Animal Source Foods to Improve Micronutrient Nutrition and Human Function in Developing Countries

Dynamics of the Nutrition Transition toward the Animal Foods Sector in China and its Implications: A Worried Perspective[1]

Barry M. Popkin*[2] and Shufa Du[†]

*Department of Nutrition, University of North Carolina at Chapel Hill, Chapel Hill, NC 27516-3997 and
[†]Institute of Nutrition and Food Hygiene, Chinese Center for Disease Control and Prevention, Beijing, China

ABSTRACT   Many changes in diet and in physical activity are occurring simultaneously in the developing world. These diet shifts include large increases in energy density, in the proportion of the population consuming a high fat diet and in animal product intake. Animal source foods (ASF) play a major role in these diet shifts. This article documents the large shifts in the composition of diets and obesity across the developing world and notes that these changes are accelerating. Using China as a case study, evidence of the speeding up of this process is presented in descriptive and more rigorous dynamic longitudinal analysis. The implications of these changes for dietary and obesity patterns and cardiovascular disease are great. Indeed, developing countries are at a point where the prevalence of obesity is greater than that of undernutrition and concerns related to intake of saturated fat and energy imbalance must be considered more seriously by the agriculture sector. Current agriculture development policy in many developing countries focuses on livestock promotion and does not consider the potential adverse health consequences of this strategy. Although linkages between ASF intake and obesity cannot be established as clearly as they are for high ASF intakes, heart disease and cancer, the potential adverse health effects linked with an increased ASF intake should no longer be ignored.   J. Nutr. 133: 3898S–3906S, 2003.

KEY WORDS: • nutrition transition • obesity • saturated fat

Although there are many important reasons for nutritionists and economists to support increased production and support of the livestock and poultry sectors, there are other equally important health and environmental reasons to limit such increases. The last several decades have seen important increases in food diversity and the intake of animal source foods (ASF)[3] in the diets of the developing world. Concurrent with increases in overall energy density of these diets, there is a higher prevalence of obesity, hypertension and diabetes and mortality linked with cardiovascular diseases (CVD). This article reviews evidence concerning whether higher animal food source consumption might be affecting diets and body composition in a manner detrimental to the health of a large and growing proportion of the total population of most lower and middle income countries.

There is a confluence of risks for various specific chronic diseases linked with a similar eating and lifestyle pattern. Broadly, it is agreed that diets that increase the risk of chronic diseases are relatively high in total fat, saturated fat, sugar, salt, alcohol, refined grains and foods of animal origin, whereas diets that protect against chronic diseases are relatively high in minimally processed grains, legumes, fiber, vegetables, fruits and foods of plant origin. Estimates of the extent to which chronic diseases can be reduced by appropriate diets and lifestyles have been made for cancer and cluster around an estimate of 30–40% (1). Comparable estimates, based on epidemiological and other analyses, could and should be made for other major chronic diseases. In fact, most of the existing research focuses on diets that modify the risk of cardiovascular disease, and the governments of many countries in the economically developed world, and more recently some countries in the developing world, have issued dietary and other lifestyle modification recommendations designed to control incidence of cardiovascular diseases (2,3). **Table 1** summarizes these general relationships. It is important to note that there is a vast and well-documented literature that stands behind these relationships with studies clearly linking relatively high intakes of ASF and saturated fats to cardiovascular disease as well as cancer.

TABLE 1

The possible effects of dietary intake and body composition on noncommunicable diseases[1]

Dietary factor	Mechanism	Health outcomes
Excess energy intake	Adipose tissue development, metabolic changes	NIDDM,[2] CHD,[2] hormone-dependent (e.g., breast) or GI (e.g., colo-rectal) cancers,[2] osteoarthritis,[2] gallbladder disease[2]
Total fat	Passive over consumption, IR	NIDDM,[3] CHD,[2] prostate cancer,[3] breast cancer,[4] colo-rectal cancer[3]
Animal fat	Unclear, fat metabolism by-products	Colon cancer[3]
Saturated fat	TC, LDL-C, TG, HDL-C	Atherosclerosis,[2] CHD,[2] hypertension,[3] NIDDM[3]
Trans fatty acids	LDL-C, HDL-C, TC, immune system	Cancers,[5] CHD[4]
Monounsaturated fatty acids	LDL-C	Cancers,[4] CHD[3]
Polyunsaturated fatty acids	HDL-C, some are anti-inflammatory	Cancers,[3] CHD[3]

TC, total cholesterol; LDL-C, low density lipoprotein cholesterol; TG, triglycerides; HDL-C, high density lipoprotein cholesterol; IR, insulin resistance; NIDDM, noninsulin-dependent diabetes melitus; CHD, coronary heart disease.

[1] Epidemiological studies support much of what is noted here but much controversy surrounds this literature and the mechanisms presented in the table. In addition, the effects of reduced physical activity are omitted, but are most important in increasing obesity, reducing fitness and increasing insulin resistance.

Category of the relationship between dietary factors and health outcomes:

[2] Well established.

[3] Fairly well established but data not complete.

[4] Still under debate.

[5] Suggestive data to date.

Source: (4).

Clearly diet is not the only risk factor for the diseases noted in Table 1 (4). There is also conclusive evidence that regular physical activity maintained throughout life, together with high fruit, vegetable and fiber-based diets, protects not only against obesity, and therefore indirectly against heart disease, but also gives direct protection against diseases of the cardiovascular system. Nonetheless, we focus this article on ASF and dietary change, and we will not examine the large and diverse literature that links these increases in energy density, saturated fats and other factors with rapid increases in the risk of major diet-related chronic diseases, including obesity.

The following section provides an overview of the rapid shift in the stage of the nutrition transition in developing countries and some evidence of the shift in nutritional status toward one that links obesity with a very different diet and lifestyle among large segments of the population. Further, it discusses briefly the shift in mortality that reveals a more complex picture of the health of developing countries that is no longer dominated by infectious and deficiency diseases.

