Chapter Number

Fungal Phenology and attendant changes in agricultural lignocelluloses waste for mushroom cultivation: Status Prospects and Applications in Food Security

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1. Introduction

The decomposition of any organic matter (paper, faecal matter, agricultural lignocellulosic waste, tree stump etc) in any community is invariably attributable to the activity of a range of microorganisms (especially fungi) and invertebrates. Organic litter from agricultural and horticultural plants can be defined as all types of biogenic material in various stages of decomposition which represent potential energy sources for consumer species. The majority of litter and agricultural waste is derived from plant sources, though that from animals is sometimes considerable; for instance the dung produced by population of large herbivores. Very large amounts of waste are produced by human population after harvest of cultivated plants. The accumulated waste in the ecosystem provide the most suitable harvest and substrate for growth of micro and macro fungi and their relatives. The release of minerals through the process of decomposition so that they again become available for absorption of plant roots is important; so is the utilization of such waste for the production of mycoprotein in mushrooms. The stages through which the carbon in the agro waste pass m before finally being converted for utilization by plants and mushroom alike may be varied and complex. Many fungi (other than larger fungi) take part in this decomposition process. A particular feature of the interrelationship of the attendant community of mycoflora is that they commonly exhibit a succession.

The term phenology refers to the science of appearance and disappearance of a phenomenon. In the simplest term phenology is the study that measures the timing of life cycle events in all living things (which has been adapted for microorganisms also). Seasonal changes include variations in day length, temperature, pH, nutrient depletion, light quality and duration which influence appearances and disappearances. During the process of decomposition the substrate is continually changing both physically and chemically, such that its suitability for colonization by different organisms also changes.

One of the characteristic features of any composting material, such as rice straw, leaves, sawdust etc; is the development of a high temperature phase. The heating is caused by the active metabolism of the resident microorganisms. Three groups of microorganism and fungi are resident: thermophile (heat loving), tolerant mesophiles and mesophile (moderate temperature loving). A thermophilous fungus is one that has a maximum temperature for growth at or above 50^{o}C and minimum for growth at or above 20^{o}C eg. *Chaetomium thermophile* grows from 27^{o}C to 58^{o}C. Thermotolerant mesophiles can be defined as having a minimum well below 20^{o}C and a maximum near 50^{o}C eg. *Aspergillus fumigatus*. Mesophilic fungi appear first (eg Mucorales) followed by *Aspergillus* species, *Penicillum* species and Deuteromycota etc. The potential for recycling organic waste with fungi is unlimited. Many mushrooms thrive in base material ambient to their natural habitat (Stamets, 1993).
This Chapter covers the following topics:

- Sources of leaf litter and lignocellulosic agricultural waste with the potential for cultivating mushrooms such as *Volvariella volvacea* and *Pleurotus* species.
- Mycoflora (Phylloplane fungi) of agricultural waste and leaf litter; their succession (Phenology) and possible benefits as biofertilizers, soil mulch to provide antibiosis against resident potential pathogens and during composting for mushroom cultivation.
- Physical, chemical and nutritional alteration of substrate for utilization by macrofungi.
- Survey of the current methods in use for assessing the efficacy of the process of composting.
- Prospects for the use of composted agro waste and leaf litter as biofertilizers and soil mulch to serve as biocontrol agents against soil-inhabiting pathogens.

2. Sources of leaf litter and lignocellulosic agricultural waste with the potential for cultivating mushrooms such as *Volvariella volvacea* and *Pleurotus* species.

In the tropics and temperate ecosystem, plant materials entering the litter are on the soil in diverse mixture of various components of the plant structure. In temperate areas most of the litter fall in autumn, but amounts produced at other times of the year should not be ignored. In the tropics, deciduous trees lose leaves at specific times of the year but the litter can be observed throughout the year in humid equatorial forests. Loss of leaves and the growth of new leaves are a common phenomenon in flowering plants (Ewusie, 1980). In the dry tropical regions of West Africa, *Acacia alba* sheds leaves mainly in the rainy season (Jung, 1969) and in the case of *Terminalia catappa* which may flower about four times in a year, there is hardly any break between the shedding of old leaves and the growth of fresh ones (Ewusie, 1980). In the silk cotton tree, *Ceiba petandra*, old leaves are shed before flowering occurs and new leaves are formed shortly after flowering has ended, but in *Bombax*, the plant remains bare for about a month after flowering before new leaves are formed (Ewusie, 1968). It is estimated that about 30% of West African trees loose an appreciable quantity of their leaves at one time or the other during the year (Ewusie, 1968) thus displaying seasonal variation. This pattern suggests that phenological changes represents adaptation to either biotic or abiotic factors (van Schaik et al., 1993). Species with complete leaf fall (deciduous species) in the West African forest include *Adansonia digitata*, *Ceiba petandra*, *Antiaris africana*, *Coffea robustus* etc.

Many wild mushrooms are generally found growing on deciduous plant leaves and wood litter as well as other materials including, cereal plant leaves, straws, corn cobs, seed hulls, coffee wastes, sugar cane bagasse and numerous other cellulosic materials. A seasonality in litter imput has marked effect on the biology of decomposing organisms. In Ghana, for example *Diospyrus* sp. yields a total leaf litter of 7.0 tons/ha/annum, 66.7% of which are leaves (Nye, 1961). The total litter fall ranges from 1.5 tons/ha/annum for spruce in Norway to 23.3 tons/ha/annum for a tropical rainforest in South East Asia. Leaves and wood form variable proportions of total litter, ranging from 21.7% of *Acacia* forest in West Africa to 80.7% for spruce in Norway.

About one third of the organic matter produced by green plants is cellulose. It is an integral part of the primary and secondary cell wall. In fully matured woody tissues 40 to 60% of the dry weight is cellulose (Hudson, 1972). Cereal straw contains about 40% cellulose and seed hairs of cotton about 95%. It is the major carbohydrate remaining in seed plants on their death and furthermore, it is not withdrawn from the plant part such as leaves when they are shed. Degradation of this cellulose is an indispensable process for the maintenance of carbon balance in nature and for utilization by many wild and cultivated mushrooms. Cellulose degradation returns an estimated 85 billion tons of carbon as carbon dioxide to the atmosphere each year (Hudson, 1972). Thus litter or lignocullulose decomposition is the process by which lignocelluloses can be recycled to release nutrients in the ecosystem for agricultural production and use by other microorganisms. Litter decomposition is thus an important component of the global carbon budget (Zabiniski & Gannon, 1997).

Table 1 shows the cellulose, hemicellulose and lignin contents of selected lignocelluloses of economic crops and trees some of which are used in mushroom cultivation (Kirk, 1983). Cellulose molecules have a thread–like structure and are combined in micelles of some sixty molecules (Kirk, 1983). The micelles are formed by hydrogen-bonding between the hydroxyl group of cellulose and the molecules of water which are absorbed by the cellulose. A large number of bonds makes the micelle very stable. The first stage in the enzymatic breakdown of cellulose involves the formation of linear chain to produce molecules of cellubiose, which are then hydrolysed with the aid of β-glucosidase enzyme to glucose. The saprophytic fungi have the ability to produce such enzymes so are the edible and wild mushrooms. Cellulose from fungal origin have been found in several basidiomycetes and *Spirotrichum pulveratentum*, *Fusarium solani*, *Penicillium funiculosum*, *Trichoderma* spp. and *Talaromyces emersonii*.

COMPOSITION (% dry wt.)			
Lignocellulose	Cellulose	Hemicellulose	Lignin
Maize straw (*Zea mays*)	67	>30	10
Rice straw (*Oryzae sativa*)	36	>25	12
Wheat straw (*Triticum aestivum*)	40	>28	17
Soybean stalk (*Glycine max*)	35	>25	20
Bagasse (sugar cane) (*Saccharum officinarium*)	41	>20	20
Hemlock wood	41	23	33
Spruce wood	41	31	27
Maple	45	29	24
Birch wood	42	38	19

Table 1. Cellulose, hemicelluloses and lignin content of selected lignocelluloses (After Kirk, 1983)

Hemicellulose occurs in smaller quantities than cellulose. They are polysaccharides of high molecular weight constituted from arabinose, galactose, mannose, xylose and uronic acids. Wood rotting fungi produce enzymes capable of hydrolyzing a variety of β-1-4 linked glycan (mannan and xylan) substrates as well as various glycosides. Endoglucanase from white and brown rot fungi all act randomly producing dimeric and highly oligomeric products. Multiple hemicelluloses activity is found in culture filtrate of many fungi including basidiomycetous ones; white rot (*Fomes annosus*), Brown rot *Polyporus*, *Ganoderma*, *Serpula* and soft rot fungi (Ascomycota, Fungi Imperfecti) after growth in a variety of substrate including simple sugars.

