Tools and techniques involved in the manufacturing of traditional watermills (chhoskor) in West Kameng district, Arunachal Pradesh

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ABSTRACT

Watermills, known locally as *chhoskor*, are the traditional method used to grind grains in many parts of the Himalayan region, including in Arunachal Pradesh. The indigenous Shertukpen tribe of West Kameng district in Arunachal Pradesh has a long history of using stone tools for grinding purposes with the help of watermills. The people of the area have consequently become skilled manufacturers of watermills for grinding purposes. This paper examines the process, steps and techniques involved in manufacturing watermills and documents the rich cultural heritage of the Shertukpen populace. To collect first-hand information and to understand the processing techniques, a simple *chaine operatoire* (operational chain) was applied to comprehend the entire process of manufacturing the region's traditional *chhoskor*. '*Chaine operatoire*' refers to the sequences involved in manufacturing an artifact or tool. The study found that the traditional craft of manufacturing watermills is disappearing. Documentation and other preservation methods are therefore essential if this endangered cultural practice is to be sustained and preserved.

Keywords

Shertukpen, watermill, tools, techniques, manufacturing

Introduction

The root of modern technology is indigenous knowledge (Subramanyam 2008). This knowledge is the product of centuries of experience acquired and developed into a spectrum of information, skills, and technology (Sarma 2016). An indigenous community is embedded in and adapted to its natural environment. Analysis of tool-making action sequences is not new in archaeology. For over 30 years, the *châine opératoire* approach has focused on describing the processes of Palaeolithic tool production, based on insights gained from the experimental replication and reading of production scars left on tools (Pelegrin 1990; Roche 2005). As its name implies, *châine opératoire* involves the reconstruction of action chains or sequences, commonly represented as flow charts. This sequential approach has been useful in reconstructing the details of particular past technologies (Lashley 1951; Miller et al. 2017).

Watermills are still prevalent in the Indian Himalayas and are vital for sustaining rural livelihoods. The people of Ladakh have used watermills since time immemorial to grind grain, with no evidence found of their having used hand-driven mills (*chakki*) (Hussain and Hussain 2014). The native peoples of Himachal Pradesh and Uttarakhand use an indigenously designed watermill known locally as a *gharat*. The *gharat* is made from natural resources that are easily available in the area and operates through the water force coming from glacier-fed rivers, perennial streams and rivulets. Thus, it enables its operator (a *gharati*) to earn an environmentally friendly livelihood. These watermills are commonly used for grinding purposes, enabling multidimensional ways to earn a sustainable livelihood in Uttarakhand (Dwivedi et al. 2023).

Arunachal Pradesh is home to several indigenous communities that widely use watermills for grinding purposes. The manufacturing of the watermill and its ancillaries is done using local resources that are available in their surroundings and by the application of traditional knowledge of and skills in stone sculpting and wood carving. Several communities, such as the Shertukpen, still use traditional techniques for manufacturing and utilizing watermills in their villages. The ready availability of raw materials in the local surroundings has enabled Shertukpen's artisans to become skilled at manufacturing traditional watermills. However, this age-old tradition is now fading away as modern technologies become more prevalent in society. This paper examines the tradition of watermill manufacturing and suggests necessary steps to revive the tradition. Moreover, we discuss the feasibility of using modern technologies to improve traditional manufacturing methods and the prospects for preserving them in the long run. Therefore, we aim to acquire first-hand knowledge of how materials are selected for manufacturing watermills and of how the parts of the watermill function and operate. This study analyses the potential of traditional watermills to improve the livelihoods of people in the study area.

