FIBER COMPOSITION OF PACKAGING GRADE PAPERS AS DETERMINED BY THE GRAFF "C" STAINING TEST

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ABSTRACT

A qualitative and quantitative analysis of the fiber components of 15 representative papers that are used for the production of corrugated board was carried out by the Graff "C" staining test. The method of processing of softwood, hardwood, and nonwood fibers was determined under a light microscope by their color reactions with the stain. All papers, due to the use of recycled pulp raw materials in their manufacturing, were found to incorporate in their furnish fibers that had been produced with a variety of pulping processes: chemical, mechanical, and semi-mechanical. The recycled-based papers (recycled-liner and recycled-medium) were proved to be the most variable comprising 12–15 different fiber components, while in some of the semi-chemicals only up to 7 components were identified. The weight percentages of the fiber components calculated by the application of weight factors showed that in almost all papers the most important fiber component from a quantitative standpoint was hardwood unbleached kraft followed by softwood unbleached kraft. Besides hardwood unbleached semi-chemical pulp and mechanical softwood pulp that were also plentiful in the papers, there was a smaller number of other components which sum, however, accounted for a significant fraction in the total furnish weight. The results taken on the total softwood, hardwood, and nonwood fibers content of the papers demonstrate that Graff "C" staining test is adequate to analyze both the structure and quality of packaging grade papers in practical industrial testing.

Keywords: Fiber analysis, Graff "C" stain, chemical pulp, semi-chemical pulp, mechanical pulp, recycled fibers, packaging.

INTRODUCTION

The fiber sources for paperboard production have shifted from roundwood to mill residues, agro-residues, and recycled paper, and the share of recycled paper is projected to increase significantly over the next years due to environmental pressure (Young 1997; Mabbe 1998; Skog et al. 1998; FAO 2001) and favorable policy (e.g. EU Packaging and Packaging Waste Directive 94/62/EC and EU Declaration on Paper Recovery of 2000). A direct consequence of the move towards higher recycling rates is the change to more heterogeneous, numerous and smaller sources for the packaging industry (CEPI 2003).

The properties of paper and paper products (carton board and corrugated board) vary greatly due to differences in raw materials (Britt 1971; Bormett et al. 1981; Thomas and Kellison 1989; Law et al. 1996; Drost et al. 2004). Corrugating packaging production is facing the challenge to

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ensure a satisfactory strength of packages despite the increase of recycled paper as the main fibrous component (packaging grade papers contain 60–100% recycled fiber). Recycled fibers tend to be broken or damaged, and they have different physical properties than virgin fibers (e.g. microfibrils on the surface of fibers tend to be collapsed) due to irreversible hardening or hornification occurring during drying and rewetting (Howard and Bichard 1992). These differences in fiber properties contribute to weaker interfiber bonding and hence to lower quality (strength) in recycled paper or paperboard products (Ince 2004). Therefore, the use of additional process technology is necessary (mechanical refining, coatings, sizing, bonding adhesives etc.) to compensate for inherent disadvantages of recycled fibers, adding to costs.

A step towards a more economical and effective utilization of paper and paper products in packaging can be the reliable characterization (qualitative and quantitative as to source) of raw pulp materials, which will allow the selection of the appropriate raw material for each end-use. The necessity of putting more emphasis on a better classification of recovered paper quality is not until now a sufficiently explored practice in the industry (García 1988). It is well known that the production methodology (chemical, mechanical, and chemical-mechanical pulping) affects the fiber bonding ability, and as a result, the strength of paper and paperboard properties (Mohlin 1989). For example, chemical pulps (kraft and sulfite) have better and more uniform fiber quality, with generally less lignin or other wood constituents and proportionately more cellulose fiber and more intact fibers than mechanical and semi-chemical pulps. Kraft pulp typically produces a stronger sheet of paper or paperboard (Ince 2004).