Lignin forms about 20 to 30% of wood and secondary cell structure of higher plants. They have considerably more complex structure than cellulose or hemicelluloses. It consists mainly of building blocks of phenyl propanes, such as coniferyl alcohol, with benzene ring carrying a hydroxyl group and one or two methoxyl group. There is ample information on research on fungal degradation of lignin (Kirk, 1983). Lignin degradation is distinct from cellulose and hemicelluloses degradation. Evidence in the past suggest that regulation of secondary metabolism, including lignin degradation is connected with glutamate metabolism (Kirk, 1983). It must be stressed that the structure of lignin is still inadequately understood and its decomposition by fungi needs further elucidation in future research.

Lignocellulose degradation is essential because of the abundance in agricultural harvest waste material. Lignocellulose plays a dominant role in terrestrial carbon cycle, lignin-degrading fungi including macrofungi and mushrooms like *Pleurotus* and *Volvariella* play a prominent role in the conversion of agricultural waste into fungal protein for human consumption. Recent studies aimed at animal feed production by controlled cultivation of lignolytic fungi on lignocellulose substrate, has resulted in protein from wood, barks and lignocellulolytic waste following cultivation of various edible macrofungi. Several tons of these lignocellulosic wastes are produced yearly in developing countries. This is partly due to the good climate found in the Tropics and Sub Tropics. Most of these wastes are obtained from cash crops which includes cocoa, coffee, kolanut, rice and maize among others. These wastes are either burnt or buried to dispose off. In Ghana, for instances a survey conducted in 1994 revealed a total of 6,573,350 Metric tons of agricultural wastes (Sawyerr, 1994). Their quantities are listed in Table 2 below:

Some agricultural by product	Estimate available quantity per annum. (metric tons)
Cocoa husks	227,870

Cocoa shells	2,622
Coffee pulp	6,143
Coffee hulls	473
Cotton Seed hulls	1,071
Cotton boll locules	7,570
Oil palm pericarp fibre	39,054
Maize stalks	916,240
Maize cobs	549,744
Rice straw	164,726
Rice bran	14,474
Cassava peelings	732,168
Cassava woody stem	1,689,618
Yam peelings	280,588
Sugar cane bagasse	14,560
Sugar cane tops	58,240
Logging wastes	862,405
Sawdust	363,504
TOTAL	6,573,350

Table 2. Available quantities of some agricultural by-products produced in Ghana (Data after Sawyerr, 1994)

3. Mycoflora (Phylloplane fungi) of agricultural waste and leaf litter; their succession (Phenology) and possible benefits as biofertilizers, soil mulch to provide antibiosis against resident potential pathogens, composting for mushroom cultivation with or without supplementation.

3.1 The role of mycoflora in composting and their succession or phenology

During decomposition or composting, the substrate is continually changing both physically and chemically such that its suitability for colonization and utilization by different organisms also changes. An apparent succession is therefore seen. Microorganisms play a key role in the decomposition process. Two major taxonomic groups involved are the prokaryotic bacteria and the eukaryotic micro and macrofungi. For the purpose of this chapter we shall confine ourselves mainly to the fungi. The main taxonomic group of saprophytic fungi in soil litter and composting lignocellulosic are:

- Zygomycota eg. *Rhizopus*, *Actinomucor*, *Mucor*, *Mortierella*, *Syncephalasstrum*
- Basidiomycota in soil and litter and ectomycorrhizal fungi with a different role especially in forest ecosystem.
- Deuteromycota or Fungi Imperfecti with a variety of genera eg. *Trichoderma*, *Penicillium*, *Cladosporium*, *Verticillium*, *Aspergillus*, *Fusarium* and *Botrytis*. All fungi without a sexual stage are placed in this group (Aspergilli and Penicilli are sometime placed in the Ascomycota).

A short time after litter fall or in a composting substrate, the fungal community is dominated by pectinolytic and proteolytic species in temperate deciduous forest. During the winter months, lignin and cellulose decomposes as well as xylanase, amylase, lipase producing fungi which are active even at low temperatures (Kjoller & Struwe, 1997). Many fungi are highly versatile and able to utilize more than one compound. After the first flush of fungal activity, chitinous fungi increases in numbers (Kjoller & Struwe, 1997). In the temperate environments, the chitinase acts upon the fungal biomass build up during the first stage of development. As fungal cell walls are rich in chitin and protein this mechanism of recycling of nitrogen is important especially in nitrogen-poor substrate (Kjoller & Struwe, 1990). In tropical West Africa, the first colonizers to appear in a compost are the Zygomycota eg. *Mucor hiemalis*, *Syncephalastrun* etc. They start after 2-3 days and decline thereafter 9-10 days to be taken over by *Trichoderma*, *Aspergillus*, *Verticillium*, *Cephalosporium* and *Cladosporium* species. Succession is the ecological term describing the sequence of organisms occurring in a given time over a defined area in a compost or any lignocellulosic litter.

3.2 Phenology of mycoflora of composting rice straw, rice husk and mixture

In a recent study Odamtten & Malm (2002) found that fungal succession in composting rice straw, rice husk and mixture of the two over 8 weeks period varied (Fig 1). Total fungi in composting rice straw alone increased from 4 to 10 in 3 weeks and thereafter declined. In the rice husk resident fungi decreased from an initial 11 species to 2 after 2 weeks composting and remained at 3 species for the next 6 weeks. In the mixed compost, fungi varied from none initially to 3 after 6 weeks (Fig 1).

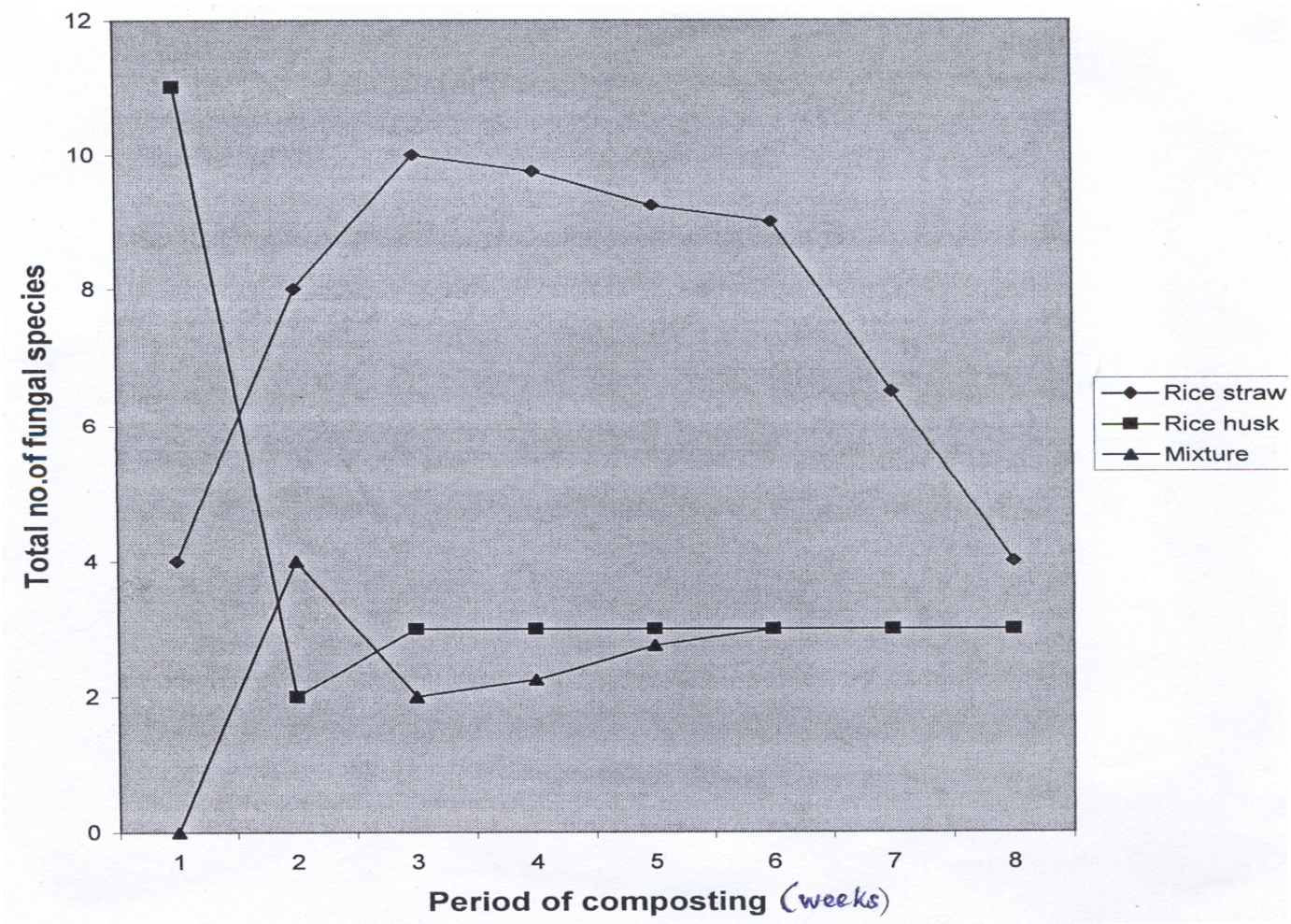

Fig.1. Records of species diversity during composting of rice straw, rice husk and a mixture of the two agricultural waste in the field at 30±2oC (Data after Odamtten and Malm, 2002)