The nutrition transition: a rapid shift toward the pattern of nutrition-related noncommunicable diseases

Throughout history, human diet, activity patterns and nutritional status have undergone a sequence of major shifts, defined by broad patterns of food use and their corresponding nutrition-related diseases (5). Over the last three centuries, the pace of dietary and activity change appears to have accelerated by varying degrees in different regions of the world. Further, dietary and activity changes are paralleled by major changes in health status, as well as by major demographic and socioeconomic changes. For example, obesity emerges early in these shifting conditions, as does the level and age at which morbidity and mortality occur. Elsewhere we described the full set of stages of the nutrition transition (5). Our interest centers on the rapid shift from a stage often termed the period of receding famine to one dominated by nutrition-related noncommunicable diseases (NR-NCD). The periods encompassing this transition are outlined in **Figure 1**. Our focus is increasingly on patterns 3–5, in particular on the rapid shift
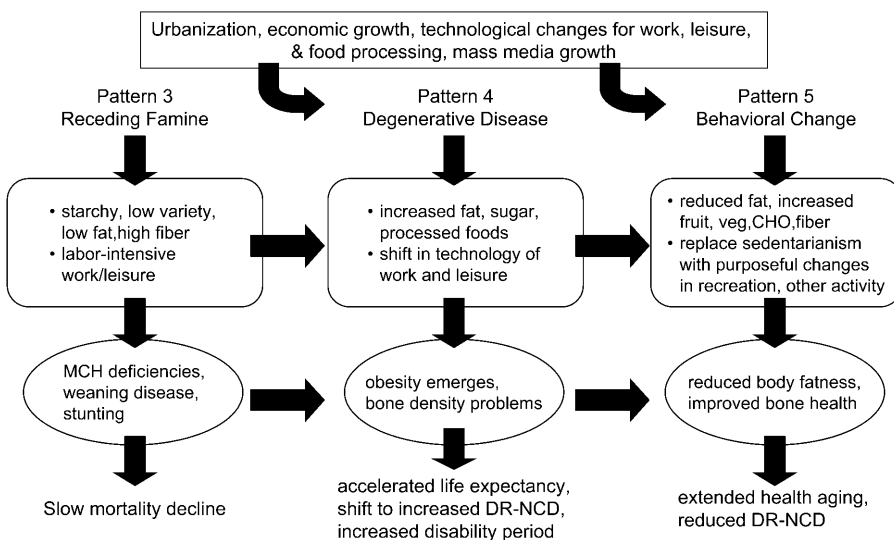

FIGURE 1 Stages of the nutrition transition.

TABLE 2

Shift in consumption in the Chinese diet (China Health and Nutrition Survey, 1989–1997) for adults, ages 20–45
(mean intake g/capita/d)

Food	Urban 1989	Urban 1997	Rural 1989	Rural 1997	Low income 1989	Low income 1997	Mid income 1989	Mid income 1997	High income 1989	High income 1997	Total 1989	Total 1997
Total grains	556	489	742	581	811	615	642	556	595	510	684	557
Coarse	46	25	175	54	226	68	98	43	78	30	135	46
Refined	510	465	567	527	585	546	544	513	517	479	549	511
Fresh vegetables	309	311	409	357	436	356	360	357	335	325	377	345
Fresh fruit	14.5	35.9	14.9	16.7	5.5	8.0	13.2	18.1	26.1	37.5	14.8	21.7
Total meat and meat products	73.9	96.6	43.9	57.6	36.3	40.2	57.5	63.9	66.5	96.2	53.3	67.8
Pork and products	66.3	81.1	40.4	48.6	30.8	32.1	49.4	55.7	65.5	80.9	48.6	56.2
Other red meat	7.6	15.5	3.6	9.0	5.5	7.9	8.1	8.2	1.0	15.3	4.7	11.6
Poultry and game	10.6	15.5	4.1	11.7	4.1	7.0	6.6	10.2	7.7	20.3	6.1	12.7
Eggs and egg products	15.8	31.6	8.5	19.6	6.0	13.9	10.6	21.7	15.8	31.5	10.8	22.7
Fish and seafood	27.5	30.5	23.2	26.9	11.8	16.4	28.7	26.0	33.4	40.1	24.6	27.9
Milk and milk products	3.7	4.0	0.2	0.9	0.8	0.1	0.2	1.4	3.5	3.6	1.3	1.7
Total animal foods	131.5	138.2	79.9	116.7	59.0	77.6	103.6	123.2	126.9	191.7	96.1	132.8
Plant oil	17.2	40.4	14.0	35.9	12.9	32.1	15.8	37.1	16.4	41.5	15.0	37.1

Source: (9).

of many of the world's low and moderate income countries from the stage of receding famine to NR-NCD (6). The importance of the shift from pattern 3 to 4 is such that for many it is synonymous with the Nutrition Transition. For convenience, the patterns are outlined as historical developments; however, earlier patterns are not restricted to the periods in which they first arose, but continue to characterize certain geographic and socioeconomic subpopulations.

For most low and middle income countries, large segments of their populations are shifting rapidly into this transition termed NR-NCD. Almost 90% of the projected world population growth over the next 20 y will take place in the developing world. Even more striking is the fact that almost all this growth will occur in urban areas. The rapid shift in stages of the nutrition transition is fueled by urbanization as well as by several less well understood shifts, including internationalization (globalization) of food production and marketing, expansion of mass media and communications and changes in the technology of work and leisure, even in the lowest income nations. Elsewhere we have presented information on these changes in detail. However, it is useful to provide some sense of the rapidity and impact of the shifts in stages of the transition.

Rapid changes in diet, physical activity and NR-NCD

In Latin America, North Africa and the Middle East, South East and East Asia and the Pacific Rim, recent changes in diet,

activity and obesity have led to a far greater burden of poor health and mortality from disease from NR-NCD than from under nutrition and infectious diseases (7). It is easiest to use data from China, where we have identical measures of diet, and of activity at work, from a large number of surveys (7,8). We supplement these data with points from other countries and then consider some obesity data from around the world.