The objective of the present work was to quantify the types of fibers on the basis of pulping processes in a variety of packaging grade papers used as linerboard and corrugating medium for corrugated board manufacturing in Spain. Information on the actual furnish composition of packaging materials is expected to help the packaging industry to evaluate its sources of supply and to utilize the available resources in an optimal manner.

MATERIALS AND METHODS

Sample selection for microscopy

Containerboard papers belong to two groups: linerboards and corrugated medium, which form the flat faces and the periodic fluted core of corrugated board structural panels, respectively. Linerboards are available in three basic forms (common names): kraft-liner, test-liner and recycled-liner. Kraft-liner is made mainly from virgin softwood and hardwood fibers but also includes some recycled fibers (e.g. clippings from corrugated board manufacture or from old corrugated containers). Test-liner consists mainly of recycled fibers, which come in many different grades and qualities from corrugated plants, stores, offices, and households. In test-liners the one face is usually of kraft-liner quality, and the other is from selected recycled fibers that increase the quality of the sheet. Recycled-liner is made from recycled fibers and it has lower quality than test-liner. There are two types of corrugating medium: semi-chemical and recycled-medium. Semi-chemical is a virgin-based medium and is increasingly used for special purposes, for example, in humid conditions. The main virgin fiber used to manufacture semi-chemical corrugating medium is semi-chemical hardwood, which is cheaper than softwood and gives good resistance to forces perpendicular to the flutes (the short hardwood fibers are less flexible than softwood fibers and give greater stiffness to the corrugated structure). Recycled-medium is the multipurpose medium most frequently used and represents the lowest grade, which has been heavily recycled.

Fifteen different packaging grade papers were selected to cover all the above qualities of linerboard (3 kraft-liners, 1 test-liner, and 3 recycled-liners) and corrugating medium (5 semi-chemicals and 3 recycled-medium) and to represent all the variety of papers available in the market at the moment for the production of corrugated board in Spain. The papers were provided by representative Spanish paper manufacturers. The characteristics of the papers are shown in Table 1.

Microslide preparation and staining

Qualitative and quantitative determination of the fiber components of paper as regards the method of pulping processes is carried out under the microscope on the basis of color reactions of fibers stained by various stains (Isenberg 1958). Among the several staining tests described in ISO 9184-2: 1990, which are used to distinguish the various pulping processes of fibers by color change, the Graff "C" staining test was selected for having the largest field of application, necessary for the high variable packaging papers. Graff "C" stain is suggested for general analysis, while other stains are used for specific purposes or to confirm results obtained with the "C" stain (Spearing and Dressler 1954; Strelis and Kennedy 1967; Parham and Gray 1990). Fresh Graff "C" stain was prepared according to ISO 9184-4: 1990 and consisted of 20 ml of aluminium chloride solution (40 g of aluminium chloride hexahydrate dissolved in 100 ml of water), 10 ml of calcium chloride solution (100 g of calcium chloride dissolved in 100 ml of water), 10 ml of zinc chloride solution (100 g of dry zinc chloride dissolved in 50 ml of water) and 12.5 ml of iodine solution (0.90 g of potassium iodide and 0.65 g of iodine dissolved in 50 ml of water). The mix was stored in a dark-colored, glass-stoppered dropping bottle, and after a leaf of iodine was added, it was kept in dark. Before use, the stain was checked with a reference sample of ECF bleached kraft pulp of *Eucalyptus globulus* that was provided by the company ENCE (Empresa Nacional Celulosa Español).