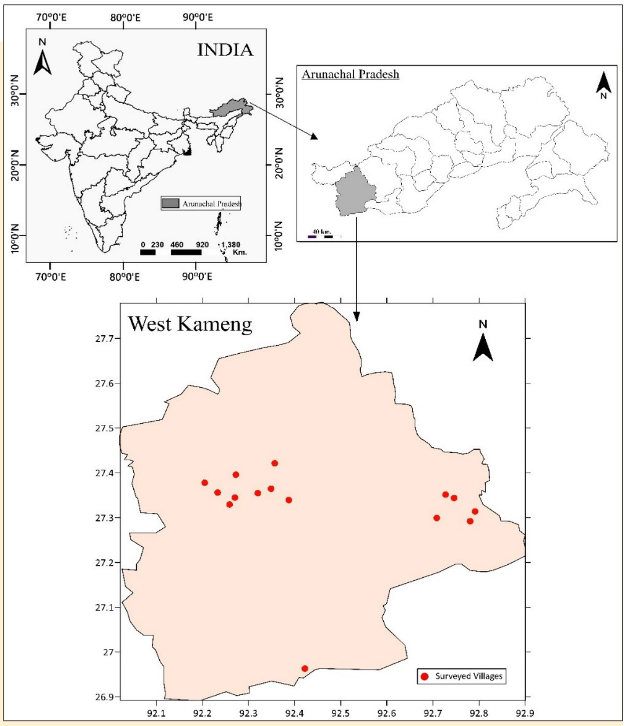

Figure 1
Map of the study area

Study area

The study area is the West Kameng district of Arunachal Pradesh, in Northeast India (Figure 1). The district shares an international border with Tibet and Bhutan. The topography of the district is mostly mountainous with tangled peaks and valleys. The forest types of West Kameng range from tropical semi-evergreen to alpine, and they are a storehouse of more than 500 species of plants of medicinal and pharmacological significance. On average, the area receives 1743 mm of annual rainfall and has a mean monthly maximum and minimum temperature of 21.44°C and −1.24°C, respectively. West Kameng district has a total population of 87,013 (Census of India 2011).

The West Kameng district is inhabited by six major indigenous groups: Aka (Hrusso), Miji (Sajolang), Bugun (Khowa), Sartang, Monpa and Shertukpen. The Shertukpens are Buddhist. The tribe is small in population – approximately 3500 (Census of India 2011) – distributed across three administrative areas: Rupa, Shergaon and Kamengbari-Doimara circles.

Methods

The study is based mainly on data acquired through primary surveys and observations. We developed and used a questionnaire to obtain information about traditional watermill manufacturing methods from a survey participant group aged 45–50 years. Interview scripts were used to survey older and younger groups, including novices and professional craftspeople. The sample size of the study was determined at 50% – for example, 15 out of 30 households in the village (Figure 2). Personal interviews and focus group discussions with elderly people and craftspeople were carried out using a simple *chaîne opératoire* to identify how raw materials are selected, how energy is spent and how techniques are applied in utilising the watermills. *Chaîne opératoire* is a means to break down each technological process into its constituent elements (or links in the chain). The interrelationships among these links focus on the technology itself, as well as the socio-cultural, political and ideological aspects that are expressed through human courses of action and

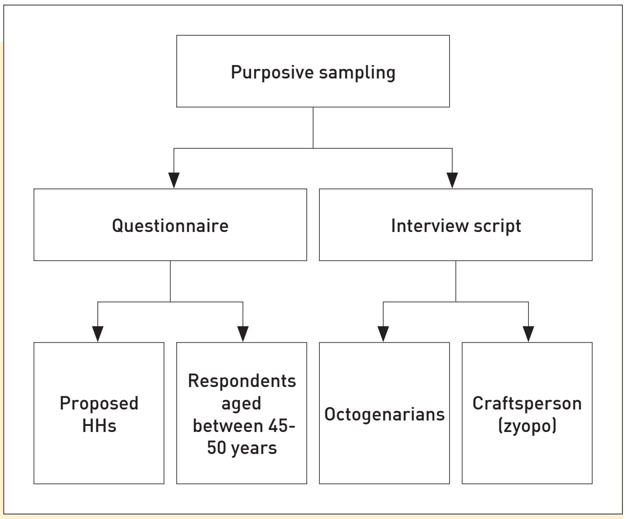

Figure 2
Methodological flow charts

speech (Leroi-Gourhan 1993). The study also discovered that manufacturing watermills is a very arduous, tedious and time-consuming process.