Dietary changes in China

Cereals. During the 1980s and 1990s China saw a profound shift in intake of cereals in both urban and rural areas, and among all income groups (**Table 2**) (9). During the 8-y period from 1989 to 1997, the total intake of cereals decreased by 127 g/capita/d (67 g for urban residents and 161 g for rural residents). The decrease in the low income group was the highest: 196 g /capita, compared with their counterparts in mid and high income groups (86 and 85 g, respectively). However, there remains an inverse relationship between income and cereal intake. For example, in 1997 the daily intake of cereals in low, mid and high income groups was 615, 556 and 510 g per capita, respectively. This included a marked shift away from coarse grain consumption such as millet, sorghum and corn. China Health and Nutrition Survey (CHNS) individual intake data (3-d intake used to create a daily average) showed a 38-g/capita/d fall in daily consumption of refined cereals between

TABLE 3

Shifts in energy sources in the Chinese diet for adults, ages 20–45 (China Health and Nutrition Survey, 1989–1997)

	Energy from fat (%) 1989	Energy from fat (%) 1991	Energy from fat (%) 1993	Energy from fat (%) 1997	Energy from carbohydrates (%) 1989	Energy from carbohydrates (%) 1991	Energy from carbohydrates (%) 1993	Energy from carbohydrates (%) 1997
Urban	21.4	29.7	32.0	32.8	65.8	58.0	55.0	53.3
Rural	18.2	22.5	22.7	25.4	70.0	65.6	65.2	62.1
Low income	16.0	19.3	19.7	23.0	72.9	69.2	68.6	64.5
Mid income	20.3	25.2	25.5	27.1	67.5	62.6	62.2	60.3
High income	21.5	30.0	31.5	31.6	65.4	57.5	55.4	54.8
Total	19.3	24.8	25.5	27.3	68.7	63.2	62.1	59.8

Source: (10).

TABLE 4

Shifts in consumption of total and saturated fat for adults, ages 20–45 (China Health and Nutrition Survey, 1989–1997)

	Percent with energy from total fat <10%				Percent with energy from total fat ≥30%				Percent with energy from animal fat ≥10%			
	1989	1991	1993	1997	1989	1991	1993	1997	1989	1991	1993	1997
Urban	13.1	2.6	2.1	1.9	19.8	51.4	58.4	60.1	49.8	64.7	69.9	68.9
Rural	21.0	10.4	8.9	3.6	12.1	23.0	23.1	29.5	33.3	41.4	44.3	39.3
Low income	30.4	16.9	13.1	5.8	9.3	14.3	14.2	21.4	26.2	32.5	33.6	32.1
Mid income	14.8	5.4	6.1	2.7	16.2	31.1	31.4	35.5	42.8	50.6	53.2	42.6
High income	10.1	1.5	1.1	1.3	18.5	51.4	56.1	54.6	47.8	63.7	69.6	61.1
Total	18.4	7.9	6.8	3.1	14.7	32.0	33.7	38.5	38.8	48.7	52.0	48.0

Source: (9).

1989 and 1997, and an 89-g/capita/d decrease in coarse cereal consumption.

Vegetables and fruits. Intake of vegetables decreased between 1989 and 1997. In contrast, the intake of fruits, which are much more expensive than vegetables, increased. CHNS data showed that the urban residents' intake of vegetables did not change from 1989 to 1997, but the intake of fruits in 1997 was 2.5 times higher than in 1989 (Table 2). As a result, the total intake of vegetables and fruits increased in urban areas during this period. The intake of vegetables of rural residents decreased by 52 g/capita/d (from 409 g in 1989 to 357 g in 1997), whereas the intake of fruits increased by 1.8 g/capita/d during the same period. As a whole, total intakes of vegetables and fruits fall from 392 g/capita/d in 1989 to 367 g/capita/d in 1997. The largest decrease occurred in the low income group, where the intake decreased from 441 to 364 g/capita/d.

The sources of dietary energy. Total energy intake increased from the 1950s to the 1980s and has subsequently begun to fall as energy expenditures at work have declined. Among the energy components, there was little change in the proportion of energy derived from protein during this period, but the proportion of protein from ASF increased considerably. Only 3.1% of protein came from ASF in 1952 and this increased to 18.9% in 1992; daily intake of fat doubled in this time period (28.3 vs. 58.3 g). Sources of energy changed remarkably, with energy from fat doubling (8).

Data from the CHNS show the shift away from carbohydrates to fat in the diet. Energy from carbohydrates (**Table 3**) (10) decreased to 59.8% in 1997 from 68.7% in 1989 for all residents, and to only 53.3% from 65.8% in 1989 among urban residents, the lowest for any group. Energy from fat increased sharply from 19.3% in 1989 to 27.3% in 1997. The shift toward a higher fat diet is shown more pointedly by examining the trends in the proportion of adults consuming levels of total fat intake that would be considered very high and low, and also those consuming high animal fat diets from 1989 to 1997 (**Table 4**).

The proportion of adults with a relatively high animal fat diet, which is the proportion consuming >10% of their energy from animal fat, is considerable, about half of the overall sample and more than two-thirds of the urban sample. China does not have a measure of saturated fat in its food composition table so this measure must serve as a proxy for high saturated fat intake.

Changes in physical activity and noncommunicable disease

Energy expenditure at work, and other data we have presented elsewhere, reflects the shifts in physical activity in China (8,11). Economic activities are shifting toward the service sector, particularly in urban areas (11). The proportion of urban adults (male and female) working in occupations where they participate in vigorous activity patterns has decreased, and increased only where the activity pattern is light (see **Table 5**). In rural areas, men have reduced their activity levels at work but women—who take on more multiple sets of occupations—have increased theirs. We have also shown marked increases in television ownership, among other shifts in activity that directly affect energy expenditures (11–13).

Although few countries have nationally representative data on diet or activity, we have solid nationally representative studies of body composition from all regions of the world. Elsewhere we have presented in detail data on patterns and trends in overweight and obesity status across the developing world. Here we highlight prevalence and trends data for a few selected countries from each region. Prevalence data in Mexico, Brazil, South Africa, Egypt, Morocco, Iran, Thailand and China are presented in **Figure 2** (10,14–19). Essentially we see very high levels of overweight and obesity status among adults in many of these countries, often levels higher than in the U.S. (e.g., Egypt). **Figure 3** presents the annualized increase in the percentage points of prevalence from countries with comparable data (10,14,17–19). Compared to U.S. and European countries where the annual prevalence increase in overweight and obesity are ~0.25 each, the rates of change are very high in many of these countries (6).