For each of the papers, microscope slides were prepared with fibers as for usual fiber analysis in accordance with ISO 9184-1: 1990. A representative small quantity (about 0.25 g) from different parts of the papers was torn into small pieces, placed in a small beaker, and boiled in water for a few minutes. The softened pieces were shaken vigorously in a large tube with the addition of some water until they were thoroughly disintegrated. The dispersed fiber suspension was diluted to a concentration of about 0.05% (wt./vol.), and then 0.5 ml of the suspension was transferred with a pipette onto clean slides placed on a hot plate. After slides were completely dried, staining of the fibers was performed by adding 2 or 3 drops of Graff "C" stain to the fiber field on each slide and then covered with a cover glass in such a way as to avoid air bubbles. The slides were allowed to

TABLE 1. *Paper characteristics.*

Paper grade	Paper ID	Production technology	Grammage (g/m^2)	Thickness (mm)
Linerboards				
Kraft-liner	KL1	Mainly virgin kraft fibers	228	0.293
Kraft-liner	KL2	Mainly virgin kraft fibers	185	0.258
Kraft-liner	KL3	Mainly virgin kraft fibers	298	0.437
Test-liner	TL	1 ply of kraft-liner quality and 1 ply of selected recycled fibers	124	0.195
Recycled-liner	RL1	Recycled fibers	126	0.194
Recycled-liner	RL2	Recycled fibers	112	0.182
Recycled-liner	RL3	Recycled fibers	152	0.228
Corrugating medium				
Semi-chemical	SC1	Mainly virgin semi-chemical fibers	161	0.256
Semi-chemical	SC2	Mainly virgin semi-chemical fibers	166	0.271
Semi-chemical	SC3	Virgin semi-chemical and recycled fibers	172	0.269
Semi-chemical	SC4	Virgin semi-chemical and recycled fibers	150	0.221
Semi-chemical	SC5	Mainly virgin semi-chemical fibers	165	0.264
Recycled-medium	RM1	Heavily recycled fibers	111	0.189
Recycled-medium	RM2	Heavily recycled fibers	107	0.172
Recycled-medium	RM3	Heavily recycled fibers	91	0.144

stand 1–2 minutes and then bringing the long edges of the slides into contact with a blotter the surplus stain was drained off. The above procedure produced a total count of between 200 and 300 fibers per slide.

Fiber identification and counting

The stained microslides were systematically examined under a Nikon Microphot EPI-U2 light microscope equipped with a 35-mm camera and a cross-hair eyepiece. The fibers were classed into softwood, hardwood, and nonwood fibers categories according to their morphology. The identification of pulping processes of fibers was based on the colors developed by the Graff "C" stain, which are accessible in ISO 9184-4: 1990 and presented in Table 2. The center marking of the eyepiece was located about 2–3 mm from one corner of the cover glass, and then the different kind of fibers passing under the cross-hair were counted by traversing the slide at horizontal lines, each 5 mm apart. Counting of fibers was made at a magnification of 80×, while at points of interest, it was necessary to move the slide vertically and increase the viewing magnification in order to study the morphological characteristics of fibers. The vertical position of the mechanical stage was noted for each particular traverse, to facilitate the return to the original line after such movements. Repeated passings along the same horizontal line were frequently required to confirm the count of each fiber type. Parts of the same fiber that passed the cross-hair more than once were counted each time. Fibers in a bundle were counted separately as they passed under the cross-hair. Fiber fragments less than 0.1 mm were ignored, as well as parenchyma cells and ray tracheids. Larger fragments of the same fiber type were counted separately as fractions, so when two or three of them were observed in the same line, they were ultimately converted into whole fibers. Fibers that appeared to have been shortened only little were counted as whole fibers. As no previous precision data were available from compositional analysis of packaging grade papers, not fewer than 600 fibers should be counted to achieve an acceptable level of precision according to ISO 9184-1: 1990. Therefore, at least two slides were counted for each paper.

