THE ENERGY AND TIME COSTS OF TECHNOLOGY: THE CASE OF THE BOW AND ARROW

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While there have been an increasing number of inquiries concerned with the efficiency of human energy acquisition systems (e.g., Harris n.d.; Rappaport 1971; Odend'hal 1972; Nietschmann 1973), attention has been focused primarily upon the gross ratios between calorie inputs and outputs. The specific energy and time costs of the basic material technologies employed in "harnessing" the energy have not been the topic of particular interest. Such data are urgently needed to more adequately test hypotheses pertaining to sequences of change in the technological dimension of human evolution. In this paper we present our observations on the energy and time investments in the manufacture of a basic item of technology: the bow and arrow.

Our data were obtained in research in a population, the Machiguenga of southeastern Peru, where the bow and arrow is a critical item in their still limited technological culture. Machiguenga men almost daily use their bow and arrows in hunting game in the tropical forest such as several species of birds, monkeys, peccary, and tapir. Hunting is, however, of secondary caloric significance for the Machiguenga relative to staples including maize, manioc, and other root crops from their swidden gardens. One young man (age 26; height 155 cms.; weight 50.4 kgs.), a regular and frequently successful hunter, worked with us at length in our measurements of the many steps of bow and arrow manufacture. The energy expenditures were obtained by using a Max Planck respirometer (model 59), a Teledyne oxygen analyzer (model 331B), and the Weir formula for calculating per minute caloric outputs; this approach is described in detail elsewhere (Montgomery, ms.) The steps deserve some detailed description, and the energy and time data can be summarized in tabular form.

Bow Manufacture

The Machiguenga use a bow made from the wood of the hardest palm tree in their forest (kuiri in Machiguenga, species as yet unidentified). The marked dispersion of mature kuiri trees (20-25 cms. dia. at base) which will yield a trunk wood at least 2-3 centimeters thick requires making a trip of some distance into the forest to locate a tree for felling. After felling, sectioning, and splitting out a rough plank for the bow, the wood is brought back to the house. A steel axe or machete is used in the preceding tasks. The wood is next shaped with a machete to a rough piece approximately 3 x 4 x 150 centimeters rectangular, and from this piece the crude form of a bow is hacked out with the machete. Then the final shaping is attained with considerable careful shaving with a steel knife. The final product is 140-145 centimeters in length, 3.5 centimeters wide and 1.3 centimeters thick at midpoint, and it tapers symmetrically to the two ends. This bow is used particularly for hunting monkeys and peccary, and a slightly shorter version (approximately 135 centimeters) is used on hunting walks in the forest when birds are the prime quarry. These bows may last up to five years, though in normal use breakage may occur sooner.

The bowstring for this bow is made from the bark fiber from the tamamrotsa tree (species unidentified) which also grows in the forest surrounding Machiguenga habitations. This tree is more readily available than the kuiri, and shorter distances have to be walked to obtain the bark. A mature specimen about 9-10 centimeters in diameter at the base will yield about 25 meters of a two centimeter wide strip of bark. The strips are simply pulled loose from the base of the trunk and stripped upwards from the standing tree. The bark is taken back to the house, and after two days' drying, the fibrous layer is separated from the outermost part of the bark strip, and the fibers are then separated, twisted, and entwined into a three strand string. The completed bowstring is about three millimeters in diameter, and it is said to last for at least one year and sometimes as long as two or three years. Enough bowstring for four bows can be made from a 25 meter strip of raw bark.

Arrow Manufacture

The arrows used by the Machiguenga are also made from locally available plant and animal products. Usually a number of arrows are made at one time, or at least certain stages for several are completed at once. Men will have between 10 and 20 completed arrows and some or all of the components for others on hand in their house.

A local cane, chakopi (species unidentified), is used for the arrow shaft. Mature stalks are cut in numbers, hardened over the fire in the house, and then thoroughly dried in the sun for three days. The chakopi plants grow along streams not far from Machiguenga homes, and at least one man had transplanted clumps of the plant to have them near his house. The desired stalks should be 8-10 centimeters in diameter, straight, and at least 100 centimeters in length. The green stalks are easily cut with a machete.

Kuiri wood and bamboo cane are used for the arrow tips. Barbed wooden tips are particularly used for monkey, peccary, and sometimes for birds, whereas the cane used for a smaller, lance-shaped tip for birds. The Machiguenga do not use poison on their arrows. The larger wooden tips are first shaped from strips of kuiri wood about 2 x 2.5 x 40 centimeters in size. These strips are whittled down with a knife to rough rounded, semi-pointed pieces notched with 4-8 notches. With additional shaping, the notches become barbs and a sharpened tip emerges. The base of the tip is shaved to fit into the shaft, and after it is fitted, the end of the shaft is bound with several wraps of cotton thread to prevent its splitting. Feathers from local game birds are cut and affixed at the butt end of the shaft, sometimes in a gradual spiral so as to spin the arrow in flight. As both the feathers and cotton string are usually on hand in the house, they represent no additional investments for arrow production as do all the other components which have been described.

The entire sequence of bow and arrow manufacture can be summarized in energy and temporal terms in the following table.

Table 1

ty	Rate of Energy Expenditure (kcal/min)	Time in mins.	Kilocalories Expended
Bow Manufacture			
1. Walk 1.61 kms into forest	7.0-7.4	29.25	210.4
(up steep slopes)	(7.4)		
(up rolling terrain)	(7.0)		
2. Felling medium sized palm	7.5	10.00	75.0
3. Sectioning felled tree	5.0	10.00	50.0
4. Splitting plank from section	5.3	9.50	50.4
5. Walk 1.61 kms back to house	4.2-4.8	25.54	116.0
(down rolling terrain)	(4.8)		
(down steep slopes)	(4.2)		
6. Rough shaping with machete	2.66	30.00	79.7
7. Final shaping with knife	2.91	90.00	262.6
Subtotal:		204.29	843.6
Bowstring Manufacture			
for 4 bowstrings			
1. Walk 1.1 kms into forest	7.0-7.4	21.38	155.1
2. Stripping 25 meters bark	2.8	16.53	46.9
3. Walk 1.1 kms back to house	4.2-4.8	17.69	78.4
4. Separating fibers	2.65	100.00	265.0

5. Twisting, entwining fibers	2.55	162.16	413.5
Subtotal x 0.25 for 1 bowstring:		79.40	239.8
Arrow Manufacture			
for 10 monkey/peccary arrows			
1. Walk out to cane patch	6.8	7.11	48.3
2. Cutting cane with machete	3.1	7.40	23.1
3. Walk back with cane for shafts	3.7	7.58	27.7
4. Rough shaping wooden tips	2.5	29.80	74.5
5. Notching wooden tips	1.5	54.54	81.9
6. Fitting and binding tips	1.2	21.76	26.1
7. Feathering shafts	1.6	41.70	66.7
Subtotal:		169.20	348.3
Total, Bow and 10 Arrows:		452.89	1431.7

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