Detailed morbidity data are not presented here, but it is clear that in some of these countries the prevalence of diabetes is equal to or higher than the U.S., for instance, Mexico (19). Evidence from many developing countries shows that nutrition-related chronic diseases prematurely disable and kill a large proportion of economically productive people. Over three-fourths of all nutrition-related chronic diseases occur in developing countries. In one study, we documented the high cost that these deaths and related hospitalizations are incurring on India and China (20). Others who have studied cause of death patterns and trends for these two countries have predicted

TABLE 5

Force distribution among adults, ages 20–45 y (China Health and Nutrition Survey 1989, 1997)

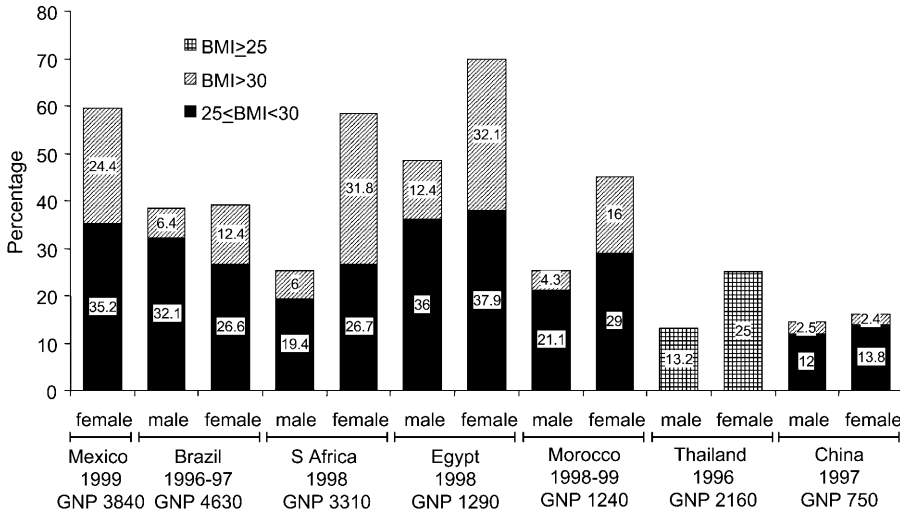|		Light (%)		Vigorous (%)	
		1989	1997	1989	1997
Urban	Male	32.7	38.2	27.1	22.4
	Female	36.3	54.1	24.8	20.8
Rural	Male	19.0	18.7	52.5	59.9
	Female	19.3	25.5	47.4	60.0

FIGURE 2 Obesity patterns among adults in the developing world: Mexico, Brazil, South Africa, Egypt, Morocco, Thailand and China.

a marked shift toward deaths from NR-NCD in each country over the next several decades. The most comparable set of mortality patterns by cause, as well as projections of mortality, come from the Global Burden of Disease project and are presented in **Figure 4** (21).

The contribution of ASF to the adverse changes in the composition of diet

In general, it is well understood that improvements in income per capita for a country are linked with increased intake of animal products and fat (22). In the case material for China, we have provided some insights into the types of shifts in the composition of diet and the role of animal products in the transition toward a pattern of NR-NCD in China. In particular, it is noteworthy that close to half of Chinese adults consume a diet with >10% of their total energy from animal fat, which is a proxy for a high saturated fat diet.

Long-term household trends in animal foods consumption

In the past 50 y, using the per capita data from the annual household survey series in China, we find that annual con-

sumption of ASF more than tripled, from a very low level of consumption of 11 kg/capita in 1952 to 38 kg/capita in 1992 **(Fig. 5)** (23). Urban residents' intake increased to 65.3 kg/capita in 1999. There was a slow rate of increase before 1979, but thereafter the rate of increase was much higher. From 1952 to 1979, intake increased only 5.6 kg (0.2 kg annually), whereas it increased by 21 kg (1.6 kg annually) between 1979 and 1992. Of the subcomponents, meat and meat products increased from 8.4 to 20.3 kg, poultry and game from 0.6 to 2.3 kg, fish from 3.2 to 7.3 kg and eggs from 2.0 to 7.8 kg, per capita, per y.

In China, meat and meat products were the main sources of ASF. At the same time the relative contribution of beef and pork products decreased from 76 to 58% in rural areas and from 57 to 44% in urban areas. The proportions of other sources increased, but at a very low level. For example, the proportion of fish increased from 11 to 16% in rural areas but showed no change in urban areas (22%); poultry increased from 3 to 10% in rural areas and from 6 to 12% in urban areas.

Using in-depth individual intake data from the CHNS we get a clear picture of the shift in diet toward ASF (see Tables 3 and 4). Urban residents' intake of ASF/capita/d in 1997 was higher than for rural residents (178.2 g for urban vs. 116.7 g for rural) and also showed a larger increase (46.7 vs. 36.8 g) from 1989 to 1997. The amount and growth in intake of ASF was positively associated with income levels. Intake in the low
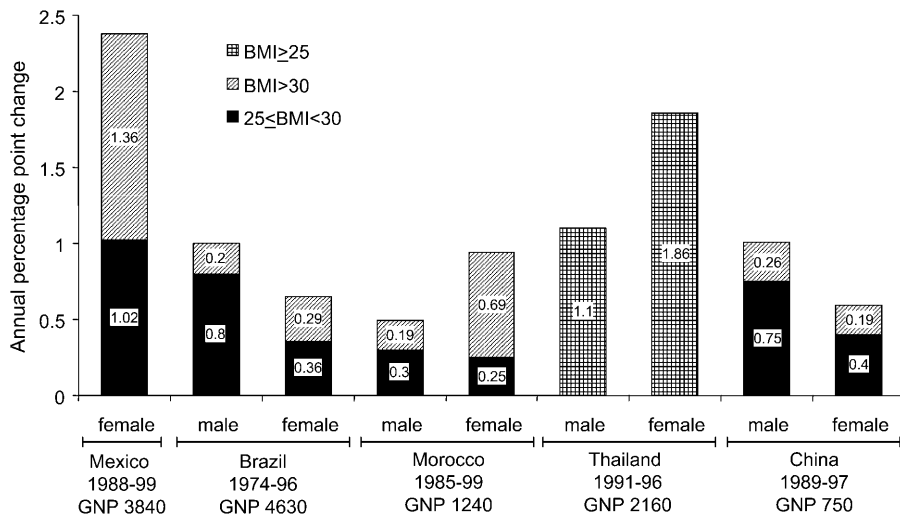