TABLE 2. *Color chart for Graff "C" stain used for the identification of pulping processes of fibers in paper, board and pulps (taken from ISO 9184-4: 1990).*[a]

Type of pulp	Color
Softwoods	
Unbleached kraft	Shades of yellow and brown
Bleached kraft	Light bluish-grey or grey
Dissolving grade kraft	Brownish purple
Unbleached sulfite	Shades of yellow[b]
Bleached sulfite	Light brownish[b]
Dissolving grade sulfite	Light brownish or purple
Semi-chemical pulp	Vivid yellow
Mechanical pulp	Vivid yellowish orange
Hardwoods	
Unbleached kraft	Bluish-green, dark blue
Bleached kraft or semi-chemical	Intense blue[c]
Dissolving grade kraft	Blue-purple
Unbleached sulfite	Yellowish-greyish
Bleached sulfite	Light blue or bluish-grey
Dissolving grade sulfite	Light brownish
Unbleached semi-chemical pulp	Greenish (different shades)
Mechanical pulp	Vivid yellow
Nonwood fibers	
Grasses unbleached chemical pulp	Greenish-blue (many-colored)
Grasses bleached chemical pulp	Grey-blue, violet-blue, intense blue
Rag (bast fibers, leaf fibers and cotton)	Wine or brown-red

[a] Identification is also based on the morphological characteristics of fibers.
[b] Presence of ray cells, which are stained yellow is an indication of sulfite pulp and helps the distinguishing from kraft.
[c] Differentiation of bleached kraft and semi-chemical hardwood pulps is not possible with Graff "C" stain.

Quantitative determination

The weight percentages of pulp constituents are calculated after conversion of microscopical data (fiber counts) through the use of weight factors (Parham and Gray 1990). The weight factor of a fiber is a dimensionless number derived by the ratio of its fiber coarseness (average weight per unit length) to that of a reference fiber, typically rag having a fiber coarseness of 0.180 mg/m (Graff 1940; Clark 1951). Determination of weight factors of fibers according to standard methodology, such as ISO 9184-7:

1994, is applicable to pulps that do not contain more than 5% of other fibers with an essentially different weight factor. The great variety of different types of fibers in the examined papers, together with the fact that the actual pulps used in the papers were not available, precluded any attempt of determining separate weight factors for each fiber category. Consequently, the weight factors used in this study are predetermined literature values recommended by ISO 9184-1: 1990 and are given in Table 3.

The total fiber count of each category was multiplied by its respective weight factor from Table 3 in order to obtain the equivalent weights, and then their percentages by weight of the total weight were calculated. The weight percentages were reported to the nearest whole number, while percentages less than 2% were reported as traces (contaminating fibers).

RESULTS AND DISCUSSION

Qualitative analysis

Table 4 presents the different fiber components identified in the papers on the basis of stain reactions (pulping processes) and morphological characteristics of fibers (softwood, hardwood, nonwood fibers). As expected due to the use of recycled pulp raw materials, all papers incorporated in their furnish fibers that have been produced with a variety of pulping processes: chemical, mechanical, and semi-chemical. Figure 1 shows selected photos of diverse stain reactions of fibers revealing the method of processing. As a result of this variability, packaging grade papers were found to contain 6–15 different fiber components excluding the traces (see Table 4). The recycled based papers proved to be the most variable, comprising 12–14 components in the case of recycled-liners and 13–15 in the case of recycled-medium. Kraft-liners and the test-liner TL also exhibited significant variability, and consisted of 9–13 components; as well as two of the semi-chemicals, SC3 and SC4, both with 14 components. Semi-chemical SC1, SC2, and SC5 were the less variable papers, having 6–7 fiber components.

It should be underlined that distinguishing the pulping processes is a difficult task due to the many shades obtained by the Graff “C” stain on all kinds of fibers (softwood, hardwood, and nonwood fibers). For example, the similar tones of blue developed in the case of hardwood fibers, and yellow and brown in the case of softwood fibers could easily lead to erroneous conclusions. It was not unusual that slight alterations in the colors of Table 2 were noted, which can be attributed not only to the inhomogeneity of the processes but also to the chemical additives in the papers. Therefore, for a more accurate interpretation of colors, previous experience acquired by testing of a wide variety of pulp types as well as knowledge of fiber morphology was applied.