Results

Process used in manufacturing watermills

The Shertukpens are skilled sculptors and stone carvers. The manufacturing of *chhoskor* requires a degree of knowledge of traditional processes using raw materials that are available in the local area. Hence, specific professional groups, known as *zyopos* in the Shertukpen dialect, are involved in the manufacturing process. Each village has one or two *chhoskors*, depending on the size of its population and the number of streams, for grinding various locally grown cereal crops. The study revealed that a decision is made collectively by the villagers to hire a *zyopo* to manufacture a watermill (Figure 3).

The *zyopo* must be skilled in identifying suitable raw materials for manufacturing the watermill. This process requires them to test the texture of certain stones by first pulverising a sample of stone to produce a powder, which is then mixed with water. If the resulting substance is sticky, it is considered to be suitable as a raw material; if grainy or granular, it is considered unsuitable. The *zyopo* mostly prefers *ling-sey* (gneiss stone), because of its hard texture. These stones are collected from riverbanks and surrounding areas or may be broken down from large

Figure 3
Zyopo (craftsperson) manufacturing grinding stones for watermill

stone blocks.

Our personal interviews with *zyopos* identified the processes involved in manufacturing *chhoskor*. First, the stone is broken into smaller pieces, which are then moulded into square shapes. Next, the square-shaped stones are carved into round shapes, which helps to balance the weight for smooth grinding. Finally, the mill stones are polished. Throughout the process, the *zyopo* ensures there is an optimum gap between the upper and lower parts of the *chhoskor* to assist the grinding process.

The *zyopo*, with assistance from a helper (*zyorok*), oversees the complete process of manufacturing the watermill. The mill is erected away from the settlement and is generally produced with minimum input from people outside the family for whom it is being manufactured. If a particular family has a long history of stone sculpting, then the offspring of that family may be more likely to become a *zyopo*, as the skills and knowledge required to manufacture a watermill are traditionally passed down from professional to helper. Over time spent observing and working with the *zyopo*, the *zyorok* may acquire the means to become a professional themself.

Indigenous tools used in manufacturing watermills

Chapzee achandu (small hoe)

The basic purpose of this tool is to shape the milling stones into the right shape and size to ensure the smooth running of both the upper and lower parts of the watermill. It is also used to add the last touches to and to polish the final construction (Figure 4).

Figure 4
Chapzee-achandu (small hoe)

Chapzee (chipping hammer)

The *chapzee* has two pointed semi-sharp edges that are used to break and penetrate solid material. It is used in the initial process of manufacturing to break down the bare stones into suitable square shapes, as square shapes more easily allow the stones to be carved into round shapes (Figure 5).

Figure 5
Chapzee (hoe)

Nzongbee (chisel)

The *nzongbee*, or chisel, is used to make deep cuts into the stone material in order to make the treads in the upper and lower parts of the grinding stones that grind the cereal grains into small, fine particles. It is also used to make a hole in the upper part of the watermill (the *haa-numu* in the local dialect) through which the cereal grains are poured into the watermill (Figure 6).

Figure 6
Nzongbee (chisel)

Thung (hammer)

The *thung* is a subsidiary tool used to strike the *nzongbee* for better cutting into hard stones (Figure 7).

Figure 7
Thung (hammer)

Handu (machete)

The *handu* is used for cutting and shaping the *chhoskor-yapche* (wooden propeller) for a better finish and an aesthetic appearance (Figure. 8).

Figure 8
Handu (machete)

Chaîne opératoire, or steps and techniques involved in manufacturing watermills

The manufacturing of watermills is a systematic and rigorous process requiring certain steps to be followed in a strict sequence. The steps are as follows.

1. Identifying and selecting raw materials

The identification and selection of raw materials is the first and most important stage of manufacturing. Manufacturing stone tools requires good knowledge of the stone and its texture. The study revealed that suitable stones for making tools are mostly collected from local riverbanks, as *zyopos* regard these stones as best suited to carving. The main criteria for stone selection are texture and hardness. To determine the suitability of the stone for making milling stones, the *zyopo* mixes a sample of powdered stone with water. If the resulting substance is sticky and thick and absorbs little water, then the stone is considered to be suitable. Granular, powdery and water-absorbing stones are considered unsuitable.