The fungal phenology in the various composts was unique. In the rice straw compost *Aspergillus flavus, A. fumigatus, A. ochraceus* and *A. niger* persisted. *A. sulphureus* and *Rhizopus oryzae* occurred but could not be isolated after 8 weeks (Table 3). The occurrence of the remaining species can be described as sporadic. Anastasi et al., (2002) found *Paeciliomyces varioti* and *Mucor pusillus* dominant in the initial stages or composition of rice straw. In the rice husk, *A. niger* and *A. ochraceus* occurred throughout. The remaining species virtually disappeared to be replaced by *Rhodotorula* sp. (20.2-60.8%). After 3 weeks of composting of rice husk, *A. fumigatus* constituted 12.7% (Table 3).

Species of fungi	% Occurrence after (weeks)

	2			3			6			8		
	a	b	c	a	b	c	a	b	c	a	b	c
Aspergillus candidus	0	-	-	3.5	-	-	3.9	-	-	-	-	-
A. carneus	0	-	-	0	-	-	-	-	-	-	-	-
A. flavus	3.5	-	-	3.5	-	-	3.9	-	-	30.5	-	-
A. fumigatus	14.3	-	2.8	12.3	12.7	-	10.4	-	53.6	27.3	-	-
A. niger	36.2	12.1	55.2	41.2	24.1	72.2	11.7	34.5	14.2	22.3	34.7	22.8
A. ochraceus	0.1	0.1	-	6.1	2.9	-	10.4	4.7	-	4.7	2.9	-
A. sulphureus	0.9	-	2.0	0.9	14.3	-	2.6	-	-	-	-	-
A. tamarii	-	-	-	-	-	-	-	-	-	-	-	-
A. tereus	-	-	-	-	-	-	-	-	-	-	-	-
A. wentii	-	-	-	3.5	-	-	-	-	-	-	-	-
Fusarium moniliforme	0.1	-	-	-	-	-	3.9	-	-	-	-	-
Aspergillus indet	-	-	-	18.4	3.2	-	-	-	-	-	-	-
Mucor haemalis	-	-	-	-	3.2	-	-	-	-	-	-	-
Rhizopus oryzae	0.2	-	-	1.8	-	-	1.8	-	14.2	-	-	-
Mucorales	-	-	-	-	-	-	-	-	-	-	-	-
Penicillium sp.	-	-	-	0.88	-	-	-	-	-	-	-	-
Rhodotorula sp.	-	-	45.0	-	20.2	27.8	-	60.8	-	-	-	-
Paecilomyces carneus	-	-	-	-	-	-	-	1.3	-	-	-	-
Penicillium verrucosum	-	-	-	-	-	-	-	1.3	-	-	-	-
Cladosporium herbarum	-	-	-	-	-	-	-	-	-		-	-
Cladosporium macrocarpum	-	-	-	-	-	-	-	7.2	-	-	--	-

Table 3. Fungal succession in the indicated composting agricultural lignocelluloses at 30°C for 8 weeks (Data after Odamtten & Malm, 2002).
Key: a. Rice straw compost, b. rice husk compost, c. mixed compost

3.3 The phenology of mycoflora populations during composting of *Triplochiton scleroxylon* (*wawa*) sawdust

Various mycoflora and microflora are involved in the composting of agricultural wastes and these range from fungi and bacteria that are thermophiles (heat loving), mesophiles (moderate temperature loving) and tolerant mesophiles. During the composting of sawdust from *Triplochiton scleroxylon (wawa)* high levels of bacteria were recorded during the 1st phase of composting and this caused ammonification which in-turn caused an increase of pH favorable for bacteria that subsequently out-compete fungi. Though there were decreases in the microbial counts these differences were marginal with a fungal population difference of 1.23 log cycles and bacterial population difference of 0.96 log cycles by day 28 of composting (Obodai et al, 2010). This indicated that relatively high numbers of microorganisms were involved in the decomposition of the compost making it suitable for growth of mushrooms. Also the microbial populations of the sawdust decreased with increasing days of composting, and different fungi appeared at different periods of composting which is in agreement with Stanek (1972) who reported that the number of micro-organisms decreased during the fermentation process in wheat straw composted for 30 days. The environmental and nutritional conditions created during composting selectively favored certain fungi to the detriment of others.

Mushroom cultivation exploits the natural ability of fungi to bioconvert solid waste generated by industry and agriculture into fungal protein food (Chiu et al., 2001;Tripathi and Yader, 1992). In nature, several species including *Pleurotus, Auricularia, Lentinula* and *Volvariella* have been isolated from decaying wood. In a recent publication Obodai et al., (2010) studied the diversity of fungi in an entire composting process of *wawa* making it suitable for the cultivation of oyster mushrooms (*Pleurotus* spp.). The phenology of the resident fungi during the composting process of 28 days is shown in Table 4. The mucorales (*Mucor pusillus* (30%) and *Rhizopus oryzae* (76.92%) together with *Paeciliomyces varioti* (70.0%) were early colonizers to be replaced by Aspergilli (*Aspergillus fumigatus* and *A. flavus)* attended by high substrate temperatures of 30°C to 50°C after 7 days. The fungal phenology after fruiting for 3 months by *Pleurotus sajor-caju* PSCH and *P. sajor-caju* is presented in Table 5. The early colonizing Mucorales and *Paeciliomyces* were replaced by the Aspergilli, *Cladosporium herbarum*, *Penicillium digitatum* and *Trichoderma viride*. In the case of *Pleurotus ostreatus* (Table 6), *T. viride, P. digitatum* and *A.*

niger predominated. At any composting period the species of fungi which appeared varied depending on the species of mushrooms utilizing the substrate.

Fungi recorded	Occurrence (%) of fungi in sawdust during composting (Days)				
	0	7	14	21	28
Aspergillus flavus	-	-	-	40.0	26.09
A. fumigatus	-	23.03	31.03	-	56.52
A. niger	-	-	-	30.0	-
Mucor pusillus	30.0	-	-	-	-
Paeciliomyces varioti	70.0	-	-	-	-
Rhizopus oryzae	-	76.92	68.97	30.0	-

Table 4. Changes in fungal phenology during composting of *wawa* sawdust for 28 days (Data after Obodai et al., 2010)

Fungi recorded	Occurrence (%) of fungi in sawdust inoculated with									
	P. sajor-caju strain PSCH					*P. sajor-caju* strain PSCH				
	0	7	14	21	28	0	7	14	21	28
Aspergillus flavus	-	-	-	40.0	26.09	-	17.91	-	-	-
A. fumigatus	-	23.03	31.03	-	56.52	10.0	-	47.5	20.0	8.0
A. niger	-	-	-	30.0	-	-	18.2	5.5	10.0	-
A. ochraceus	-	-	-	-	-	5.0	-	-	-	-
Cladosporium herbarum	-	-	-	-	-	5.5	13.56	47.5	60.0	60.0
Mucor pusillus	30.0	-	-	-	-	-	-	-	-	-
Penicillium cyclopium	-	-	-	-	-	15.0	-	-	-	4.0
P. digitatum	-	-	-	-	-	-	30.21	5.5	20.0	8.0
Paeciliomyces varioti	70.0	-	-	-	-	-	-	-	-	-
Rhizopus oryzae	-	76.92	68.97	30.0	-	-	-	-	-	-
Trichoderma viride	-	-	-	-	-	12.0	20.11	-	-	22.5

Table 5: Changes in fungal phenology after fruiting for 3 months for Pleurotus sajor-caju strain PSCH and PSCM on *wawa* sawdust (Data after Obodai et al., 2010)

Fungi recorded	Occurrence (%) of fungi in sawdust				
	0	7	14	21	28
Aspergillus flavus	20.21	-	-	-	-
A. fumigatus	7.31	-	11.76	25.41	-
A. niger	-	6.25	23.53	21.31	14.28
A. ochraceus	21.0	-	-	-	-
Cladosporium herbarum	-	-	41.17	-	28.75
Penicillium digitatum	30.38	48.25	-	27.97	14.28
Mycelia sterila	-	-	-	-	14.28
Trichoderma viride	12.0	45.5	-	26.31	14.28

Table 6. Changes in fungal phenology after fruiting for 3 months for *P. ostreatus* strain OT-3 on *wawa* sawdust (Data after Obodai et al., 2010)

3.4 Phenomenon of antibiosis

During growth of fungi in a compost, there is production of metabolites. Antagonism between fungi may be in the form of competition for nutrients, chemical antibiosis and lysis of mycelium. Antibiosis is the inhibition of one generation by the metabolic product of another. Although it is usually an inhibition of growth and sporulation, it may be lethal. The metabolite penetrates a cell and inhibits activity by chemical toxicity. Lysis is destruction and decomposition of biological materials by enzymes of the parasite. Fungal phenology observed in the compost may be partly attributed to antibiosis and lysis of mycelium.