TABLE 3. *Assignment of weight factors to the different fiber categories (type of pulping) according to predetermined values recommended by ISO 9184-1: 1990.*

Fiber category	Weight factor
Softwoods	
Unbleached kraft and sulfite	1.0[a]
Bleached kraft and sulfite	0.9[a]
Dissolving grade pulp	0.85
Semi-chemical pulp	1.4
Mechanical pulp	1.5[b]
Hardwoods	
Chemical pulp	0.5[c]
Semi-chemical pulp	0.9
Mechanical pulp	0.9
Nonwood fibers	
Grasses unbleached chemical pulp	0.6[d]
Grasses bleached chemical pulp	0.4[d]
Rag	0.8[e]

[a] Weight factor recommmended for most of the papermaking softwood species.

[b] Average of weight factors of groundwood and thermo-mechanical pulp.

[c] Average of weight factors of hardwood species identified in the papers, mainly eucalyptus, poplar, birch and beech (identification was based on the presence of different vessel elements).

[d] Average of weight factors of straw and esparto (bleached and unbleached).

[e] Average of weight factors of bast fibers (flax and jute), leaf fibers (abaca and sisal) and fruit fibers (cotton staple and cotton linters).

Quantitative analysis

The weight percentages of fiber components calculated in the papers by the application of weight factors together with the number of fibers counted for each category are given in Table 4. In all papers, the chemical unbleached kraft pro-

TABLE 4. *Percentage by weight of fiber components of packaging grade papers.*[a]

