, woods are primarily composed of cellulose, lignin, and hemicellulose, and during their thermal decomposition hemicellulose in the first to degrade, followed by cellulose, and then lignin (Browning, 1967). As seen in Table I, the major component in mesquite is lignin (63.96%), whereas in hickory cellulose is by far the major component. In contrast, mesquite has only a small amount of cellulose. This probably accounts for the general observation that mesquite burns hotter than most wood sources.

The moisture and nitrogen contents of the two woods were not very different. During wood pyrolysis, nitrogen may serve as the nitrogen component in the formation of certain heterocyclics such as the nitrogen component in the formation of certain heterocyclics such as pyrazines, which can make significant contributions in flavor (Maga, 1985).

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Table II. PAH Composition and Content (μg/kg) in Mesquite and Hickory Wood Smokes and in Grilled Patties of Varying Fat Content[a]

compd	smoke		mesquite wood pattie			hardwood charcoal pattie		
	mesquite	hickory	70% lean	80% lean	90% lean	70% lean	80% lean	90% lean
pyrene (P)	155	104	63	54	38	7	5	5
benzo[*a*]pyrene (BaP)	74	41	42	37	26	1	ND	ND
benzo[*e*]pyrene (BeP)	36	20	9	9	6	2	ND	ND
1-methylpyrene (1MP)	27	18	4	1	1	3	ND	ND
dibenzo[*ae*]pyrene (DaeP)	4	ND	1	ND	ND	ND	ND	ND
dibenzo[*ai*]pyrene (DaiP)	3	ND	ND	ND	ND	ND	ND	ND
dibenzo[*ah*]pyrene (DahP)	3	ND	ND	ND	ND	ND	ND	ND
dibenzo[*al*]pyrene (DalP)	2	ND	ND	ND	ND	ND	ND	ND
indeno[1,2,3-*cd*]pyrene (IcdP)	53	24	22	20	15	5	4	ND
fluoranthene (FL)	162	94	103	78	57	9	7	6
benzo[*b*]fluoranthene (BbFL)	34	22	24	21	16	ND	ND	ND
benzo[*j*]fluoranthene (BjFL)	24	11	7	7	5	ND	ND	ND
benzo[*k*]fluoranthene (BkFL)	35	14	14	10	8	ND	ND	ND
benzo[*a*]fluorene (BaFU)	66	24	28	23	17	2	1	1
benzo[*b*]fluorene (BbFU)	31	17	12	10	10	7	5	2
anthanthrene (AN)	22	7	8	7	5	ND	ND	ND
anthracene (A)	47	31	31	28	20	2	ND	ND
benzo[*a*]anthracene (BaA)	60	38	37	31	16	1	ND	ND
2-methylanthracene (2MA)	11	4	3	ND	ND	1	1	ND
9-methylanthracene (9MA)	3	1	ND	ND	ND	ND	ND	ND
dibenzo[*ac*]anthracene (DacA)	5	ND	2	ND	ND	ND	ND	ND
dibenzo[*ah*]anthracene (DahA)	2	ND	ND	ND	ND	ND	ND	ND
9,10-diphenylanthracene (DPA)	3	ND	ND	ND	ND	ND	ND	ND
phenanthrene (PA)	204	114	64	50	22	16	15	10
1-methylphenanthrene (1MPA)	17	7	5	5	4	3	1	ND
2-methylphenanthrene (2MPA)	21	15	8	6	5	3	2	ND
3,6-dimethylphenanthrene (DMPA)	6	ND	ND	ND	ND	ND	ND	ND
chrysene (CH) + triphenylene (TPA)	72	49	41	35	33	4	3	ND
picene (PI)	7	ND	1	ND	ND	ND	ND	ND
perylene (PER)	14	4	3	ND	ND	ND	ND	ND
benzo[*ghi*]perylene (BghiPER)	47	29	17	16	10	2	ND	ND
total PAH	1250	688	549	448	314	68	44	24

[a] ND = not detected. Values reported are the average from the analyses of duplicate lots of products.

Smoke Source. The PAH data for both condensed wood smoke and patties of varying fat content grilled over different wood sources are summarized in Table II. In the case of condensed mesquite wood smoke, a total of 31 individual PAH were identified having a composite concentration of 1250 μg/kg of wood. Major compounds included PA, FL, and P. BaP was present at 74 μg/kg, with the corresponding value for condensed hickory wood smoke being 41 μg/kg. Total PAH concentration for hickory smoke condensate was approximately half that of mesquite. A total of 22 PAH compounds were found in hickory smoke, with the major compounds being the same as those found in mesquite. The compounds identified in both wood sources are the same as those found in various grilled food systems (Larsson et al., 1983; Lawrence and Weber, 1984; Vaessen et al., 1984).

Fat Content. Lijinsky and Ross (1967) and Doremire et al. (1979) reported that the fat content of charcoal grilled meat can significantly influence PAH levels, with the higher the fat content, the larger the amount of PAH found in the meat. This trend was clearly evident in the current study. Overall, the 90% lean patties and approximately half the total PAH concentration as the 70% lean products irregardless of wood source while the 80% lean patties were approximately in the middle of the two extremes. In addition, fewer individual PAH compounds were detected in the leaner patties. For example, the 90% lean patties grilled over mesquite wood had 19 individual compounds whereas with the 70% lean patties 24 such compounds were detected. In the case of hardwood charcoal, the numbers were 5 and 16, respectively.