FIGURE 3 Obesity trends among adults in Mexico, Brazil, Morocco, Thailand and China.
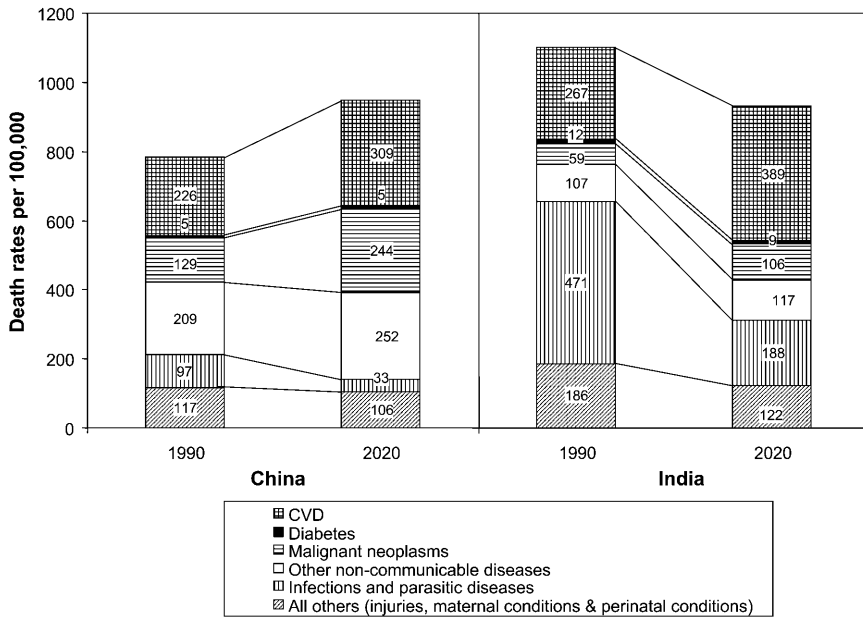
FIGURE 4 Mortality trends in China and India, 1990 and 2020.

income group was 77.6 g/capita/d in 1997, an increase of 18.6 g, whereas it was 123.2 and 19.6 g in the mid income group, and 191.7 and 64.8 g in the high income group. The intake level and the increase in the high income group from 1989 to 1997 were almost three times those in the low income group.

Table 4 also shows that the proportion of individuals in Chinese society that consume a high ASF, fat-based diet is increasing rapidly. The Chinese food composition table does not measure saturated fat so we use ASF fat as a percent of energy as a proxy measure of a high saturated fat diet. We see that over 60% of the urban sample of Chinese and close to half of all Chinese now consume too high a level of saturated animal fats.

Income and trends in ASF consumption

More instructive than this static look at trends is to examine how a more complex analysis of the dynamic longitudinal shifts in diet are affecting dietary patterns of rich and poor Chinese, and what changes we might project in their diet for the next several decades. To do this, we build on earlier modeling of the income and consumption relationship—where we showed that the changes in meat intake in that country will change rapidly as income improves (24). In particular, by analyzing these dynamic changes, we get a sense of how the economic transitions in China are affecting household intake of ASF for each income group.

We linked the adults in the CHNS from the 1989, 1991, 1993 and 1997 surveys to examine how changes in income affected shifts in diets of Chinese adults aged 20–45 in 1989 over the 1989–1997 period. This analysis, using a random effects model, controls for the prices of the key food stuffs examined at the community level, the price of kerosene and gas (to control for cost of living), education, region and urban-rural residence status, age, gender and household size. The question asked is: how will a change in income affect a change in food choice? We present here only income elasticity that is derived from this random effects model. In these graphs we present estimates of the income elasticity for each time period with 95% confidence bands for the income elasticity for selected foods and macronutrients. The confidence interval is estimated for each income level. We also examine the changes from 1989 to

1997 in the income elasticities, and confidence bands about these temporal changes in elasticities. The consumption measures are regressed on log household per capita income. The income elasticities are the derivatives of these functions of per capita income with respect to log per capita income. These are graphed against the logarithm of household per capita income to display elasticity differences across income levels. The confidence bands come from bootstrap standard errors of the elasticities and of the across time pointwise differences. The unit of observation for the bootstrap replications is a household (containing up to 8 y of data for up to several prime aged individuals).

The effect of income changes on total intake of ASF are shown in **Figure 6**. For every 10% increase in income, intake of ASF by the low income group would have increased by 3–4% in 1989. In contrast, among higher income groups the increase would have been ~2% (Fig. 6, *left panel*). The income elasticity is also inversely related to income in 1997 (Fig. 6, *middle panel*); however the change is significantly higher for the higher income groups (Fig. 6, *right panel*). These income-related differences over time are not, however, significantly different from zero, whereas the 1989 and 1997 results are all statistically significant.
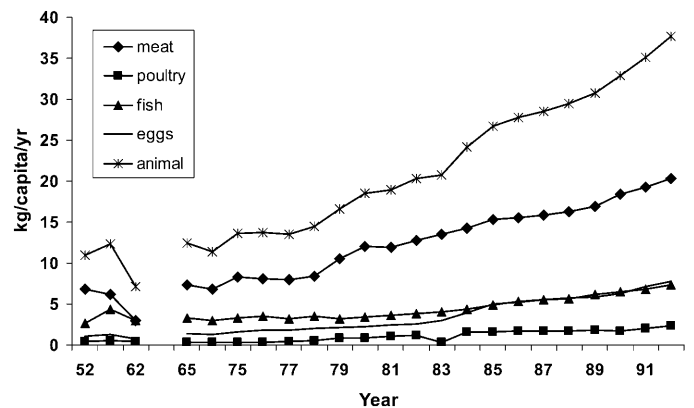