2. Breaking down the stones

Generally, the *zyopo* collects suitable square- or rectangle-shaped stones to save time and labour in converting them into tool stones. If such stones are unavailable, the *zyopo* may have to excavate or break them from the surrounding rocks. In such cases, the collected stones are first broken down into squares and then converted into circular shapes using indigenous tools such as hammers and chisels. Once a suitable stone is chosen, a hole is carved out in the middle of it using a local chisel-type tool called a *nzongbee*. The depth of the hole varies according to the requirements of the users.

3. Shaping and polishing the stones

At this stage, a *chapze*e (small hoe) is used to carve a small hole on the inner faces of the upper and lower stones of the rotary quern. The holes help to maintain a proper balance between the two stones and to derive a finer texture of flour. Care is needed in making these holes, as they determine the mill's grinding capacity and output. A bigger hole adjoined by a smaller one is carved out on the upper milling stone through which to pour the grains down towards the gap between the two stones for grinding. A wooden handle is attached through the smaller hole to rotate the rotary querns. Finally, the milling stone is polished for aesthetic reasons.

Our interviews with the *zyopos* revealed that they follow certain strict social norms during the manufacturing process. The process begins when the *zyopo* is requisitioned by a village to manufacture a watermill. According to tradition, the *zyopo* and his helper then carry out the work in isolation, away from public view. This process can take two to three months. It is accepted belief that if the manufacturing process is conducted in public, this will hinder progress of the work and result in a poorly finished product. After the carving process is completed, the milling stone is handed over to the village, after which a thanksgiving ritual and ceremony are organised. Indigenous tools traditionally used in manufacturing *chhoskors* are made of iron and have wooden handles (typically made of *quercus alba spp.*, or white oak wood). These chisels, hammers, hoes, etc. are used for carving, shaping, molding and polishing processes.

4. Preparing the wooden pillar and propeller

The watermill is a congregation of various parts, each of which plays an important role in the operation of the watermill. Once the shaping and polishing of the grinding stones is complete, the *zyopo* makes a wooden log to act as a support system for the body. *Quercus alba spp.* is considered the most suitable wood species for a watermill, as it is hard in texture and less porous, making it it an efficient water repellent. The wooden pillar (*zung-seng*) is attached to the body of the grinding stone along with a wooden propeller (*chhoskor-yapche*). The propeller (also made of *Quercus alba spp.*) is carved in rectangular shapes using a *nzongbee* (or chisel). When the water stream strikes the propeller, it compels it to rotate in a clockwise manner, which rotates the grinding stones resting upon the wooden pillar.

Parts and functions of the *chhoskor*

The study shows that many households in the survey area do not possess rotary quern and nutting stones. Hence, they are dependent on the community *chhoskor* to grind their food grains. These unique, indigenous community watermills, usually set up in small streams and rivulets, process huge quantities of grains into flour. The *chhoskor* includes a water reservoir, regulator (wooden plank), wooden channels, stone platform, wooden turbine, propeller, pair of milling stones, wooden container, etc. The water reservoir is built about 4–5 m above the watermill so that it can produce force or a current to rotate the wooden turbines. The water regulator, or wooden plank, is fitted at the mouth of the water reservoir to control the speed of the water for the rotation of the turbines. A long wooden channel is attached to the water regulator to maintain enough slope and velocity of the water to rotate the turbines. The base of the watermill is made of flat stone or a wooden plank with a hole in the centre to which the turbine is fixed.

Figure 9
Characteristics of *choskor* (watermill) of Dikshipam village. (a). *Wooden propeller/turbine* (chhoskor-yapche), (b). *Wooden adjuster* (sarr) *attached to the vertical wooden pole* (zung-seng), (c). Chhoskor *attached to propeller, while resting on a wooden plank* (bleng), (d). *Measuring the mean size of the* chhoskor *(Dikshipam village).*
Source: Thongdok and Sati 2024

The turbine and propellers (*chhoskor-yapche*) (Figure 9a) are made of pine or white oak wood. The propeller is fitted with the turbine at the bottom, while the upper end is attached vertically to the milling stone. When the water from the channel hits the turbine, it rotates the propeller as well as the attached grinding stone. An adjuster (*sarr*) (Figure 9b) is attached to the vertical propeller to derive both fine- and coarse-grain outputs. The pair of watermills are similar to the traditional *ran-thok* (rotary quern) (Figure 9d). The only difference in the watermill is that the milling stones are fixed with a wooden propeller and the energy is derived from the streams instead of from manual labour.