If one looks specifically at BaP, it can be seen that with hardwood charcoal pattie fat content did not influence BaP formation. However, with patties grilled over mesquite wood, major amounts of BaP were present even in the 90% lean product (26 μg/kg of meat), which increased to 42 μg/kg in 70% lean patties.

In conclusion, this study clearly demonstrates that under certain conditions the use of mesquite wood as a fuel source for grilling beef containing significant amounts of fat can result in the formation of numerous types and amounts of PAH due to the unique composition of mesquite wood.

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Registry No. A, 120-12-7; AN, 191-26-4; BaA, 56-55-3; BbFL, 205-99-2; BjFL, 205-82-3; BkFL, 207-08-9; BaFU, 238-84-6; BbFU, 14458-76-5; BaP, 50-32-8; BeP, 192-97-2; BghiPER, 191-24-2; CH, 218-01-9; DacA, 215-58-7; DahA, 53-70-3; DMPA, 1576-67-6; DPA, 1499-10-1; DaeP, 192-65-4; DahP, 189-64-0; DaiP, 189-55-9; DalP, 191-30-0; FL, 206-44-0; IcdP, 193-39-5; 2MA, 613-12-7; 9MA, 779-02-2; 1MP, 2381-21-7; 1MPA, 832-69-9; 2MPA, 2531-84-2; P, 129-00-0; PA, 85-01-8; PER, 198-55-0; PI, 213-46-7; TPA, 217-59-4; N_2, 7727-37-9; lignin, 9005-53-2; cellulose, 9004-34-6; hemicellulose, 9034-32-6.

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Effect of Oxidative Sulfitolysis of Disulfide Bonds of Glycinin on Solubility, Surface Hydrophobicity, and in Vitro Digestibility

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The effect of disulfide bond cleavage on the solubility, surface hydrophobicity, and pepsin and pancreatin digestibility of glycinin and its components was studied by turbidity, 1,8-anilinonaphthalenesulfonate extrinsic fluorescence, ultraviolet absorbance, and polyacrylamide gel electrophoresis measurements. Disulfide bond cleavage increased the solubility of glycinin and its basic and acidic polypeptide components. It increased the surface hydrophobicity of acidic polypeptides and decreased that of glycinin and basic polypeptides. The digestibility of the acidic subunits with pepsin and pancreatin was enhanced whereas glycinin and basic polypeptides showed decreased digestibility following disulfide reduction. The decrease in the surface hydrophobicity and protein digestibility of glycinin might be due to the aggregation of the basic polypeptides primarily through hydrophobic interactions.

INTRODUCTION

Although there is increasing usage, soy proteins have not yet realized their anticipated widespread use in food products. Because functional properties are directly affected by physicochemical properties of proteins, a better understanding of physical characteristics of soy proteins is essential for manipulating their functional properties in foods. (Kinsella et al., 1985; Kinsella, 1985). Two physicochemical properties that may govern many other functional properties are solubility and surface hydrophobicity (Kinsella et al., 1985). The interaction of the food protein with water is manifested by its solubility. The distribution of nonpolar patches on the protein surface determines its surface hydrophobicity, which tends to reduce solubility. Apart from the functional properties, nutritional quality of a protein is also important for the widespread usage of a protein in food formulations. Nutritional quality of a protein depends not only on its amino acid composition but also on the bioavailability of the essential amino acids. This, in turn, is affected to a large extent by the digestibility of the food protein (Del Valle, 1981). Antinutritional factors such as protease inhibitors, lectins etc., may contribute to the low digestibility of these proteins (Liener, 1978). But in addition the tightly folded native conformation of soy proteins may also be responsible for the limited digestibility of these proteins (Wolf, 1978; Rothenbuhler and Kinsella, 1985).

Soy protein is composed of mainly two components, glycinin and conglycinin. Glycinin, the major fraction of soy proteins, has a molecular weight of 350 000 and is made of two identical half-molecules. Each of these consists of three acidic (M_r 37 000–40 000) and three basic (M_r 18 000–20 000) polypeptides. Glycinin has 18–20 disulfide bonds of both inter- and intramolecular nature that contribute to the compact structure of this protein (Kella et al., 1986; Draper and Catsimpoolas, 1978). From the amino acid composition of glycinin's polypeptides it is known that about two-thirds of the S–S bonds of glycinin are contributed by the acidic polypeptides and the rest by basic polypeptides (Iyengar and Ravestein, 1981). The presence of several intramolecular disulfide bonds apparently decreases the digestibility of glycinin, and hence reduction of these should enhance its digestibility. Cleavage of the S–S bonds of glycinin using β-mercaptoethanol in the presence of 6 M GuHCl followed by the blockage of free sulfhydryl groups by iodoacetamide improves its tryptic digestibility (Lynch et al., 1977). However, these chemical modifications are not acceptable for food applications. Since sulfite is permitted in processed foods at certain levels, a method based on sulfite reduction was developed

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