FIGURE 5 Trends in Chinese household food consumption of animal foods (kg/capita/y).
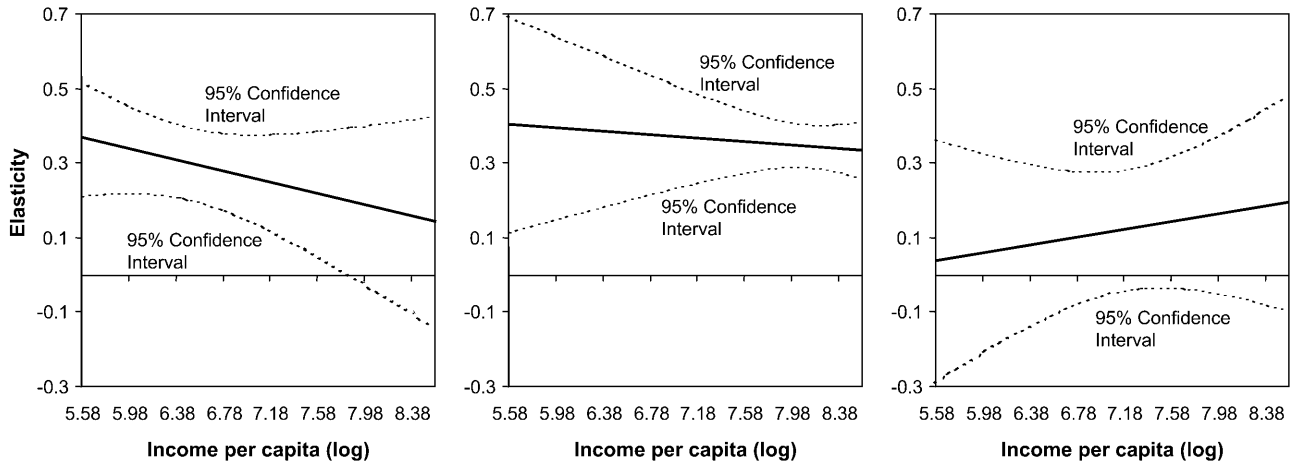
FIGURE 6 The relationships between income changes and the consumption of animal source foods: income elasticity and change in the income elasticity 1989–1997 in China.

DISCUSSION

Can we afford livestock? A complex balancing act

Examination of the effects of income increases on the likelihood and quantity of consuming poultry are illustrative of these dynamic shifts. **Figure 7** shows how inverse the income elasticity of poultry is in 1989 and 1997. The inverse income-poultry intake pattern is similar for each year. However, as for total ASF the difference is much greater for the higher income groups than the lower income groups (Fig. 7, *right panel*). Similarly, pork intake among consumers shows greater increases among higher income groups (Popkin, B. M., unpublished results). Interestingly, as the confidence intervals show, the change in income elasticities between 1989 and 1997 was not significant or even very different for two food groups, namely for pork and edible oil. The patterns for beef and mutton are somewhat comparable to those for poultry.

The nutritional implications of these dietary shifts are seen in **Figure 8**. Here we show that in both 1989 and 1997 (*left* and *middle panels*, respectively) lower income households are increasing their likelihood of consuming a high fat diet (>30% energy from fat) at a fast rate. Moreover, for every 10% increase in income, adults who are in low income groups would consume 1–2% more energy from fat in 1989 and 2–2.5% more in 1997, with each 10% income increase.

Clearly, in the developing world many changes in diet and also in physical activity are occurring simultaneously. Heart disease and cancer are rapidly increasing, as is obesity. Total fat intake in developing world diets is increasing; moreover it is clear that saturated fat intake from animal food products must be greater. The only measure of this in the CHNS data base is energy from animal fats—an imperfect proxy. This measure shows over half of the sampled Chinese adults consume excessive energy from animal fats. ASF play a major role in the shift in the composition of these diets by increasing saturated fat intake, which is linked to shifts in disease patterns. Dozens of studies have shown that high levels of consumption of ASF increase the risk for heart disease, but few studies provide a clear direct linkage with increased obesity. The causal linkage between these dietary trends and obesity is disputed by many, whereas there is a greater consensus about the role of saturated fat and other fats as a causal factor in cardiovascular disease and many cancers. Indeed, just as studies of meat intake as a component of reduced risk of micronutrient deficiency have
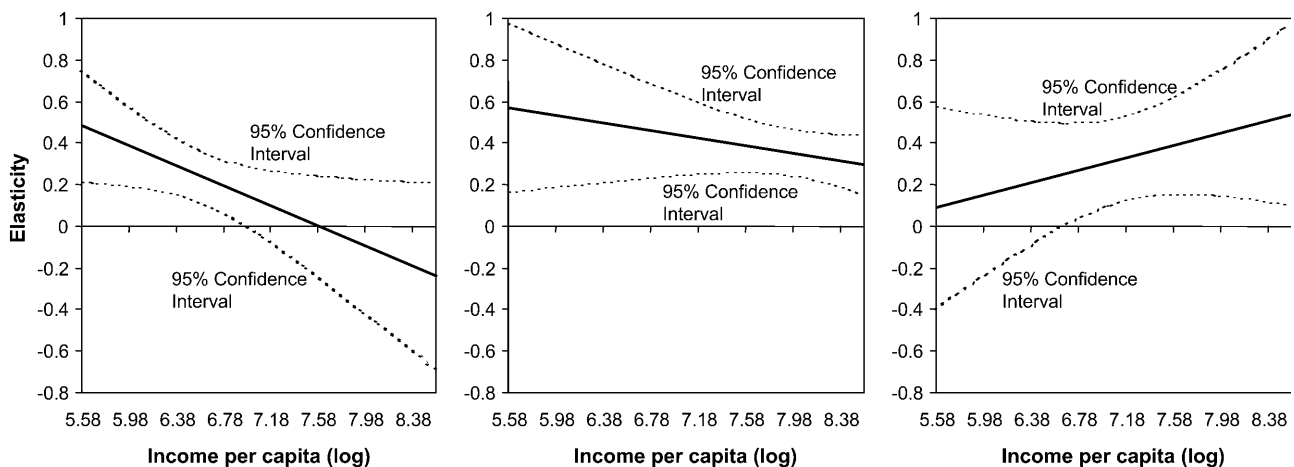