Several members of the genus *Aspergillus* appear to be capable of hydrolyzing the β-(1-4)-glucosidic linkage in the cellulose chain (Steward and Walsh, 1972). *Aspergillus fumigatus* and *Trichoderma viride* are among the strong cellulolytic group. The moderately cellulolytic ones are *Fusarium moniliforme*, *F. oxysporum*, *F. solani*; *Aspergillus japonicas*, *A. ochraceus* are in the weak cellulolytic category with *Rhizopus oryzae* and *A. flavus* classified as non-cellulolytic. *A. fumigatus* has been found to be more in rice straw compost forming 89.6% of the initial population and also the most abundant in the rice husk (Odamtten and Malm, 2002) while *A. niger* predominated in the mixed compost constituting 72.2%. Presumably, cellulolytic activity of fungi might be species and strain specific as well as dependent on the substrate metabolites by the fungus (Odamtten and Malm, 2002).

4. Physical, chemical and nutritional alteration of substrate for utilization by macrofungi

4.1 Temperature

Various physical, chemical and nutritional changes occur during the composting of agricultural lignocellulosic waste. A number of factors are responsible for variation in the breakdown of composts. One of such important characteristic feature is temperature as it affects the rate of metabolism of decomposition. Fungi are divided into psychrophiles (cold loving environment 2-10^{o}C), mesophiles (intermediate temperature 20-30^{o}C) and thermophiles (high temperature beyond 30^{o}C depending on the preferred optimum temperature for their growth. Temperature within the core of the composts (rice husk, rice straw and mixture of the two) reached above 35^{o}C at mid-day (12-14 GMT) in Ghana (Fig. 2) (Odamtten and Malm, 2002) indicating high mycoflora activity while in a typical warm sawdust derived from *Triplochiton scleroxylon*, temperature values ranged from 56^{o}C at 4 days to 29.5^{o}C on the 28th day (Table 7) (Obodai et al., 2010). Bacteria and fungi are collectively responsible for most of the initial decomposition and heat generation in compost. The influence of temperature on fungal ability to decompose has been examined in a study on enzyme activities of fungal strains isolated from soils (Flanagan, & Scarborough, (1974). It has been shown that the isolated fungi were very enzymatically versatile and that some species exhibited varying temperature optimum for the production of different enzymes. For example, some species showed optimal cellulolytic activity at 5^{o}C but optimum pectinolytic activity at 20^{o}C (Kjoller & Struwe, 1990; 1997). This versatility may have wide ecological implications in compost substrates for mushroom cultivation in different regions of the world under varying environmental conditions.

4.2 Moisture content

Moisture content below a critical level (<30%) will invariably decrease microbial activity and the resident microorganisms in the composting substrates will be dormant. On the other hand, a moisture content that is too high (>65%) can cause oxygen depletion and lose of nutrients through leaching (Tiquia et al., 1996). In subsequent anaerobic environmental conditions decomposition rate decreases and odour and other problems arise (de Bertoldi et al., 1985; Fogarty & Tuovinen, 1991; Golueke, 1992; Tiquia et al., 1996). In the case of sawdust from *wawa* composted for 28 days, the moisture content of the sawdust from the core portion of heap ranged from 58.44 and 71.02% for 28 days and 0 day respectively (Obodai et al., 2010). These values are however, within optimal moisture content required for best growth of *Pleurotus* species (Kurtzman & Zadrazil, 1982; Stamets, 1993). The moisture content of three potential utilizable leaf of *Tapinanthus bangwensis* parasitizing *Murraya koningii*, *Oncoba spinosa* and *Rothmania longiflora* placed in a specially designed composting chamber decreased from 75% to 20% in 12 weeks (Fig 3) (Odamtten and Abu-Juam, 2010). This was attended by an increase in the pH of the substrate from acidic $\leq$ 6.5 to basic $\geq$ 8.5 in 12 weeks. Moisture content of substrates with potential cultivation of *V. volvacea* ranged from 69.0% to 79.1% with attendant ERH 78.85% for best growth (Obodai, 1992).

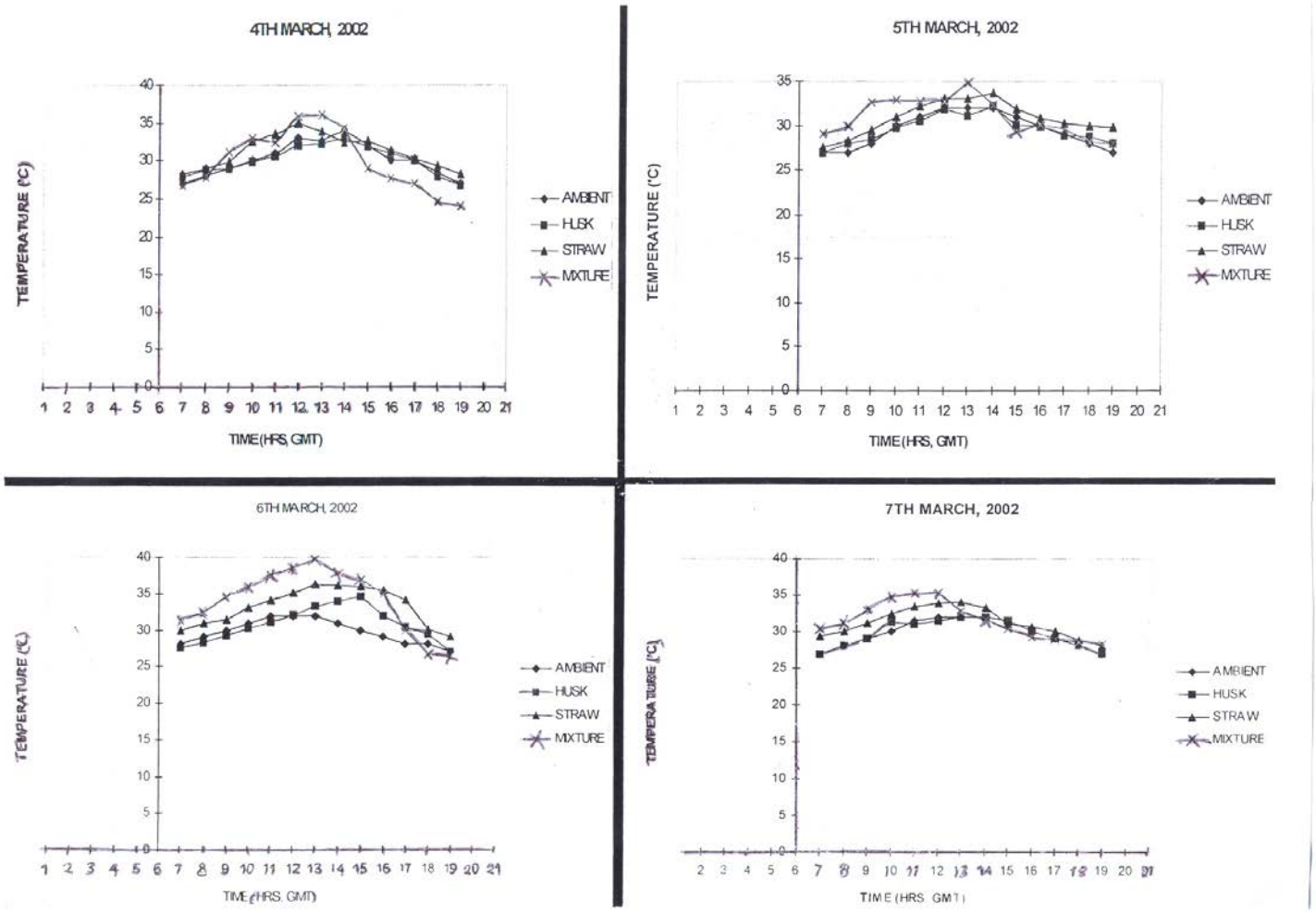

Fig. 2. Dirnal changes in the core temperature of composting rice husk, rice straw and mixture of the two between 4-7th March, 2002 (Data after Odamtten and Malm, 2002).