	Weight[c] (%)														
	Linerboards							Corrugating medium							
Fiber component[b]	KL1	KL2	KL3	TL	RL1	RL2	RL3	SC1	SC2	SC3	SC4	SC5	RM1	RM2	RM3
Softwoods															
Chem. pulp															
Unbleached kraft	32 (147)	29 (133)	49 (244)	25 (116)	12 (51)	13 (55)	15 (64)	<2 (5)	<2 (6)	14 (59)	9 (37)	2 (9)	17 (75)	15 (66)	14 (58)
Bleached kraft	4 (22)	5 (23)	2 (12)	5 (28)	5 (23)	3 (15)	5 (22)	<2 (7)	<2 (3)	4 (18)	6 (29)	<2 (8)	4 (17)	7 (32)	5 (24)
Unbleached sulfite	5 (24)	—	5 (27)	4 (18)	2 (7)	2 (7)	4 (18)	—	—	2 (9)	3 (14)	<2 (2)	6 (24)	2 (9)	2 (8)
Bleached sulfite	4 (21)	<2 (3)	4 (20)	5 (27)	2 (11)	<2 (7)	3 (12)	<2 (1)	<2 (3)	2 (10)	2 (10)	<2 (8)	3 (16)	3 (12)	<2 (6)
Semi-chem. pulp	2 (6)	10 (32)	<2 (4)	2 (5)	2 (7)	3 (10)	<2 (3)	6 (25)	4 (17)	10 (32)	3 (9)	3 (12)	2 (6)	3 (10)	2 (6)
Mechanical pulp	3 (8)	4 (13)	5 (15)	6 (18)	6 (17)	6 (18)	7 (21)	<2 (3)	3 (9)	3 (8)	8 (22)	<2 (2)	9 (25)	9 (25)	7 (20)
Sub-total	49 (228)	48 (204)	66 (322)	47 (212)	29 (116)	27 (112)	34 (140)	9 (41)	9 (38)	35 (136)	31 (121)	9 (41)	41 (163)	39 (154)	31 (122)
Hardwoods															
Chem. pulp															
Unbleached kraft	33 (312)	34 (308)	20 (196)	27 (250)	37 (317)	42 (397)	32 (270)	2 (26)	3 (29)	24 (207)	30 (256)	4 (44)	36 (312)	30 (258)	33 (276)
Bleached kraft[d]	4 (35)	2 (22)	<2 (13)	3 (29)	5 (40)	5 (48)	4 (35)	<2 (5)	<2 (7)	3 (26)	5 (40)	2 (16)	3 (28)	7 (61)	7 (58)
Unbleached sulfite	<2 (8)	<2 (3)	2 (17)	3 (25)	<2 (12)	2 (21)	4 (38)	4 (50)	4 (41)	2 (18)	2 (15)	5 (50)	2 (16)	<2 (7)	<2 (11)
Bleached sulfite	4 (35)	4 (33)	3 (26)	5 (50)	7 (56)	5 (45)	6 (55)	2 (22)	<2 (3)	6 (51)	8 (68)	<2 (15)	3 (27)	5 (40)	4 (37)
Unbleached Semi-chem.	4 (23)	5 (27)	5 (27)	9 (46)	14 (65)	9 (48)	13 (62)	77 (496)	76 (457)	21 (101)	16 (76)	78 (448)	6 (27)	9 (43)	15 (70)
Mechanical pulp	<2 (2)	<2 (6)	<2 (5)	3 (14)	<2 (5)	2 (11)	<2 (6)	4 (26)	4 (21)	2 (10)	2 (11)	<2 (2)	3 (13)	2 (11)	3 (15)
Sub-total	47 (417)	47 (399)	31 (284)	49 (414)	64 (495)	65 (570)	61 (466)	90 (625)	87 (558)	58 (413)	62 (466)	90 (575)	53 (423)	54 (420)	63 (467)
Nonwood fibers															
Grasses															
Unbleached chem. pulp	—	2 (12)	<2 (6)	2 (12)	<2 (9)	3 (22)	2 (12)	—	—	<2 (6)	<2 (6)	—	2 (16)	<2 (6)	2 (11)
Bleached chem. pulp	2 (22)	2 (26)	<2 (12)	<2 (14)	3 (30)	2 (27)	<2 (15)	—	<2 (4)	3 (27)	4 (38)	<2 (6)	2 (17)	3 (29)	2 (18)
Rag[e]	2 (11)	<2 (7)	<2 (8)	<2 (8)	3 (14)	3 (12)	2 (8)	<2 (5)	4 (22)	4 (21)	3 (16)	<2 (2)	2 (13)	3 (17)	2 (12)
Sub-total	4 (33)	5 (45)	3 (26)	4 (34)	7 (53)	8 (61)	5 (35)	<2 (5)	4 (26)	7 (54)	7 (60)	<2 (8)	6 (46)	7 (52)	6 (41)
Total fiber count	678	648	632	660	664	743	641	671	622	603	647	624	632	626	630

[a] Fiber counts in parenthesis.

[b] Classification according to application of Graff "C" stain and morphological characteristics of fibers.

[c] Percentages less than 2% are traces (contaminating fibers).

[d] Or bleached semi-chemical.

[e] Bast fibers, leaf fibers and cotton.