FIGURE 7 The relationships between income changes and the quantity consumed of poultry: income elasticity and the change in the income elasticity between 1989 and 1997 in China.
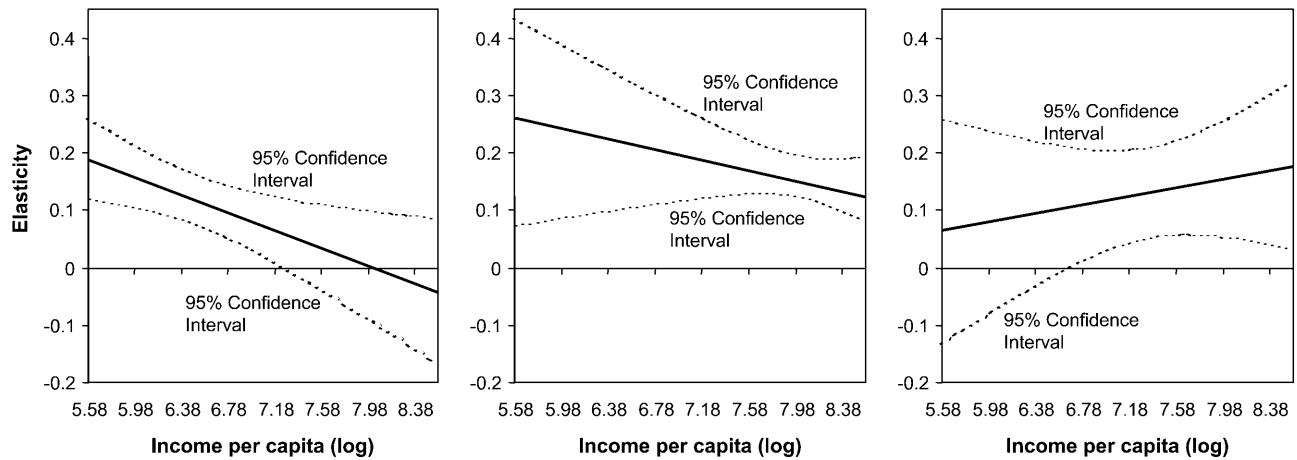
FIGURE 8 The relationships between income changes and the proportion of energy from fat consumed: income elasticity and the change in the income elasticity between 1989 and 1997 in China.

not yielded conclusive results, there is limited direct observational evidence that ASF are the cause of this shift in diet and obesity patterns. However, there are hundreds of clinical and larger trials that do show the opposite: that a grain- or vegetable-based diet is important for preventing and managing these chronic diseases. Although ASF are linked with an increased risk of these chronic diseases, it is important to note that this article is not repeating or even summarizing that literature.

This article focuses on dietary intake dynamics and then, concomitantly, obesity increases. Elsewhere, we review the evidence that links fat intake with obesity, but there is much less consensus about the exact role of ASF in the etiology of obesity (25). There are some who might argue that ASF do not have a major effect on obesity and diabetes because they are lower glycemic index foods (26); however, there is certainly little consensus for that argument.

Others have argued, in some cases quite convincingly, that a vegetarian diet is the most healthful diet (27). Campbell, Burkitt and others have argued this case based on ecological analyses of diet-disease relationships for vegetarians (28–31). Willett has noted that the avoidance of red meat is likely to account in part for low rates of cardiovascular disease and colon cancer (32,33) but he also shows in that article and many others that higher whole grain and fruit and vegetable intakes are the critical dietary factors (34,35). Certainly, increased fiber, fruit and vegetable intake is linked with reduced energy density in the diet and reduced total energy intake (36–38). Conversely, animal fats are the major source of saturated fats in most nonvegetarian diets. But the critical issue is to promote a balanced more healthful diet that includes far more higher fiber foods and far more fruits and vegetables, while limiting the high levels of ASF that are beginning to emerge in many countries.

There are of course other reasons to discourage or promote ASF. These include the effect that increased ASF intake will make on world food prices and subsequently on food intake of the poor, particularly in sub Saharan Africa, as well as environmental degradation, in some locations, and risk of diseases such as Bovine Spongiform Encephalopathy (BSE). Weighed against these and the health consequences are the beneficial employment opportunities in the meat production industry, as well as the important role that animal source foods play, when consumed in moderation, on human health.

Do we need a new model of development?

We are of the opinion that a different model of agricultural development is needed. The classical model is that governments promote cereal production first. After meaningful growth in the farm sector is attained, the promotion of livestock production is viewed as a way to generate added employment and income for farmers. There is a vast array of arguments for promoting livestock and ASF, but few have questioned this model for its adverse health effects in the developing world. Most research, as shown in the other articles presented in this supplement, focuses on the nutritional benefits of animal foods for infant growth and development. If animal food intake is not excessive, it certainly may represent an important dimension of a healthy diet with its potential for providing calcium (milk and milk products), vitamin B-12, absorbable iron and zinc and other nutrients. But when consumed so that saturated fat levels are high as they appear to be in China, the health risks are potentially significant, as are related costs in terms of health care utilization and lost productivity (20).

Overall, we note that long-term investment in ASF, and the crops needed to produce cheap animal products, most certainly has distorted relative food prices, but limited research has been undertaken on the total effect of these investments on overall dietary patterns or the composition of ASF in the total diet. Any distortion would reduce production and increase prices of pulses and fruits and vegetables and other healthful foods. More documentation of the effects of large subsidies on ASF will be needed to fully understand the implications of the long-term support for the ASF sector around the world.

What should we promote?

We do not believe the answer is any form of vegetarianism. One can consume a relative good quality vegetarian diet with some attention to protein sources (tofu, tempeh, etc.) but low fat dairy products, eggs, fish and other lower fat ASF such as poultry clearly enhance dietary quality significantly. The critical point is that the agricultural model that the developed countries (and increasingly the developing countries) followed overly promoted the animal food sector, and distorted prices and hence consumption against an array of other components of a more healthful dietary intake pattern. We must now consider new approaches that may include deemphasizing ASF

production in some locations, and ensuring healthy range of intake depending on life stage.

LITERATURE CITED

1. World Cancer Research Fund in association with American Institute for Cancer Research (1997) Food, Nutrition and the Prevention of Cancer: A Global Perspective. American Institute for Cancer Research, Washington, DC.

2. World Health Organization (1990) Diet, Nutrition, and the Prevention of Chronic Diseases: Report of a WHO Study Group. WHO Technical Report, Series 797. World Health Organization, Geneva, Switzerland.

3. Labarthe, D. R. (1998) Epidemiology and Prevention of Cardiovascular Diseases: A Global Challenge. Aspen Publishers, Gaithersburg, MD.

4. Popkin, B. M., Horton, S. & Kim, S. (2001) The nutrition transition and prevention of diet-related chronic diseases in Asia and the Pacific. Food Nutr. Bull. 22: 1–58.

5. Popkin, B. M. (1994) The nutrition transition in low-income countries: an emerging crises. Nutr. Rev. 52: 285–298.

6. Popkin, B. M. (2002) An overview on the nutrition transition and its health implications: the Bellagio meeting. Public Health Nutr. 5: 93–103.

7. Popkin, B. M. (2002) The shift in stages of the nutrition transition in the developing world differs from past experiences! Public Health Nutr. 5: 205–214.