Period of composting	pH	Moisture	Temperature
0	7.03	71.02	31.5
7	6.74	70.03	56.0
14	6.42	69.62	34.0
21	7.34	63.54	31.0
28	6.47	58.44	29.5

Table 7. Changes in the physical characteristics of *wawa* sawdust during compositing (Data after Obodai et al., 2010)

4.3 pH

pH is an important factor in the growth and development of microorganisms. The pH values of fermenting *wawa* sawdust substrate ranged initially at a neutral pH of 7.03 and reduced finally to a slightly acid pH of 6.47 after 28 days (Table 7). The decline could be attributed to the breakdown of soluble and easily degradable carbon sources resulting in decrease in pH due to organic acid formation (Beffa et al., 1996b; Finstein & Morris, 1975; Gray et al., 1971). In the case of composting *T. bangwensis* leaves, there was increase in pH from $\leq$ 6.5 to $\geq$ 8.5 in 12 weeks. This was attended by a decline in fungal activity and decrease in moisture content (Fig. 4). The early colonizers *Mucor pusillus*, *Rhizopus oligosporus*, *R. oryzae* and *Syncephalastrum racemosum*, *A. niger* and *T. viride* were replaced by later colonizers *Fusarium*, *Penicillium purpuregenum*,

Paeciliomyces varioti. *Curvularia lunata* and *Alternaria solani* presumably preferred the higher pH in the medium for growth. The pH values of five agricultural unammended lignocelluloses waste with the potential for cultivation of a local isolate of *Volvariella volvacea* (Bull ex fr) Sing was variable ranging between pH 5.37-7.37 (Ofosu-Asiedu et al., 1986) which is within the optimum for best growth of *V. volvacea* (Oei, 1996).

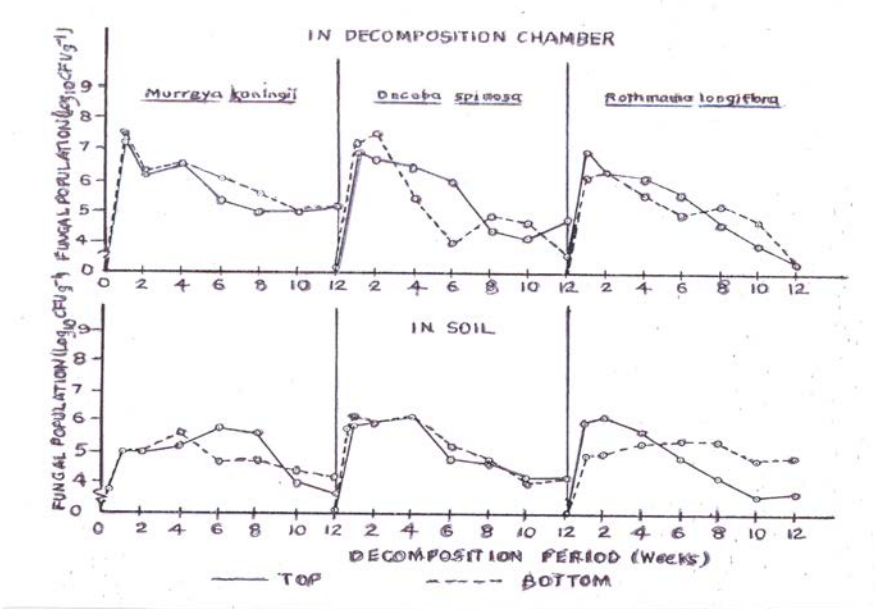

Fig. 3. Phenology of total fungal population in composting leaves of *Tapinanthus bangwensis* severed from the indicated plants and composted in either the decomposition chamber or in soil for 12 weeks at 28±3°C

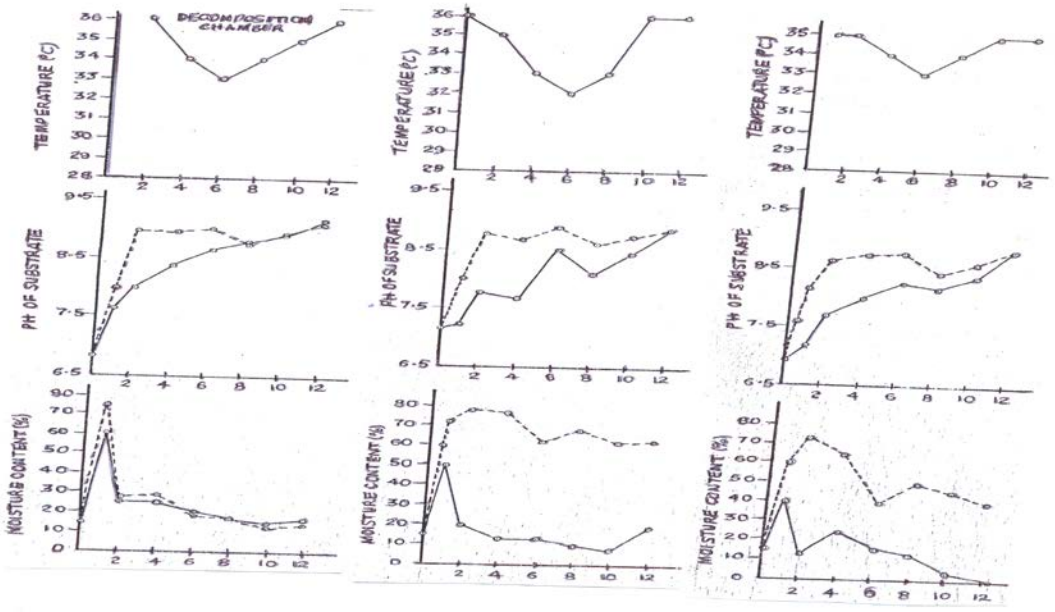

Fig. 4. Changes in some indicated physical factors in the decomposition chamber during the decomposition by fungi in *Tapinanthus bangwensis* leaves severed from (left) *Murreya koningii*; (middle) *Oncoba spinosa* and (right) *Rothmania longiflora* plants.

4.4 Chemical and nutritional alteration of substrate

The changes which occur in the substrate makes it utilizable by the macrofungi for human consumption later. In a typical case of the *wawa* sawdust undergoing composting, the dry weight of cellulose, hemicellulose, crude fibre and organic matter decreased within 28 days while lignin increased (Fig 5) (Obodai et al., 2010). The lignin polymer of aromatic compounds is relatively difficult for cellulolytic organism to decompose (Chang-Ho, 1982; Insam & de Bertoldi, 2003). Invariably, the sawdust undergoes composting to breakdown the cellulose and lignin components of the wood to release nutrients for the establishment of the mushroom mycelium (Obodai et al., 2002; Sawyerr, 1994) after microbial degradation and mineralization (Mckinley & Vestal, 1984). The fungi identified have been found to degrade cellulose, hemicelluloses, starch and to a limited extent lignin (Ryckeboer et al., 2003). Besides a carbon source, microorganisms require macronutrients such as N, P and K and trace elements for their growth. Nitrogen is a critical element for fungal growth as well. If nitrogen is limiting during composting the degradation process will be slow. Analyses of the various organic constituents of *wawa* during the 28 days composting (as well as in some other composting waste) showed that there was a gradual decline in nitrogen (Fig. 5) (Obodai et al., 2010). This is indicative of the utilization by the microorganisms during decomposition of the fermenting substrates. Thus it is essential that the nitrogen content of the substrate be supplemented to alter both pH and nitrogen utilization by the mushroom mycelium at the bagging stage.