This arrangement allows users to easily control the mill to derive the desired coarseness of the flour. According to the villagers, in the past, every village had at least one *chhoskor*. However, as streams have dried up over time, as the population has expanded and as deforestation in the upper catchment areas has increased, the number of watermills has diminished. Moreover, the *chhoskor* cannot be easily shifted to another location once it is set up in a particular place, due to its heavy weight. All these factors, along with increased access to modern facilities, have led to the abandonment of watermills in the study area. The study found only two *chhoskors* in the subject area. Of these, the watermill in Dikshipam village (Figure 9) was operational, while the other – in Shergaon village (Figure 10) – was functioning only partially due to seasonal drying up of the stream. The two watermills also differed

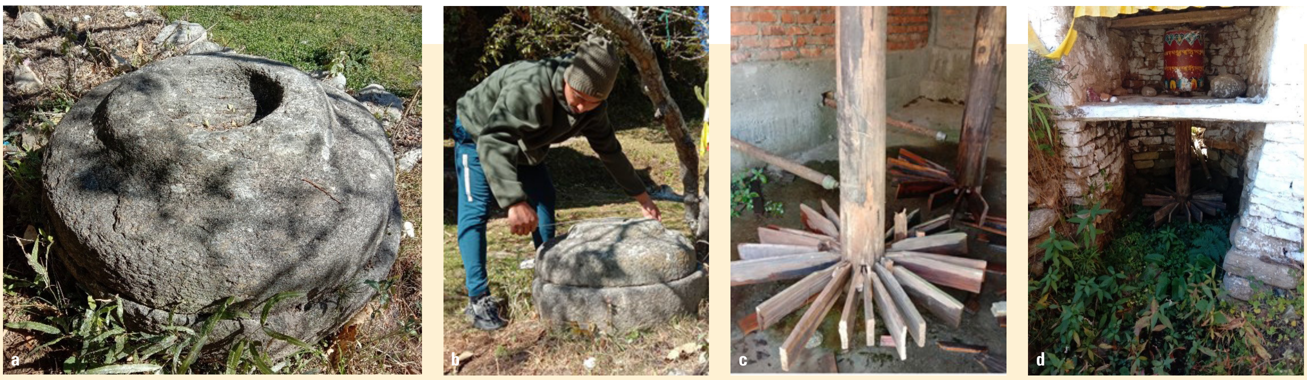

Figure 10
Characteristics of *choskors* of Dikshipam and Shergaon villages. (a). *Complete part of a* chhoskor *with both the upper and lower stones still resting on each other,* (b). *Measuring the average size of the* chhoskor, (c). *Wooden propeller/turbine* (chhoskor-yapche) *in a dilapidated condition,* (d). *Unused and abandoned* chhoskor.

Table 1
Raw materials and average size of the parts of a *chhoskor*

Grinding materials	Parts	Average size (cm)	Raw materials used (scientific name)	Local name of raw materials
Dikshipam *chhoksor*	Lower stone (*ukhu*)	Diameter: 57 Thickness: 16	Gneiss stone	*Ling-sey*
	Upper stone (*getheng*)	Diameter: 57 Thickness: 17	Gneiss stone	*Ling-sey*
	Wooden plank (*bleng*)	Length: 125 Breadth: 137	*Castanopsis spp. & Pinus wallichiana*	*Hing-rhee & Bchee-hing*
	Propeller (*yapche*)	Length: 62 Height: 15	*Quercus alba*	*Hing-pu*
	Adjuster (*sarr*)	Length: 30	*Quercus alba*	*Hing-pu*
Shergaon chhoskor	Lower stone (*ukhu*)	Diameter: 66 Thickness: 19	Gneiss stone	*Ling-sey*
	Upper stone (*getheng*)	Diameter: 66 Thickness: 20	Gneiss stone	*Ling-sey*

Source: Field survey, 2021

in size, with the one in Shergaon being slightly larger (Table 1).