8. Du, S., Lu, B., Zhai, F. & Popkin, B. M. (2002) The nutrition transition in China: a new stage of the Chinese diet. In: The Nutrition Transition: Diet and Disease in the Developing World (Caballero, B. & Popkin, B. M., eds.), pp. 205–222. Academic Press, London, UK.

9. Popkin, B. M., Lu, B. & Zhai, F. (2003) Understanding the nutrition transition: measuring rapid dietary changes in transitional countries. Public Health Nutr. 5: 947–953.

10. Du, S., Lu, B., Zhai, F. & Popkin, B. M. (2002) A new stage of the nutrition transition in China. Public Health Nutr. 5: 169–174.

11. Popkin, B. M. (1998) The nutrition transition and its health implications in lower income countries. Public Health Nutr. 1: 5–21.

12. Paeratakul, S., Popkin, B. M., Ge, K., Adair, L. S. & Stevens, J. (1998) Changes in diet and physical activity affect the body mass index of Chinese adults. Int. J. Obes. 22: 424–431.

13. Bell, A. C., Ge, K. & Popkin, B. M. (2002) The road to obesity or the path to prevention? Motorized transportation and obesity in China. Obes. Res. 10: 277–283.

14. Benjelloun, S. (2002) Nutritional transition in Morocco. Public Health Nutr. 5: 135–140.

15. Bourne, L. T., Lambert, E. V. & Steyn, K. (2002) Where does the black population of South Africa stand on the nutrition transition? Public Health Nutr. 5: 157–162.

16. Galal, O. M. (2002) The nutrition transition in Egypt: obesity, undernutrition and the food consumption context. Public Health Nutr. 5: 141–148.

17. Kosulwat, V. (2002) The nutrition and health transition in Thailand. Public Health Nutr. 5: 183–189.

18. Monteiro, C. A., Conde, W. L. & Popkin, B. M. (2002) Is obesity replacing or adding to under-nutrition? Evidence from different social classes in Brazil. Public Health Nutr. 5: 105–112.

19. Rivera, J. A., Barquera, S., Campirano, F., Campos, I., Safdie, M. & Tovar, V. (2002) Epidemiological and nutritional transition in Mexico: rapid increase of non-communicable chronic diseases and obesity. Public Health Nutr. 5: 113–122.

20. Popkin, B. M., Horton, S., Kim, S., Mahal, A. & Shuigao, J. (2001) Trends in diet, nutritional status and diet-related noncommunicable diseases in China and India: the economic costs of the nutrition transition. Nutr. Rev. 59: 379–390.

21. Murray, C. J. L. & Lopez, A. D. (1996) The Global Burden of Disease. Harvard University Press, Boston, MA.

22. Drewnowski, A. & Popkin, B. M. (1997) The nutrition transition: new trends in the global diet. Nutr. Rev. 55: 31–43.

23. State Statistical Bureau (2001) China Statistical Yearbook, 1952–2000. State Statistical Bureau, Beijing, China.

24. Guo, X., Mroz, T. A., Popkin, B. M. & Zhai, F. (2000) Structural changes in the impact of income on food consumption in China, 1989–93. Econ. Dev. Cult. Change 48: 737–760.

25. Bray, G. A. & Popkin, B. M. (1998) Dietary fat intake does affect obesity! Am. J. Clin. Nutr. 68: 1157–1173.

26. Ludwig, D. S. (2002) The glycemic index physiological mechanisms relating to obesity, diabetes, and cardiovascular disease. JAMA 287: 2414–2423.

27. Melby, C. L., Toohey, M. L. & Cebrick, J. (1994) Blood pressure and blood lipids among vegetarian, semivegetarian, and nonvegetarian African Americans. Am. J. Clin. Nutr. 59: 103–109.

28. Campbell, T. C., Chen, J., Brun, T., Parpia, B., Qu, Y., Chen, C. & Geissler, C. (1992) China: from diseases of poverty to diseases of affluence. Policy implications of the epidemiological transition. Ecol. Food Nutr. 27: 133–144.

29. Campbell, T. C. & Chen, J. (1994) Diet and chronic degenerative diseases: a summary of results from an ecologic study in rural China. In: Western Diseases: Their Dietary Prevention and Reversibility (Temple, N. J. & Burkitt, D. P., eds.), pp. 67–118. Humana Press, Totowa, NJ.

30. Campbell, T. C. & Chen, J. (1994) Diet and chronic degenerative diseases: perspectives from China. Am. J. Clin. Nutr. 59: 1153S–1161S.

31. Campbell, T. C. (1994) The dietary causes of degenerative diseases: nutrients vs foods. In: Western Diseases: Their Dietary Prevention and Reversibility (Temple, N. J. & Burkitt, D. P., eds.), pp. 119–152. Humana Press, Totowa, NJ.

32. Van Dam, R. M., Willett, W. C., Rimm, E. B., Stampfer, M. J. & Hu, F. B. (2002) Dietary fat and meat intake in relation to risk of type 2 diabetes in men. Diabetes Care 25: 417–424.

33. Willett, W. C. (1999) Convergence of philosophy and science: the third international congress on vegetarian nutrition. Am. J. Clin. Nutr. 70: 434S–438S.

34. Liu, S., Manson, J. E., Lee, I. M., Cole, S. R., Hennekens, C. H., Willett, W. C. & Buring, J. E. (2000) Fruit and vegetable intake and risk of cardiovascular disease: the Women's Health Study. Am. J. Clin. Nutr. 72: 922–928.

35. Michels, K. B., Giovannucci, E., Joshipura, K. J., Rosner, B. A., Stampfer, M. J., Fuchs, C. S., Colditz, G. A., Speizer, F. E. & Willett, W. C. (2000) Prospective study of fruit and vegetable consumption and incidence of colon and rectal cancers. J. Natl. Cancer Inst. 92: 1740–1752.

36. Bell, E. A. & Rolls, B. J. (2001) Energy density of foods affects energy intake across multiple levels of fat content in lean and obese women. Am. J. Clin. Nutr. 73: 1010–1018.

37. Bell, E. A., Castellanos, V. H., Pelkman, C. L., Thorwart, M. L. & Rolls, B. J. (1998) Energy density of foods affects energy intake in normal-weight women. Am. J. Clin. Nutr. 67: 412–420.

38. Rolls, B. J. (2000) The role of energy density in the over consumption of fat. J. Nutr. 130: 268S–271S.