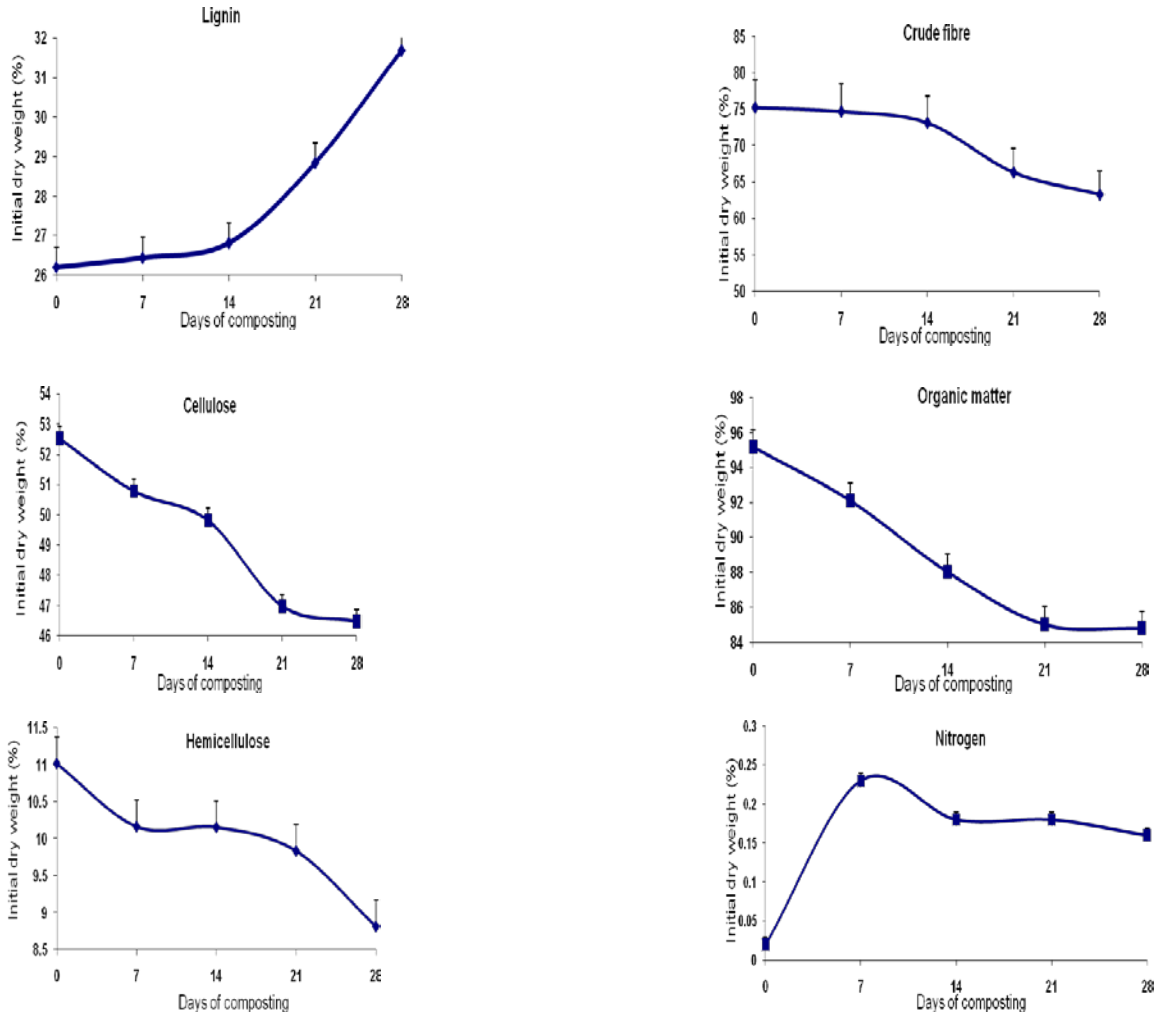

Fig. 5. Changes in lignin, cellulose, hemicellulose, crude fibre, organic matter and nitrogen during composting of *wawa* sawdust for 28 days (Data after Obodai et al., 2010).

There are references in the pertinent literature showing correlation between mushroom yield and supplementation of compost composition with chemicals and additives (Allison & Kneebone, 1962; Stamets, 1993;). Supplementation of sterile wheat straw substrate with ammonium nitrate, soya bean meal or alfafa meal changed the nitrogen content of the sporophore of *Pleurotus sajor-caju* (Zadrazil & Brunnert, 1980). The yield of *P. sajor-caju* on sterile wheat substrate could be increased 50% by supplementation with ammonium nitrate and about 300% with soya bean or alfafa meal (Zadrazil & Brunnert, 1980). Similar results were reported by Kalberer (1976) who found that grass meal supplementation increased the yield of fruit bodies of *P. ostreatus*; the effect of supplementation was about three times higher for *P. sajor-caju* than *P. ostreatus.* According to Quimio (1980), additives like cotton seed increased yield of *Pleurotus flabellatus* and improved the textural and flavor characteristics of the mushroom. The best cummulative yield of *P. sajor-caju* (from Hong Kong), *P. sajor-caju* (Mauritius) and *P. ostreatus* was obtained 21 days on *wawa* sawdust supplemented with 5% leaves of *Leuceana leucocephala* (Obodai, 1992) whilst *P. ostreatus* strain EM-1 gave a 57% increase over the control when *wawa* sawdust was supplemented with 15% of groundnut testa (Obodai & Johnson, 2002).

Organic nitrogen sources usually support better growth of *Volvariella* mycelium than inorganic substances (Chandra & Purkagastha, 1977; Chang-Ho and Yee, 1977; Rangaswami, 1956). Asparagine and peptone are good stimulators. Cotton waste is rich in asparagine, glutamine and glycine and the latter is depressive to cellulose decomposition of *Volvariella*. Supplements added to basal compost benefit *Volvariella* either directly or by enriching the growth of microorganisms for satisfactory composting. Rice bran, chicken manure and other organic nitrogen base agricultural by-products are commonly mixed into the compost base to increase nitrogen level of compost and to improve texture quality. Rice bran and soya bean meal contain 0.68% and 1.27% nitrogen respectively. Rice bran is rich in lipids and may stimulate higher mushroom yield because some fatty acids, eg. linoleic acids have been found to stimulate yield and primordium formation (Hayes, 1972) and fructification (Schinsler, 1967; Schisler and Sinden, 1966) in *Agaricus* species.

4.5 Fungal succession during composting of cotton waste and other useful lignocelluloses for the cultivation of *Volvariella volvacea*

V. volvacea or the oil palm mushroom locally called 'domo' in Ghana is widely eaten and in recent times cultivated. Various agricultural waste materials have been used in the cultivation of this edible mushroom. These include rotting oil palm truck, palm kernel refuse (Zoberi, 1979), citronella, coffee pulp and rice straw (Peerally & Sutra, 1972a), banana waste, molasses and on remnants from the distillation of Geranium (Peerally & Sutra, 1972b); on heaps of peeling of *Zanthosoma sagittifolia* corms, *Manihot ultisima* tubers (Raameloo and Walleyn, 1993). Other substances used in the cultivation of *V. volvacea* are rice straw, sugar cane bagasse, water hyacinth and cotton waste (Chang and Quimio, 1982). Obodai (1992) used different substrates (*wawa* sawdust, rice straw, maize stover, dry banana leaves, cocoa shells and oil palm pericarp for the cultivation of *V. volvaceca* in Ghana with variable results.

Bacteria population in the dry banana leaves, maize stover, oil palm pericarp and rice straw were 0.3-0.6 log cycles lower after 30 days than what was obtained initially. The only exception was in the cocoa shell substrate which contained slightly higher final population (0.2 log cycles higher) than what existed at the commencement of the experiment. In almost all the substrates *Aspergillus niger* was initially present and persisted after 30 days with the exception of rice straw (Fig. 6). Only *A. flavus* was initially resident in rice straw substrate but was replaced by *Coprinus cinereus* (20.0%) and *Trichoderma viride* (7.1%) at the end of 30 days. Maize stover substrate recorded *A. niger* (5.1%) initially, after 30 days, *A. niger* (19.4%), *A. flavus* (3.1%), *A. fumigatus* (24.4%), *C. cinereus* (10.0%), and *T. viride* (21.9%) could be isolated as well. Cocoa shell substrate initially recorded *A. niger, A. flavus* and *C. cinereus*. *A. fumigatus* predominated (59.2%) after the experiment.

Banana leaves initially harboured *A. niger, A. flavus*, *A. fumigatus* constituting 19.7, 20.4, and 19.7% of the total population respectively (Fig.6). After 30 days of growth of *V. volvacea* mycelium, *Penicillium digitatum, C. cinereus* and *T. viride* appeared as well. Finally, while *A. niger* persisted in the oil palm pericarp substrate throughout the experiment, *A. flavus, A. fumigatus* and *C. cinereus* were isolated in the compost at the end of the experiment. It is striking that the species composition of the substrates differed at the beginning of the experiment and also varied considerably after utilization of the substrate by *V. volvacea* mycelium. *V. volvacea* produced 55 fruit bodies on dry banana leaves only yielding 491.5g after 13 days and thereafter declined.

Recent studies by Odamtten and Kwarkye-Dankyi (2009) elucidated the fungal phenology in cotton waste compost used in the cultivation of *V. volvacea.* The raw uncomposted cotton waste harboured 16 fungal species (*A. flavus, A. fumigatus, A. ochraceus, A. terreus, A. ustus, Botrytis cinerea, Cladosporium cladosporiodes, C. herbarium, Coprinus cinereus, Curvularia lunata, Mucur haemalis, Penicillium sp Pullularia pullulans, Rhizopus oryzae, Scopulariopsis brevicaulis and Trichoderma viride*)

predominated by *T. viride*, *Coprius cinereus*, *Cladosporium herbarum* and *Aspergillus fumigatus* in decreasing order. After 4 weeks of cultivation of *V. volvacea* in the compost, *T. viride* predominated. Harmful fungal species which affect cultivation of *V. volvacea* (*A. fumigatus, Coprinus cinereus, A. niger* and *T. viride* were present in the raw material and persisted. Composting did not get rid of these harmful fungi, implicating these fungi, especially *C. cinereus* in the depressed yield of *V. volvacea* on cotton waste.