Discussion

The Shertukpen people inherited their manufacturing skills from their ancestors, who were prominent stone and wood crafters. The manufacturing of *chhoskors* is tedious and laborious work, requiring a skilled *zyopo* (professional craftsman) to ensure the weights of the upper and lower parts of the stone of the watermill are balanced so as to achieve effective rotation. An anomaly in the weight results in poor-quality grinding and possible complications when in use. The *zyopo* ensures a proper gap is achieved between the two stone slabs for a better grinding process and, most importantly, skilled carving of the stone threads for better and fine grinding of cereal crops. The study showed that Shertukpens are steeped in the culture of grinding practices and regard stone tools as being of socio-economic significance.

The stone used for a quern needs to be resistant to wear and durable. The grinding stones used for watermills are preferably of metamorphic origin. The study found that the Shertukpens use gneiss stone in the manufacturing of watermills, which is also the practice in Jammu and Kashmir (Slathia et al. 2018). It also found that the Shertukpens' manufacturing processes conform with those of the neighbouring Monpa tribe, as reported by Sarma (2016). Moreover, watermills typical of Ladakh (known as *ranthak*) are similar to those of the tribe under study (Hussain and Hussain 2014). These watermills are all efficient and environmentally friendly, in comparison to mechanical mills, since they are constructed from existing natural resources that are easily available in the local area and are operated by means of manual labour, which produces less noise and no pollution emissions. Further, the flour produced by these traditional mills is reported to be of the highest quality (Thongdok et al. 2022). Stone milling has been found to have very little effect on macro-element losses and no effect on micro-element losses, thereby producing flours with a high nutritional value (Albergamo et al. 2018).

The region's rugged and undulating topography necessitates narrow roads that discourage the import of commodities, resulting in a need for locally produced food. Consequently, agriculture practice – mainly cereal grains – prevails in the region, which encourages the utilisation of watermills in rural areas. The challenges faced by the villagers in remote areas in the region are uncompensable. Thus, the traditional watermill plays a huge role in the sustainability of livelihoods in isolated villages of the Himalayan region.

Conclusions

There is a need for intervention by the state government. The state government should evolve policies to engage the *zyopos* (professional groups) in teaching the skills and techniques of grinding practices manufacturing at the institutional level, with some monthly remuneration. This would support the aged professionals, while encouraging younger people to learn traditional skills and techniques. Such an initiative would also alleviate the unemployment problem in rural areas. There is a need to establish a museum to preserve vulnerable grinding tools such as the rotary quern (*ran-thok*), nutting stone (*ling-chhom*), and *chhoskor* (watermill) and to promote their importance through exhibitions and research.

Several factors have led to the depletion of the indigenous watermill culture, including changes in the agricultural pattern in the study area. Hence, the local authority or government should develop policies and provide subsidies that will encourage the villagers to cultivate cereal crops, which would reassure villagers about opting for and using watermills to grind their grains. More importantly, the lack of interest among the younger generation is leading to the dearth of transmission of skills and knowledge in manufacturing. The younger generation is reluctant to learn and conserve the age-old tradition of watermill manufacturing. These days, people generally prefer to use electric grinding machines rather than watermills, which will ultimately lead to the exhaustion of watermill culture in the study area. Furthermore, there are currently very few remaining *zyopos.* Due to their advancing age, they are unable to carry out the manufacturing process or to pass on their skills and techniques. The existing *zyopos* are not even able to execute repair and maintenance work, resulting in the existing watermills being in a barely operating state or a dilapidated condition. The decline in the number of craftspeople and professionals has seen a decline in the maintenance of existing watermills. The working capacity of such *chhoskors* could be reinvigorated and enhanced through the introduction of modern equipment and technological enhancements. Alternatively, the watermills could be rehabilitated as mini-hydels, as they have great potential for generating hydroelectricity.

Additionally, the authors of the present study propose that the sound and sustainable practices of traditional watermill culture, and the indigenous knowledge system of tools and techniques involved in manufacturing watermills, are worthy of preservation as examples of centuries-old traditions of a tribal community. As such, they might pave the way for future preservation practices of intangible heritage and sustainable utilisation of natural resources.

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Conflict of interest

The authors of this article declare that they have no financial interest in the content of this article.

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