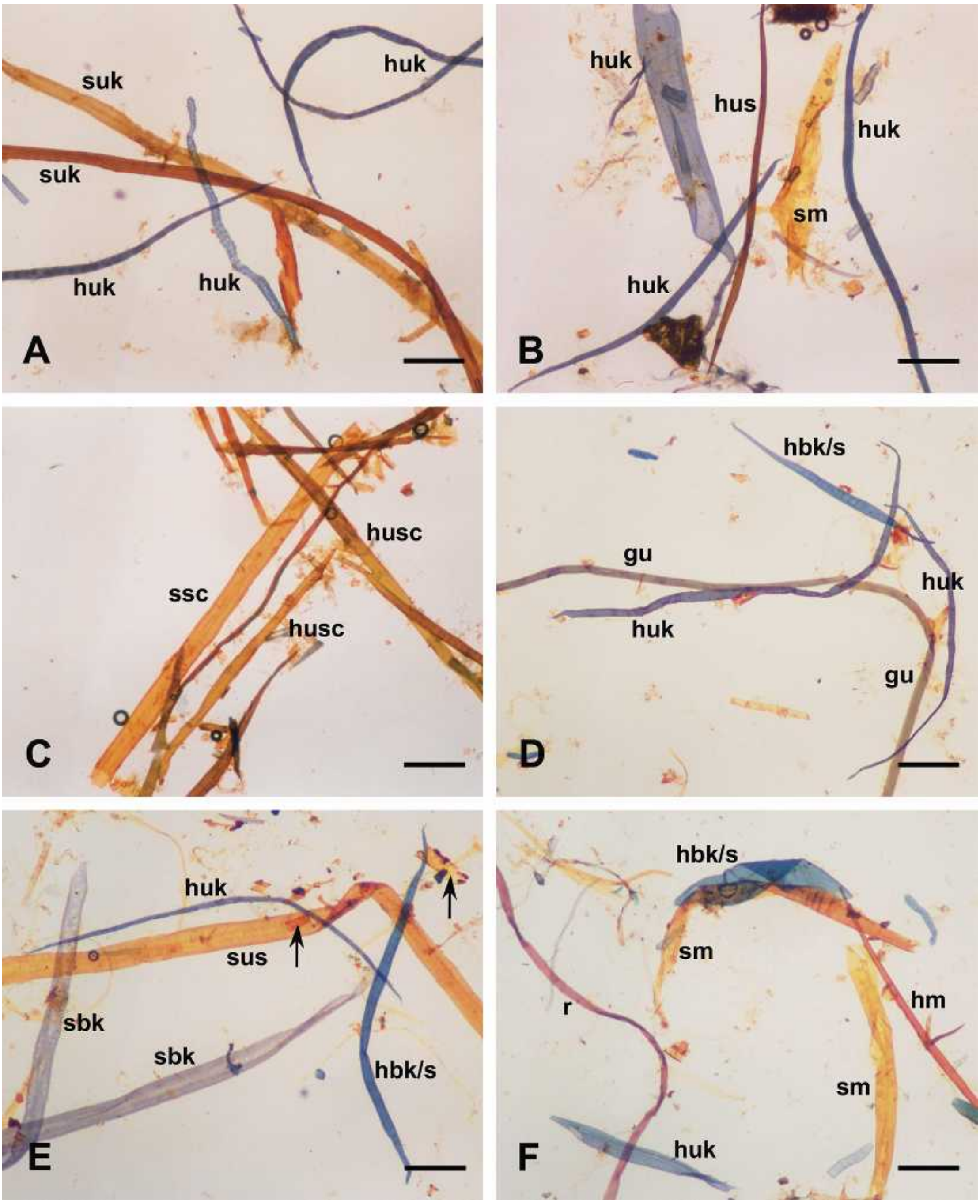

FIG. 1. Identification of pulping processes on the basis of the stain reactions of fibers with the Graff "C" stain in papers KL1 (A), TL (B), SC1 (C), RM1 (D), RM3 (E) and RL2 (F). Arrows, pitch content of ray cells that has stained yellow indicating the presence of unbleached sulfite softwood pulp; suk, softwood unbleached kraft; huk, hardwood unbleached kraft; hus, hardwood unbleached sulfite; sm, softwood mechanical; ssc, softwood semi-chemical; husc, hardwood unbleached semi-chemical; gu, grass unbleached; hbk/s, hardwood bleached kraft or hardwood bleached semi-chemical; sbk, softwood bleached kraft; sus, softwood unbleached sulfite; hm, hardwood mechanical; r, rag. The color chart for Graff "C" stain is given in Table 2. Scale bars = 180 μm.