5. Survey of the current methods in use for assessing the efficacy of the process of composting

Samples of compost should be taken at weekly intervals (0, 7, 14, 21 and 28 days) from the central portion of the heap and put into sterile bags and quantitative estimation of crude protein, crude fibre, cellulose, hemicellulose, lignin, organic matter and ash can be carried out, using the standard methods as described by AOAC (2005).

Lignin and cellulose content are usually determined by acid detergent fibre ADF method (AOAC, 2005). Hemicellulose content is estimated by neutral detergent solution using 1g of dried sample (AOAC, 2005). The difference between the acid detergent fibre and neutral detergent fibre gives the value for hemicellulose content. Ash, organic matter and crude fibre are determined by AOAC, (2005) method and percentage crude fibre calculated.

The dilution plate technique is used in estimating fungal and bacterial populations. About 10 g fresh weight of sample is placed in 250 ml Erlenmeyer flask containing 100 ml sterile distilled water. The mixture is shaken at 140 rev. min^{-1} in a Gallenkamp Orbital Shaker for 30 min. Aliquot (1ml) of the suspension is placed in sterile universal bottles (MaCartney tubes) containing 9 ml of 0.1% peptone, and serially diluted up to $1:10^5$. The fungal population is enumerated on Oxytetracycline Glucose Yeast Extract Agar (OGYE, Oxoid, Basingstoke Hampshire, England) with the use of tetracycline supplement incubated at 25^{o}C for 3 to 5 days. Aerobic bacterial population is enumerated on Plate Count Agar (PCA, Oxoid, Basingstoke Hampshire, England) incubated at 37^{o}C for 24h. The fungi is identified using their morphological and cultural characteristics as outlined by Samson et al., (1995).

In recent years the use of molecular methods such as Polymerace Chain Reaction (PCR) and/or sequencing of specific genomic regions has gained popularity. These methods are characterized by rapidity and reliability and overcomes problems associated with selective cultivation and ambiguity caused by different media.

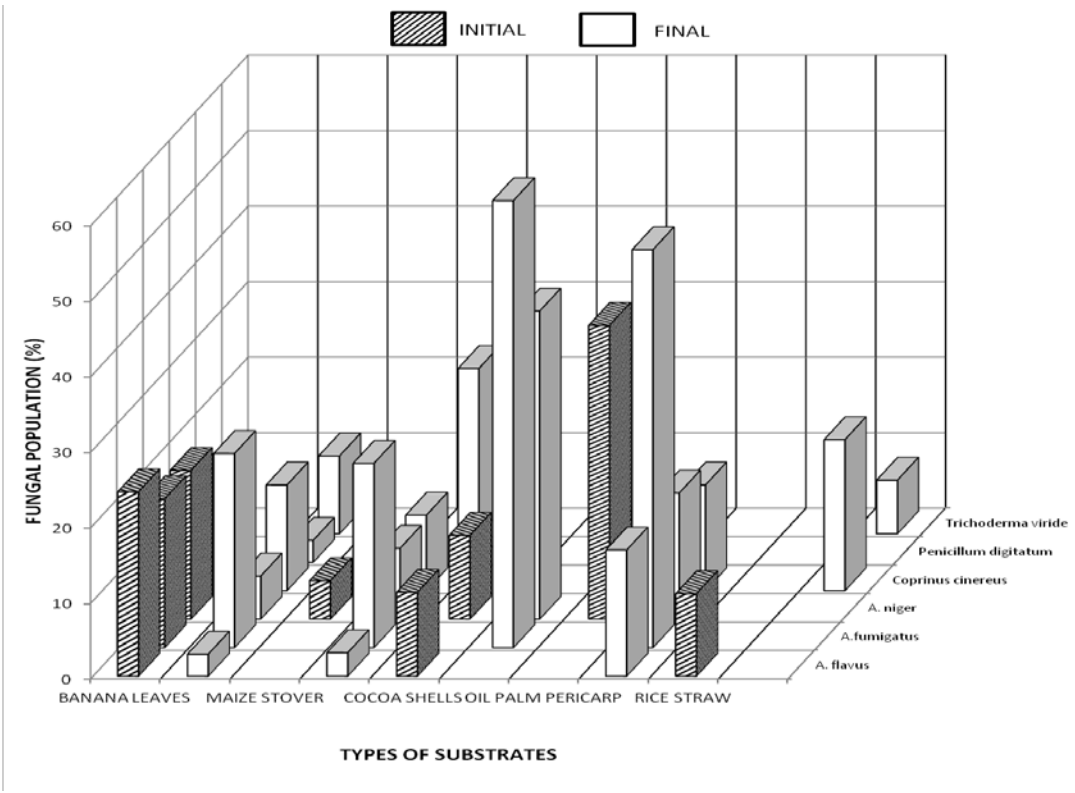

Fig. 6. Occurrence of some harmful fungi found in the substrate before and after cultivation of *Volvariella volvacea* at 28°C for 30 days.

6. Prospects for the use of composted agro waste and leaf litter as biofertilizers and soil mulch to serve as biocontrol agents against soil-inhabiting pathogens

Soils play a vital role in food and plant dry matter production, as a reservoir for water and a buffer and filter for pollutants. Soils store about twice as much carbon as does the atmosphere and are an important link in the natural cycle that determines atmospheric carbon dioxide levels. Nutrients for growth of plants and other resident living organisms are derived from decomposed organic products in the soil ecosystem.

Despite the agricultural importance of these soils, there is a general belief that their fertility is depleting, especially in Africa where there is in some cases over application and some misapplication of agro-chemicals hence the recorded diminishing yields in such soils (MOFA, 1998; Owusu–Bennoah et al., 2000). The maintenance of detritus litter is very important for sustainable crop productivity (Ahenkorah et al., 1999). The use of naturally produced biofertilizers from organic waste has become the order of the day even in the developed countries which produce the agro-chemicals. The production figures of agricultural waste biomass in Ghana are not readily available. However, the abundance of agricultural lignocelulose is common knowledge. Recent data in 2010 from Ghana suggested that about 65% of waste composition in the Accra Metropolitan Area alone consists of organic matter; paper accounts for 6% of the waste (AMA, 2000). Together, both organic and inert (plastic, glass, metal, textile etc.) accounted for about 82% of the waste. The trend is not different for most of the city and urban areas in West Africa. Over two decades ago it was estimated that 2.5 billion tons of cereal straws, 560 million tons of leguminous crop residues and 23.4 million tons of sugarcane bagasse are produced every year throughout the world. This might have been increased significantly since then. The process of decomposition (composting) of such lignocellolose recycles nutrient back into the ecosystem for use by plants and fungal bioprotein biomass production. Nutrients held in organic combinations within the crop residues are released through the decomposition process for use by other organisms and plants.

Litter decomposition is a very important component of the global carbon and other nutrient budget. Due to strong climatic control of decomposition, climatic change may significantly affect the pathway (Zabinski and Ganroon, 1997). The overall

amount of cellulose degraded worldwide each year is about equal to the annual production of 28 billion tonnes. Without decomposition of the debris by composting the earth would be covered with plant and animal bodies. A given microbe species has the innate ability of decomposing only certain components in the plant and animal residue, and a number of species are required to decompose a resource completely. This is the succession or phenology of microorganism observed in the composts as reported in this chapter. It is now common knowledge that fungi, bacteria and protozoa are often involved in decomposing a single substratum. A conservative estimate by Melting (1993) of the number of microorganisms in fertile soil or plant litter is : true bacteria (10^8 - 10^9cfu/g); actinomycetes (10^7- 10^8cfu/g); protozoa (10^3-10^5cfu/g); algae (10^3-10^6cfu/g) and fungi (10^5-10^6 cfu/g). This estimate does not include larger soil animals such as nematodes, earthworms, mites, ants or other worms and arthropods. Succession or phenology of microorganisms especially fungi within the decomposing detritus helps us to understand the dynamics of the decomposition process, and the species that colonise the detritus are responsible for the release of essential nutrients and chemicals used in antibiosis against potential competitors and pathogens.