cess proved to be the major pulping method both of softwood (9–49%) and hardwood fibers (20–42%), except the semi-chemical process in papers SC1, SC2, and SC5. In almost all papers the most important fiber component from a quantitative standpoint was hardwood unbleached kraft followed by softwood unbleached kraft. However, the above was not observed in kraft-liner KL3 with softwood unbleached kraft (49%) being the main fiber component and in the semi-chemicals SC1, SC2, and SC5 having hardwood unbleached semi-chemical as principal component (77%, 76%, and 78%, respectively). Hardwood unbleached semi-chemical fibers were also abundant in the other papers, and their weight percentage varied from 4% (paper KL1) to 21% (paper SC3). Mechanical softwood pulp was plentiful in the papers, and the highest values (7–9%) were determined in the recycled-medium papers.

Mechanical hardwood pulp (maximum weight percentage 4%) and semi-chemical softwood pulp, with the exception of papers KL2 and SC3 both with 10%, were minor components. Also small (2–6% per weight) was the share of softwood and hardwood fibers produced with the unbleached sulfite process, and the same occurred with bleached kraft and sulfite pulp (2–8% per weight). As for the nonwood fibers, the papers contained mainly bleached pulp from grasses and rag (up to 4% per weight), while unbleached grass fibers were usually absent or traces. These minor components reflected the heterogeneous raw pulp materials used for the production of the papers, though their sum accounted for a significant fraction in the total furnish weight. That was to a large extent apparent in the recycled based papers (recycled-liners and recycled-medium), test-liner TL and in two semi-chemicals, SC3 and SC4. The latter finding, together with the fact that semi-chemical fiber content was not the highest in the total weight of papers SC3 and SC4, highlighted the increasing trend of using recycled fibers also in the production of semi-chemical grades.

Besides the above results on the method of processing of fibers, this study has determined the softwood, hardwood, and nonwood fibers content in the papers. Except for kraft-liners, in all other papers hardwood fibers were found to be the main fiber component varying from 47–90% per weight. The stiff kraft-liners had greater softwood content than hardwood, up to a weight of 66% (paper KL3). Nonwood fibers entering the manufacturing process through recycling comprise a significant fiber component in most of the packaging grade papers as their percentage by weight varied between 3–8%. Papers with higher weight percentages were the recycled based (recycled-liners from 5% to 7% and recycled-medium from 6% to 7%) and the semi-chemicals SC3, SC4 (both with 7%). Only in the semi-chemical papers SC1 and SC5 were nonwood fibers found to be a trivial component (percentages less than 2%).

CONCLUSIONS

The methodology (proper differentiation of the colors, fiber definition and counting and weight factor selection) involved weak assumptions associated with potential errors, which are however inherent in any fiber analysis (Parham and Gray 1990).

Packaging grade papers, linerboards, and corrugating medium incorporate different types of fibers that have been produced with a great variety of pulping processes. The phenomenon is expected to be more severe in the future due to the increasing recycling rates set by environmental and economic pressure and, therefore advanced methods are needed for a better evaluation of the heterogeneous raw pulp materials.

As industrial packaging is based on the characteristics of its constituent fibers, information on the fiber composition of the variety of grade papers is of primary importance for a continual control of fiber sources. The Graff "C" staining test is actually used mainly to assure the purchasers that the composition of a given paper product is in accordance with the specifications (García 1988). The results of this study show that it can also be used successfully as a diagnostic method for assessing the potential quality distribution of fibers from different sources. For example, the determination of the total weight of inferior fibers in the variable raw pulp materials can lead to an estimation of the quality of the produced papers and to a prediction of the most efficient blend of fibers in order to achieve a desired end product.

Results from the Graff "C" staining test refer not only to the pulping method of fibers but also to the total softwood, hardwood, and nonwood fibers content. These overall results demonstrate that Graff "C" staining test is adequate to analyze both the structure and quality of packaging grade papers in practical industrial testing. Besides the physical-mechanical characterization of paper and corrugated board (Markström 1988), Graff "C" staining test can be a complementary test to evaluate the packaging behavior depending on the grade papers composition.

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