The production of low-cost biofertilizers from agricultural waste products should engage the attention of African researchers. The adoption of new alternative appropriate technologies can curtail cost of food production by reducing the soil bank of detrimental agrochemicals and may be able to increase organic matter in soil by improving both fertility and the physical and biological properties of the soil (Garner, & Mokwunye, 1995; Soltner, 1996). The value of biofertilizers is the fact that they should be able to replace soil nutrients removed by the plants. The quality, timing of application and ratio of soil amendment to enhance productivity must be painstakingly worked out in future studies. It should be possible to quatify, by proximate analysis, the concentration of nutrients produced by biofertilizer during composting so as to guide one in the formulation, line of application and the environmental parameters which would enable the farmer derive maximum benefit. This suggestion was informed by preliminary studies aimed by using composted coffee husk, fresh cocoa pod husk, dry cocoa pod husk, rice husk, rice straw and mixture of rice husk and rice straw to improve the growth and fruiting of okra (*Abelmoschus esculentum*). All six composts tested variably depressed seed germination of okra and seedling development (Odamtten & Avle unpublished data). On the other hand cowpea (*Vigna unguiculata*) cultivated in soils amended with rice straw, rice husk and mixture of rice straw and rise husk grew better. This finding contrasts the report of Odamtten &Avle (unpublished data) for okra. A mixture of soil with rice straw compost significantly improved and stimulated nodulation by roots. The composting process in soil was more efficient with rice straw compost and could support better vegetative growth of cowpea and efficient formation of larger and numerous viable root nodules (Table 7). Rice husk was less efficient and mixed compost was intermediate (Odamtten & Malm, unpublished data). Root nodules formation is a characteristic feature of the Leguminosae to which cowpea belongs. It was obvious that *Rhizobium* which forms symbiotic association in the nodule was not depressed in the soil by amendment. Rice straw composed in soil used in cultivation of cowpea was presumably serving as a biofertilizer for enhancing nodule formation on the cowpea.

Type of treatment	Number of nodules/plant (Mean ± S.E)	Diameter of nodules/plant (Mean ± S.E)
Soil only	8.0±4.1[a]	2.2±1.1[d]
Soil + mixture of husk and straw	7.0±3.3[a]	3.2±1.1[e]
Soil + rice husk	4.3±1.4[d]	2.5±1.0[e]
Soil + rice straw	11.0±5.0[c]	2.9±1.3[e]
Mixture of rice straw + rice husk only	-	0.0±0.0
Rice husk only	0.00±0.0	0.0±0.0
Rice straw only	-	-

Table 7. Comparative nodulation of cowpea (*Vigna unguiculata*) seedlings in the indicated soil/compost combination growing in plants for 42 days at 28-32^{o}C

* Plants died before end of experiment

\- Seeds died after germination

(Data after Odamtten & Malm, unpublished data)

The value of biofertilizers is that it is able to replace soil nutrients removed by plants, especially in the soil degraded and depleted on nutrients. However, future studies should examine the quantity (nutrient level etc.), time of application and ratio of the biofertilizer to soil etc. formation and other environmental parameters that would enable the farmer derive maximum benefits. There is another added value of biofertilizers. A number of studies have been to elucidate the antimicrobial activities of plant extracts. The leaf litter being decomposed may have an added value of yielding metabolic products which may serve as a biofungicide. Antimicrobial activity in plant leaves used as a mulch has been reported for

Jatropha podegrica (Odebiyi, 1985), *Eucalyptus (*Delacasse et al., 1989)., certain Sudanese plants Almagboul et al., (1985), Argentine higher plants (Tomesi et al., 1986), neem plant (*Azadiracta indica*) (Manu et al., 2000; Plange & Hayford, 2000; Youdeo, 2000).

The semi-parasite *Tapinanthus bangwensis* (Loranthaceae) infest and destroys crops and forest trees in Ghana and throughout West Africa. The parasite occurs on 75% plant species within sixty genera and 29 families (Odamtten and Annang, 1989). The list has been extended since then (Odamtten Unpublished data). The parasite usually becomes established at the periphery of the crown of host trees because the seedling requires relative high insolation for photosynthesis. This habit is of interest in the control of the parasite because it can be severed from the host with minimum loss of the host plant (Odamtten and Okyere, 1994). The leaves contain biotoxins which has fungicidal activity against *Aspergillus flavus* (Ahiabu, 1985). The leaf exudates of *T. bangwensis* severed from several host plants prevented the formation of sclerotia by *Sclerotium rolfsii* (Odammtten and Okyere, 1995). This in-vitro fungistatic effect of the phytotoxins on *Sclerothium rolfsii* was confirmed in the studies where slcerotia were placed directly on moistened leaves of host and non- host plants. It was assumed that *Tapinanthus bangwensis* leaves contain sufficient nutrients to support fungal growth and that theoretically, *S. rolfsii* should be able to colonise them. There is also the added antibiosis effect of saprophytic fungi in the soil during the decomposition of the leaf which might augment or modify the killing effect of the leaf exudate on sclerotia of *S. rolfsii*. Curiously, *T. bangwensis* parasitizing *Pithecellobium dulce* contrasting with materials derived from all the other hosts (*Murrega koningi*, *Rothmania longiflora*, *Tabeibua pentaphylla*, *Lagerstroemia indica*) stimulated sclerotium formation (85-173 sclerotia / leaf) (Odamtten and Okyere 1994). Thus *T. bangwensis* shrubs severed from P. dulce were unsuitable for the control of *S. rolfsii* and the leaf extract of *T. bangwensis* removed from *P. dulce* suppressed growth of sclerotia formation by phytotoxins from *T. bangwensis*. Indeed studies by Odamtten & Annang (1989) showed that the quality of active ingredients (alkaloids and phenolic compounds) in the leaf extract of T. bangwensis differ significantly from host to host. The highest quantity detected so far was in *T. bangwensis* shrub parasitising *Murrega koningii* and *R. longiflora* (Odamtten and Annang, unpublished data).

Microbial succession during decomposition of *T. bangwensis* may interplay with other factors to augment the inhibitory factor from the leaf exudate of T. bangwensis. The early colonisers of decomposing *T. bangwensis* leaves include *Sycephalastrum racemosum* (Mucorales), *Rhizopus oryzae* (Mucorales) and overtaken after 7-14 days by *Aspergillus* species (*A. japonicas, A. flavus, A. niger, A. alutaceus, A. ruber, A. fumigatus, A. sulphureus*) and *Penicillium digitatum* (Odamtten and Abu-Juam, 2010). *Aspergillus* species seem to predominate the fungal flora during decomposition of *T. bangwensis* in the presence of sclerotia of *S. rolfsii*.

7. Conclusions and Recommendations

Decomposition of any organic and agricultural lignocelluloses is a well-known phenomenon. Although the natural process is attributed to the microorganisms and especially resident mycoflora, the process has not been fully elucidated in some instances. It is known that the decomposing organisms act in concert to change the substrate chemically and physically in order to reduce the "bound' nutrients for utilization by fungi and other bioderioagents as well as serving to recycle nutrients in the ecosystem. In the case of agricultural lignocelluloses waste, the process of composting makes the substrate utilizable by the macrofungi to produce mycoprotein for human consumption.

Information on the phenology of the resident mycoflora not only helps us to know and understand the process and the species responsible for the decomposting process and release of the nutrient but also those that the exert inhibitory effect (antibiosis) on the mushroom to be cultivated on the composted substrate. For example, *Coprinus cinereus*, *Aspergillus fumigatus*, *A. niger* and *Trichoderma viride* are harmful to the cultivation of *Volvariella volvacea*. There are special agricultural waste, leaf litter, and garbage produced annually in tropical Africa which can be harnessed for edible mushroom cultivation. However, research is required to understand the composting process and amendment of the substrates to be used for future fungal protein cultivation. Countries in the developed world of USA, Europe and in Asia have taken the lead in this direction. Very little of export of mushroom from Africa is known although there is a huge potential for mushroom cultivation to alleviate poverty. Some edible mushroom eaten and found in Africa eg. *Volvariella*, *Pleurotus*, *Macrolepiota*, *Agaricus*, *Auricularia* and *Schizophyllum* using agricultural lignocelluloses come readily to mind as potential species to be cultivated under local farmhouse conditions.(Obodai et al., unpublished data; Odamtten, 2009). There is another economic benefit. The spent compost from mushroom cultivation contain residual useful nutrient constituents which may be incorporated into the soil as natural biofertilizer to boost agricultural production. This is another relevant area for future research to replace lost nutrients in degraded soils. The added value of using decomposting leaf litter, agricultural lignocellulose as soil mulch is the antimicrobial potential of their extract. Anti fungal activity in plant leaves used as soil mulch have been highlighted in this chapter. Over 104 plants belonging to 24 families have been tested for the presence of

alkaloids, antraquinones, courmarins, flavonoids, saponins, steroids, terpenes and tannins. Forty two plants gave positive test for alkaloids, 65 for courmarins, 77 for flavonoids, 35 for saponins and 27 for tannins. Antraquinones were detected in only 4 plants. These compounds have been implicated in fungistasis against soil-borne plant pathogens (Tomesi et al., 1986). The leaf extract of *Chromolaena odorata* containing these active ingredients was fungicidal against *Fusarium moniliforme* in soil (Odamtten 1992). The scientific bases for use of weeds on local farm as soil mulch to retain soil moisture should form the basis for future research in litter decomposition for control of plant diseases.

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